Journal Frequency: 4 Issues Per Year (Biannual)
Publisher: Scholar Craft Education & Research Hub
Vol. 2 No. 3, 2024 - FALL
ISSN (Online): 3006-7219
ISSN (Print): 3006-7200
RECOGNIZED IN "Y" CATEGORY BY
RESEARCH JOURNAL OF PSYCHOLOGY

Biological Alternative Conceptions of Secondary School Students About Heredity: A Case Study

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Abstract

Primarily the study is intended to diagnose Alternative conceptions of secondary level student about heredity to comprehend the main ideas of the heredity like cell cycle, mitosis, meiosis. Like vise it also explored the main reasons that develop alternative conceptions. To attain the objectives of the study case study was acquired. Four (4) public schools of Bahawalpur city were selected through random sampling. Formerly 200 students of IX grade were selected as a purposive sample of the research work. A distinct instrument labelled as a diagnostic test to quantify the alternative conceptions about heredity (DT). Renowned and experienced subject specialists of biology authenticated the (DT). To find the reliability a pilot test was intended through test retest method. The coefficient relation (r) was (0.96). To measure the internal consistency of the instrument. the Cronbach alpha coefficient was calculated through SPSS 2026 version; its value was (0.87). On the base of result of diagnostic test interview 50 students were selected purposively. The result indicated that 20% items were concept based. So prior weak knowledge, second language difficulty, poor explanation of lecture created alternative conception. On the base of findings recommendations were proposed e.g. (active participation of learning, use of teaching aids) for better understanding.

Keywords: *Secondary school students, alternative conceptions, Biology, Heredity, Mitosis, Meiosis, Cell cycle, Student solved manuscript.*

Introduction

Biology education is a broad term that denoted to the procedure, teaching and learning in subject of Biology. In most of the countries, Biological education is facing a lot of challenges at secondary level. These challenges cannot be overcome only through teaching. However, it needs an inclusive effort to evaluate the comprehensive knowledge and alternative conceptions of learner about biology (Lamanauskas, 2007). Teachers facing many challenges including comprehension, pronunciation, Biological terminologies, vocabulary words, dictation problems and capacity to apply scientific terminology (Akram, Mahmood, & Waqas, 2024). Many secondary school students face learning difficulties about fundamental concepts of heredity in biological education. Concepts develop when thoughts and ideas formed on the base of chromosomes, events of mitotic phases and heredity (Adams, 2015).

The problems related to understanding or constructing concepts are referred to as alternative conceptions, which explain students' hesitation. According to (Duit, 2007) , learners hesitate due to the difficult concepts, those were previously unclear to them. Students conceptual difficulties in Biology leads toward problem of alternative conception for Biology teachers, Problems related to concepts are known as student's alternative conception. Students hesitate to reply the questions about alternative conception (Franke, Hildebrandt, & Dorn, 2013). Student's alternative conceptions in Biology create problems for teacher and student. Heredity is considered a s the most challenging Biological alternative concept. About this topic, not only pre-service teachers but in-service teachers and students have learning problems (Machová & Ehler, 2023).

For the current research, the topic of heredity was selected due to the following reasons. An understanding of genetics and heredity related topics are difficult too. It needs a substantial description of the topic (Mussard & Reiss, 2022).

1.Heredity is considered as a tough topic for students to learn as well as for the instructors to teach According to a survey held to determine the most difficult Biology topic at secondary school level and the top three topics were about heredity (Reiss & Mussard, 2022).

The goal of Biological education about heredity is life-long learning with better understanding of main ideas and key concepts of Biological Science. To develop the confidence, to frame ability of asking questions, moreover, to develop positive attitude and ability of interaction towards Biological literacy about heredity(Penick, 1995) .

2. The ideologies of heredity have application in routine life (Reid, 1905)

3. The topic of heredity is common in Science and biology. Sometimes it creates confusion and student cannot correlate the information in Biological and Scientific context (Perrone, 2007)

Williams, DeBarger, Montgomery, Zhou and Tate (2012) examined understanding of high school Students about heredity. At Higher secondary student level students faced difficulty in understanding of synapsis, autosomes, chromatin, chiasmata formation difficulty in understanding of synapsis, autosomes (Kurahashi, Kogo, Tsutsumi, Inagaki, & Ohye, 2012). Like vise, they highlighted the alternative conceptions to help the learner in understanding of the topic heredity and make teaching-learning process meaningful (Cheng Li, Md Zalli, Jamil, & Mahmood, 2023). Students emotional, educational and Social life shaped by the school activities (Bidwell & Ryan, 2006). Schools improve development, achievement, engage in challenging work, focus quality of teaching and personalize learning of youth (Bernstein-Yamashiro & Noam, 2013) .

(Ojo, 2024) diagnosed the alternative conceptions of students of secondary school of Nigeria in heredity through concept inventory. The alternative conceptions of learner may change with the change in variable like age, religion, gender, culture, school climate and geographical areas (Mahmood, Ismail, & Omar, 2024). Literature provides evidence about Pakistani students. They face difficulty and are uninterested in Biology (Losh, 2010). Biology is the compulsory subject for secondary school students in Pakistan. A terrible way of teaching was adapted as science subjects taught without experiment. A good approach of teaching is to ask student to perform and teacher must give logic and meaningful comprehension of the process (Khan & Iqbal, 2011)

The factors contributed towards the problem was inappropriate teaching methodology, weak scientific context, inadequacy of laboratory, inactive students (Haron et al., 2024) etc. Research in biological education depicts that the learners feel difficulty to understand the abstract form of biological alternative conception. In developed countries, many researchers tried to explore the alternative conception and find the best possible reasons behind these alternative conceptions. Inadequate availability and utilization of laboratory facilities create hurdle in effective teaching and meaningful learning of biology. To avoid alternative conceptions of students at secondary school level, teachers and stakeholders must be trained for utilization of facility Though, in Pakistan and in other countries as well less research work is done. We can say serious attempt is lacking in this domain, to overcome the problem (Ngozi & Halima, 2015).

The Research Questions

Consequently, current study intended to find the answers of the given questions.

1. What are the common alternative conceptions of Biology students at secondary School level?

2. What are the reasons behind the alternative conception of Biology students at secondary school level?

Research Methodology

The recent study embraced the diagnostic test and interview, case study research design was adopted in a balanced way. The topic of heredity is in Punjab Text Book Board syllabus of Biology of grade IX. The population includes all students of IX grade learning Biology in Bahawalpur. Out of 10 schools three public schools of Bahawalpur city were selected through a technique of simple random sampling. Then sample of study was selected purposively which consist of 200 students of IX class. 200 Biology students of IX class were selected purposively, as a sample of study. Alternative conception of secondary school student in heredity investigated by intending a special test. Test was developed to gauge the alternative conceptions of students. On the basis of result of the result test, 30 students were selected purposively through a semi structured interview. Furthermore, during interview, a think aloud protocol sheet was provided to each student. The discussion was recorded and responses were investigated to diagnose the alternative conceptions in subtopic of Biology that is heredity and also find factors that create alternative conceptions.

Validity and Reliability

A concept inventory was developed in context of objectives, for measuring student's alternative conceptions in heredity. The content validity of instrument was done through piolet study (for this purpose 50 students were provided the diagnostic test). After that 5 expert Biology teachers were consulted to checked and validate the test. The test consists of 30 MCQs. These questions were constructed from Punjab Text Book Board syllabus in Biology for IX class. Following topics were selected, phases of cell division, mitosis, meiosis, cell structure and function. An effort was made to reduce prediction through four options in every item. Piolet testing of the instrument was done through test retest procedure to determine the reliability correlation coefficient as well that was o.97.

To measure the consistency of the instrument the Cronbach alpha was intended through SPSS version 2026. Its value was 0.759. The researcher also designs the think aloud protocol sheet under the guidance of literature review. To differentiate metaphase from anaphase. Additionally, the opinion of five renounced experts of biological education was taken during the development of interview questions and think aloud protocol sheet. The focus of question was on learner's background teaching methodology, use of AV aid, prior knowledge and participation of student during lecture (Sack, Camprodon, Pascual-Leone, & Goebel, 2005).

Data Analysis

The qualitative data collect through a student solved manuscript data was analyzed through statistical package for social science (SPSS 26). Percentage and frequency of each correct and incorrect statement was recorded. To calculate the difficulty of item in diagnostic test interview the item was considered difficult in which learner correctly attempt the statement and percentage was below 40% (Obomanu, 2012).

Qualitative content analysis was done through interview of students in which the qualitative

data was gathered. In order to investigate the collected data of interview and responses of written test, qualitative content analysis was intended(Forman & Damschroder, 2007). The response of learners was analyzed independently and separately by two researchers. Afterward they discussed the response to conclude.

Item 1: (4) Which of following not involve in reproduction

A. Germ cell B. Reproductive cell C. Somatic cell D. Gametes

Table 1. For Item 1 description of Students' Answers among the Options

Options	A	B	C*	D	Total Students
Frequency	25	17	127	31	200
Percentage	12.5	8.5	63.5	15.5	

According to Table 1 Students those answered correctly were 63.5% while 36.5**%** respondents answered the item 1 incorrectly. The table presented that most of respondents have proper understanding about topic. That's why it is obvious that majority of students have no any alternative conception about item 1. Through interview rationalization of student's alternative conceptions were further analyzed. That's why 40 respondents who had more alternative conceptions were interviewed to rationalize their responses, response of Madiha is given below.

Interviewer: Why you select option (a) "Germ cells are not involved in reproduction.

Madiha: Because, I am not familiar with this term so I thought maybe it is correct option. Another student sana describe the reason of here selected option in such a way:

Sana: In daily life teachers and students use word "gamete" involve in reproduction (e.g.) gamete is sex cell. So I thought that germ cell is not involve in reproduction.

It was explored after discussion that best possible cause of alternative conception was lack of use of this term so students were not familiar about the terms "germ cell". Moreover, teacher does not explain multiple terminologies relevant to the topic and biological term use in casual way. Through discussion it was concluded that the most probable reason of the alternative conception was misunderstanding of term, misinterpretation of knowledge and visualization error.

Item 2: Recognize the thread-like structures, which appear inside the nucleus at the time of cell division, are called _____.

A. Aster B. Centriole C. Chromosomes D. Spindle fibers

Table 2. For Item 2 description of Students' Answers among the Options.

Options	A*	B	C	D	Total Students
Frequency	63	59	43	36	200
Percentage	31.5	29.5	21.5	17.5	

Table 4.2 shows that only 31.5% students choose correct answer, while 68.5% students answered incorrectly. It was evident that understanding of maximum students definitely

possessed alternative conception. While 31.5% students answered correctly about the statement showed they had clear concepts about statement. The scholar organized semi structured interview on 40 pupils. To determine best possible reason behind the alternative conception. Respondents rationalize their answer during discussion. For instance, Usman defend his response as follows.

Interviewer: Why did you select the option (c)? Do you have any genuine reason?

Usman: I observe slides of different stages of cell division, in slides tiny threadlike structures were present, during lecture teacher also told that during cell division chromosomes appear as threadlike structures .so I thought that chromosomes are thin structure so I selected option (c). Another student who selected wrong option (d) justified her answer in such a way.

Fatima Zia: Because in diagram I saw thread like structure and ask to my elder sister about these structure my sister told me that these are spindle fibers so I confidently select option (d) spindle fiber. Interviewer: Have you ever seen structure of aster? Fatima Zia: No never seen.

The discussion showed that pupil has illogical justifications in support of their alternative conceptions. It is evident that their concepts were not clear about meta phase and prophase. That's why students were asked to imagination the structure of metaphase and anaphase and sketch the diagram on a sheet.to mention the alternative conception. So it might be true that the best possible reason behind such alternative conception was misapprehension of the prior knowledge and error of visualization.

Item 3: (18) Select that how many autosomes are present in a human being?

A. 20 pair B. 22 pairs C. 23 pair D. 44 pairs

Table 3. For Item 3 description of Students' Answers among the Options.

Options	A	B*	C	D	Total Students
Frequency	13	77	83	27	200
Percentage	6.5	38.5	41.5	13.5	

According to the table 4.18 answer of 38.5% students was correct. While 61.5% students answered about item incorrectly. It was quite clear that most of pupils did not understand the topic. It was because of alternative conception they possessed. About item 3 the researcher organized a semi structured interview and a student diagnostic test to determine the probable reason of these alternative conception. During interview students given chance to justify their answer they give reasons of their responses in following way:

Interviewer: Are you sure that 22pairs of autosomes present in human being? Please justify your answer.

Irna: I have studied in my text book of 9^{th} class that human being have total 23 pairs of chromosome. My teacher also told that human has 1 pair of sex chromosome. So it means there are 22 pairs of autosomes.

Another learner Samena rationalize her response as: I selected the answer 23 pair option (c).

Because human being has total 46 chromosomes when they pair, they will form 23 pairs so 23 is correct answer.

During interview it was interpret that the maximum respondents were confused about no of pair of chromosome. So learners were motivated to write no of pairs on page, to alleviate their perplexity. After discussion it was conclude that the one of possible reason behind the alternative conception was the language problem and insufficient description of the topic created this alternative conception in students.

Item 4: (20) Zygote is a _____cell
A. Haploid B. Diploid C. Triploid D Tetraploid
Table 4. For Item 4 description of Students' Answers among the Options.

Options	A	B*	C	D	Total Students
Frequency	36	143	8	13	200
Percentage	18.0	71.5	4.0	6.5	

Table 4.20 depicts that 71.5% of students selected correct option while 29% of students replied incorrectly the statement. It was evident that most of student's concepts about the topic were very clear. While 28.5% pupils selected incorrect answer of the statement. They surely possessed alternative conception about item. During interview students were asked to rationalize the answer. The pupil responds in following way:
Interviewer: Why did you select this option (a)?

Aliha: Because it is developed inside womb.

Interviewer: How you came to know?

Aliha: My tuition teacher told that sex cells are haploid and haploid cells develop inside womb.

Aiman Fatima: Correct answer is diploid that is option (b). Because they have two cells. She selected correct option but Concept about diploid was restricted up to two, student not able to understand that term diploid related to no of chromosome not to no of cell. As a result of conversation it was evident that pupil had illogical justifications behind these alternative conceptions. Even they had no any concept about the correct meaning of the word egg and sperm, haploid and diploid. it can be analyzed through discussion that the reason behind alternative conception perhaps was misunderstanding of terminologies, concepts were not clear and Language confusion.

Item 5. Traits are under control of
A. Gene B. A[ell C. Genetics D. Chromatid
Table 5. For Item 5 description of Students' Answers among the Options---

Options	A*	B	C	D	Total Students
Frequency	116	37	28	19	200

Percentage	58.5	18.5	14.0	9.5	

With reference to the table 4.22, 58.5% respondents were replied correctly while incorrect responses toward the item were 41.5%. It was evident that understanding of maximum students about the statement was clear. While 41.5% students respond wrongly toward the item, they obviously possessed alternative conceptions about the item. The scholar conducted a diagnosed test interview on 40 learners to explore the reason of diagnosed alternative conceptions.

During interview he respondents were inquired to validate the answered learner expressed their views in such a way.

Interviewer: What do you think about Allel and gene?

Rakhshanda: Allel and gene are same thing.

Interviewer: How you came to know about this?

Asma: Once my friend told me that allel and gene are synonyms.

Interviewer: What do you think about genetic?

Sobia: It control trait.

Interviewer: Will you defend your answer?

Sobia: Yes, my mother said I have resemblance with my father and it is because of inheritance and heredity related to genetics. So I thought it is obvious that traits are under control of genetics. That is the reason I selected option (c) that is genetics. After investigation, it was apparent that learners had illogical motives to build the alternative conceptions. So it was concluded through debate that prior knowledge alternative conception, self-assumption and daily life experience created misunderstanding of terminology (alell) leads the development of persistent alternative conception.

Best Possible Reasons behind Alternative conceptions

During semi structured interview statements about alternative conceptions were discussed. All possible information from respondents including alternative conceptions were gathered through questions related to their responses of main questions. Respondents were asked to explain and justify their answers. During interview answers of the respondents were recorded and organized in categories to develop the themes. The study revealed that how students developed alternative conceptions. The research work created a link between the alternative conception and knowledge transferred to the respondents. After deep analysis of answers of the respondents causes of alternative conceptions were explored. Main reasons of alternative conceptions in biology about heredity are misinterpretation of fore-knowledge, Language confusion, and error of visualization.

Conclusion

The result of the research work reveals that students of 9th grade possessed numerous alternative conceptions about heredity in biology. There were different types of alternative conceptions due to various reasons. Several alternative conceptions were hold by the secondary school learners while studying heredity topic in biology. These thoughts were the result of life experiences, casual language and prior concepts. The most possible cause of alternative conception of secondary school learner in biology was prior information and misinterpretation of the biological terminologies. One of the reason was misunderstanding of biological terms. And related vocabulary suggested that teachers must use animated videos to teach abstract concepts for instance pairing of chromosomes, chromatin composition (Lujan & DiCarlo, 2024).

Other main problem was English as a second language of Pakistani students. Vygotsky claimed in 1978 that concepts cannot be developed without language. Concepts must be taught in context through suitable language. When they try to understand the statement they try to translate the scientific terms into Urdu that leads toward misunderstanding. Moreover, usage of inappropriate words result in language misunderstanding (Monteiro & Keating, 2009). Stated that use of non- technical words was main reason of misunderstanding for students noticed that inappropriate usage of language was the main source of alternative conception. Tobias (1994) said connection between scientific language and mother language develops a bridge between new and prior knowledge. If such bridge not form due to language issue, then alternative conceptions in biology arise (Nusbaum & Margoliash, 2009).

Maximum secondary school students were unable to use appropriate vocabulary about scientific terms. The frequent use of improper scientific terms like mitosis, meiosis, cell cycle, nucleolus, chromosome, chiasmata, autosomes (etc.). Misapprehension of fore-knowledge was another reason of scientific alternative conception specifically in biology at secondary school students. alternative conceptions of preceding knowledge enhanced when learner not understand the topics. Learners were not able to interpret the information from the content due to such erroneous and inert prior information. For example, response of student in item 2 depict that Usman showed visualization error about structure of chromosome and assumed that inside slide thread like structure and thought that in metaphase chromosomes are thread like and thin. Like vise another respondent misinterpret the fore-knowledge and considered that all and gene are same.

Time to time research work conducted to deal with diagnosed alternative conceptions. For instance, collaborative learning, cooperative learning, and designed teaching sequence (Hartelt, Martens, & Minkley, 2022). Respondents lingered their thoughts generally in biology. During mental model development about abstract ideas such overgeneralizations are involve in biological science**.** It was also explored that visualization error also involve in elevating the alternative conceptions. For instance, inappropriate labeling of diagram in text book was also the cause of visualization error. Visualization error of the learner's response supported in identification of prior unexplored alternative conceptions in Biology. Findings of the current research work confirmed the (Özmen, 2008) that prior misconceptions lead toward the new alternative conceptions. During studying learners linked the new content with cognitive knowledge. If they possessed alternative conceptions these will obstruct the succeeding learning. In return new information could not associate with existing structure and concepts leads toward alternative conceptions(Özmen, 2008).

Recommendations

On the base of the problem and findings of the current work following recommendations were drawn: 1. The current research held at secondary school level More investigation is needed at higher secondary level. 2. Keeping in view the strength of (alternative conception) research work,, the research should be extending at higher secondary school level.to explore the alternative conceptions and their reasons in other science subjects like physics, chemistry and in general science courses.3. The instructor must be potential to identify the learners alternative conceptions.as soon as possible. 4. Instructor should adopt some strategy toward right learning approach like appropriate use of media, diagrams, models to reduce the alternative conceptions.

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