



A Review of Misconceptions in Biology

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Abstract: In learning process, school education is the foundational part of the education system. To strengthen further education and to make the coming generation more confident and competent it is necessary to enrich school education. Science is one of the important school subjects comprising of facts, theories, principles and laws in both concrete and abstract form. Abstract concepts sometimes may lead to misconceptions or alternative conceptions among students. Misconceptions can be identified by students' prior knowledge, understanding or logic which are incompatible with accepted scientific knowledge. To overcome misconceptions several tools and techniques have been discussed in previous research works. It has been proved in various studies that early diagnosis of misconceptions is needed as they are pervasive and resistant to change (Haslam & Treagust, 1987; Osborne, 1983). In the present paper 23 published studies between 2006-2022 were selected on the basis of predetermined criteria. Findings of the review revealed that the number of studies on biological misconceptions has increased in the last few years. In addition, majority of the studies were conducted with secondary school students as well as with preservice teachers. It has been found in these studies generally three-tier, two tier, diagnostic test and open-ended tests were used to address misconceptions. Moreover, most of the studies were conducted with the sole purpose of determining misconceptions in students instead of eliminate it.

Key Words: Misconceptions, conceptual change strategy, two-tier diagnostic test.

Introduction:

We are living in rapid growing era of technology. We cannot imagine our life without science and technology. Science is advancing day by day. Science makes our life easier and comfortable. That's why to build scientific attitude and having accurate scientific knowledge in students, it's very essential to remove all kinds of beliefs, knowledge and conceptions which are contrary to the scientific truth or beliefs. Students arrive in the classroom with some prior knowledge and experience. When this knowledge is inappropriate and not in harmony with scientific knowledge, these are termed as misconceptions.

Concept of Misconception:

The review of literature describes many definitions of misconceptions. According to Fisher (1983) misconceptions are ideas that are at a variance with accepted views. Misconception refers to students' ideas that are different from the ones generally accepted by scientists (Odom & Barrow, 1995). Tomita (2008) proposed when students enter science classrooms, they often hold deeply rooted prior knowledge or conceptions about the natural world. These conceptions will influence the way they interpret their formal

science experiences in school. Some of this prior knowledge provides a good foundation for further formal learning of science, while other conceptions may be incompatible with currently accepted scientific knowledge known as ‘alternative ideas’ (Brown, 1994).

Braund (1991) used the term ‘misconception’ and ‘misunderstanding’. The term ‘misconception’ is derived from two words ‘mis and ‘conception’. ‘Mis’ means wrong or incorrect ideas and conception is a notion or idea or understanding about a specific subject or topic. As per literature review several terms have been used synonymously for misconception as preconceptions (Cardak, 2009), naïve conceptions, naïve theories, non-scientific beliefs, alternative conceptions (Wandersee, Mintzes, & Novak, 1994; Coll and Treagust, 2001), alternative frameworks. In the present review study alternative conception term is used. Alternative conceptions are not preferred in learning and teachers try to keep them at the lowest level possible, because alternative conceptions may direct students to incorrect conclusions while learning negatively affects their accurate construction of new information in their minds (Albanese & Vicentini, 1997; Tsai, 1999).

Facts and numerous studies show that misconception is not a new term in the present era of research. In science education identification of misconception and its diagnosis related several works have been reported since 90’s and still going on. Previous studies show that misconception existed everywhere in almost all disciplines not only in science but also in the field of mathematics (Orhun, 2001), Geoscience (Kusnick, 2002), Psychology (Gardner & Brown, 2013), Geography (Desfandi, Abdi, Gadeng & Sofia, 2019). Its identification and remediation are crucial at initial stage in any discipline which boost up future learning. We can classify misconceptions in science according to its existing nature among learners. In different studies it is categorized in different ways as given in Table 1.

Table 1. Types of Misconceptions

International Research Council (1997)	Smith (2010)	Putri et al. 2017, Yasri (2014)
<ul style="list-style-type: none"> • Preconceived notions • Vernacular misconceptions • Non-scientific beliefs • Conceptual misconceptions • Factual misconceptions. 	<ul style="list-style-type: none"> • From experience misconceptions • Self-constructed misconceptions • Taught-and-learned misconceptions • Vernacular misconceptions • Religious and myth-based misconceptions 	<ul style="list-style-type: none"> • Common sense misconceptions • Content-based misconceptions • Non-scientific misconceptions • Vernacular misconceptions • Nature of Science (NOS)-based misconceptions

Misconceptions can be interpreted as differences in basic perceptions between students and scientific community so it causes students’ systematically incorrect understanding. Therefore, it may be concluded that the misconception is a mismatch in understanding concepts between students and scientific community. Abimbola and Baba (1996) found several misconceptions and alternative conceptions in a biology textbook and encouraged teachers to find the inaccuracies and act as a filter to students. Many previous studies reported a number of sources or factors responsible for causing alternative conceptions among students. It may be daily life experiences (Halim, Quinn, Olsen, Gere & Shultz, 2018), text books (Deshmukh and Deshmukh, 2011), teachers (Barras, 1984; Yates and Marek 2013; Hala, Syahdan, Pagarra & Saenab 2018), oversimplification (Hershey, 2004), language (Comins, 1993; Clerk & Rutherford, 2000; Sharma, 2009;) & cultural beliefs (Ododo, 2014).

When we talk about biology different concepts like our body structure, its function, plants, animals, environment revolves around our eyes. Study of biology first of all acquaints us with the knowledge of ourselves, our body, its basic structure and how it functions well. It also tells us about our environment, its

sustainability, how can we live and survive for a long. Knowledge of Biology links us with ourself as well as with our environment.

There are many abstract concepts in biology also like other sciences which are difficult and confusing therefore resulting into misconceptions. Since biology is a conceptual science, students may find biological concepts difficult. Therefore, students tend to memorize the biological concepts rather than using conceptual learning techniques (e.g. Özcan, 2000). Previous researches as Amir & Tamir (1994), Kose (2007), Yuruk & Eroglu (2016) gave its proof through their work that we must be aware about the existing misconceptions in biology. Providing opportunities for its correction not only to continue later education but also for ourselves to become scientifically correct.

Research Questions:

Learning new concepts is greatly related with previously learned concepts in any subject areas so it is important to identify and eliminate the existing misconceptions. Therefore, the aim of this review is to examine and integrate the previous literature related to misconceptions in biology. There are ample studies on misconceptions in biology in terms of its identification or remediation but very limited studies were found that combine and integrate the previous works on misconceptions in biology. Therefore, this study is helpful in finding the answer for the following questions:

1. What types of researches have been conducted on misconceptions of biology?
2. Which methods/ways are employed to determine misconceptions in biology?
3. Which techniques are used to overcome the misconceptions in biology?
4. What are the topics of biology on which studies focus on?

Method:

In the present study, conceptual review was conducted in order to investigate the studies related to misconceptions in biology. Conceptual reviews are the type of reviews in which the researcher aims to provide an overview of the literature in a given field, including main ideas, models and debates (Petticrew & Roberts, 2006). It consists of three phases: (i) Determining the inclusion criteria and review procedure, (ii) Reviewing the literature, (iii) Analysis procedure.

Determining the inclusion criteria and review procedure: In this phase we decided the inclusion criteria for selecting the studies. The inclusion criteria consisted of studies which were-

- i. empirical studies
- ii. written in English language
- iii. specifically focussed towards misconception in biology

Review of literature was carried out from 2006-2022 on misconceptions in biology by using JSTOR data base, google scholar, Education Resources Information Center (ERIC) and institutional access to journals. For searching the literature different keywords were used as: misconceptions in biology, conceptual change strategy, diagnostic test, two tier diagnostic test in the title selecting both international and national journals.

After investigating all the literature obtained from different databases and keywords and removing the duplicates from the results, forty studies were searched between 2006 to 2022. All the forty studies were subjected to detailed analysis and realized that only 23 of them ensured the predetermined criteria. Remaining researches specifically focused on misconceptions in other disciplines of science (such as physics, chemistry) rather than biology, or they were review studies instead of empirical ones. As a result, those studies were removed from the analyses and focused only on 23 studies (Table 2).

Analysis of Studies:

Table 2: An analysis of studies on misconceptions in biology (n=23)

S.N	Author	Year	Title	Topics	Method	Tools used for determining misconceptions & or to overcome them.
1.	Yenilmez and Tekkaya	2006	Enhancing students' understanding of photosynthesis and respiration in plant through conceptual change approach (quasi-experimental study)	photosynthesis and respiration in plant	Quantitative (experimental)	Firstly, 233 8 th grade students' understanding of photosynthesis and respiration in plants was investigated by two-tier diagnostic test as a pretest and posttest. Then conceptual change instruction combining conceptual change text and discussion web were used to explicitly dealt with students' misconceptions.
2.	Narendra D. Deshmukh, Veena M. Deshmukh	2007	A study of students' misconceptions in biology at the secondary school level	Life processes (syllabus at IX class)	Qualitative	Open-ended test containing 8 questions was administered for 9 th class students related with syllabus at secondary level. The sample comprised 110 secondary students aged 16 to 18 years from two high school classes.
3.	Sacit Kose	2007	The effect of concept mapping instruction on overcoming 9 th grade students' misconceptions about diffusion and osmosis	Diffusion & osmosis	Quantitative (experimental)	Diagnostic test was administered as pretest and posttest related to the topic diffusion and osmosis for 9 th grade students. Concept mapping instruction was employed for both identification as well as for overcoming misconceptions among students.
4.	Sacit Köse	2008	Diagnosing Student Misconceptions: Using Drawings as a Research Method	Photosynthesis & respiration	Quantitative	Drawing method in conjunction with interview was used to investigate misconceptions about photosynthesis and respiration from total 156 third year pre-service students aged 20-25.
5.	Mustafa Urey & Muammer Calik	2008	Combining different conceptual change methods	Concept of cell	Quantitative	Conceptual change methods (analogy, conceptual change text and worksheet) within the 5E model were used

			within 5E model: A sample teaching design of 'cell' concept and its organelles			which is not only very effective in enhancing students' understanding but also eliminate students' misconceptions related with the topic of cell and its organelles.
6.	Guliz, Aydin et.al	2009	Students' misconceptions about the subjects in the unit "The systems in our body"	Systems in our Body (The skeletal system, The circulatory system & the respiratory system)	Quantitative (Experimental study)	mind-mapping & concept-mapping were used for 6 th grade class students to enhance meaningful learning
7.	Didem Kılıç and Necdet Saglam	2009	Development of a two-tier diagnostic test concerning genetics concepts: the study of validity and reliability	genetics	Mixed method	Two-tier diagnostic test was used to evaluate secondary students' ideas concerned with fundamental concepts of genetics and interview was also conducted with 21 secondary education students.
8.	Narendra D. Deshmukh	2011	Students' misconceptions and cultural beliefs in biology at the secondary school level	Heart, respiration, photosynthesis, vitamins and a balanced diet	Qualitative	Questionnaire with five open ended questions on topic heart, respiration, photosynthesis, vitamins and a balanced diet was conducted on 9 th class students and teachers both. Semi-structured Interview was also conducted of a few students to find out the sources of misconceptions.
9.	Hakan Kurt, Gülay Ekici, Özlem Aksu, & Murat Aktaş	2013	Determining cognitive structures and alternative conceptions on the concept of Reproduction (The case of pre-service biology teachers)	Reproduction	Qualitative	Free word association test and drawing-writing technique (qualitative research method was applied)
10.	Dilek Celikler and Zeynep Aksan	2013	Determination of knowledge and misconceptions of pre-service elementary science teachers about the greenhouse effect by Drawing.	Greenhouse effect	Quantitative (descriptive analysis)	Analyzed knowledge of pre-service teachers about the greenhouse effect by drawing and writing.

11.	Benedict Tlala, Israel Kibirige & Joseph Osodo	2014	Investigating grade 10 learner's achievements in photosynthesis using conceptual change model (quasi experimental)	Photosynthesis	Quantitative (quasi-experimental)	Conceptual change model (CCM) approach was used to minimize students' misconceptions of photosynthesis in six stages.
12.	Galvin, E., Simmie, G. M., & O' Grady, A.	2015	Identification of misconceptions in the teaching of biology: A pedagogical cycle of Recognition, Reduction & Removal	Photosynthesis & respiration	Quantitative (experimental)	Used paper pencil multiple choice diagnostic test to identify the misconceptions in the topic photosynthesis and respiration for pre-service and secondary school students both.
13.	Manmeet Oberoi (Baweja)	2017	A study of misconceptions in biology at secondary school level.	Adaptations, Habitat, Biosphere, Ecosystem, Food chain & food web, functions of Ecosystem, Biomass & Biodiversity	Descriptive method (two phases) 1. Construction & standardization of concept Achievement Test 2. Field work	Three-tier test (Concept Achievement Test) was conducted to collect data from 912 secondary school students (9 th) with respect to the unit of environment.
14.	Kyungwoon Seo, Soonhye Park, & Aeran Choi	2017	Science Teachers' Perceptions of and Approaches towards Students' Misconceptions on Photosynthesis: A Comparison Study between US and Korea	photosynthesis	Qualitative	A web-based on-line survey consisting of open-ended questions was administered to 85 & 81 secondary science teachers of US & South Korea respectively.
15.	Silva, M & Almeida, A.	2017	Primary school pupils' misconceptions of the human respiratory system in primary school students: From identification to destruction	Human respiratory system	Quantitative (quasi-experimental)	Questionnaire consisted of open and closed questions was administered to 38 students of 6 th year of schooling to determine the prevailing misconceptions related with human respiratory system.

16.	A. S. Halim et al.	2018	Identifying and Remediating Student Misconceptions in Introductory Biology via Writing-to-Learn Assignments and Peer Review	protein structure, photosynthesis, recombinant DNA, and enzymes	Qualitative	Writing to learn is an effective pedagogy that involves cognitive and metacognitive process that enhance students' learning via promoting reflective thinking. Four Writing to learn assignments were given to 36 first year university students.
17.	Mustafa Urey	2018	Defining the relationship between the perceptions and the misconceptions about photosynthesis topic of the preservice science teachers	photosynthesis	Quantitative (Descriptive research method)	Data were collected from total 355 preservice teachers by using "photosynthesis concept achievement test" consisted 4 questions: 1 st & 2 nd are open ended, 3 rd is drawing question & 4 th is related with misconceptions about the concept of photosynthesis.
18.	Rahmi Susanti	2018	Misconception of biology education student of teacher training and education of Sriwijaya University to the concept of photosynthesis and respiration	Photosynthesis and Respiration	Descriptive study	Subjects were 58 first year students of Biology Education of the Faculty Teacher Training and Education University of Sriwijaya. Diagnostic test consists of 16 questions, 10 questions of multiple choice and 6 of choice with reason.
19.	Helmi, Rustaman, Tapilouw & Hidayat	2019	Misconceptions types analysis on mechanism of evolution (descriptive qualitative method)	Mechanism of Evolution	Qualitative (descriptive study)	Three tier diagnostic test consisting 20 questions conducted on university students on the learning material of evolution mechanism.
20.	Hadi Suwono, Triastono Imam Prasetyo, Umie Lestari, Betty Lukiati, Rifka Fachrunnisa, Sentot Kusairi, Muhammad Saefi, Ahmad Fauzi & Mochammad Fitri Atho'illah	2019	Cell biology diagnostic test (CBD-Test) portrays pre-service teacher misconceptions about biology cell	Cell biology: cell organelles, photosynthesis, respiration, mitosis, meiosis	Quantitative	Three tier diagnostic tool was used to gather data from 204 pre service biology teachers of 4 th semester.

21.	Rogayan, D.V. Jr. & Albino, M.M.	2019	Filipino Students' Common Misconceptions in Biology: Input for Remedial Teaching	Four subfields of biology including ecology, botany, genetics and zoology.	Descriptive-survey research	Survey questionnaire was used as a primary data gathering tool and 100 public secondary school students of grade 10 were involved in the study.
22.	Andariana, A., Zubaidah, S., Mahanal, S., Suarsini, E.	2020	Identification of biology students' misconceptions in human anatomy and physiology course through three-tier diagnostic test.	Human anatomy and Physiology	Descriptive quantitative study	Three-tier diagnostic test was conducted on 128 students enrolled in the Institute of Teacher Training and Educational Sciences.
23.	Roy, A., & Mohapatra, A. K.	2022	A Gender-based Investigation of Indian Senior Secondary Students' Misconceptions about Plant Reproduction through Concept Inventory.	Plant Reproduction	Quantitative & Qualitative (Mixed)	Data were collected by using closed-ended concept inventory from 102 senior secondary students of class XII. Interview was also conducted with few students.

Findings:

❖ Findings related to research question no. 1:

Types of studies conducted on misconceptions in Biology:

A variety of studies employed to identify and remediate misconceptions in biology. Some of them (Yenilmez & Tekkaya, 2006; Sacit Kose, 2007) are experimental type. Objectives of these studies are not only to determine the existing misconceptions regarding the concept but also applied some instructional techniques to eliminate them. Sacit Kose (2008) & Dilek Celikler and Zeynep Aksan (2013) conducted descriptive type of studies to investigate and analysed misconceptions by using drawing method on the topic photosynthesis-respiration and greenhouse effect respectively. Similarly, Hakan Kurt et.al (2013) & K. Seo et.al (2017) performed qualitative type of study using free word association test and web-based online survey with open-ended questions respectively to explore the current misconceptions. Some other studies such as Didem Kilic & Necdet Saglam (2009) & Roy. A., & Mohapatra, A.K. (2022) also applied mixed method to identify the misconceptions among students.

❖ Findings related to research question no. 2:

Methods/ways to determine misconceptions in Biology:

Most of the studies applied only a single tool for data collection, while few studies (Sacit Kose, 2008; Guliz AYDIN et.al, 2009; Kilic & Saglam, 2009) were conducted to use combination of tools. Among 23 studies, thirteen studies (56%) used three tier, two-tier, diagnostic test and open-ended test for collecting data. In these tests, four tests were three-tier diagnostic test (Oberoi,2017; Helmi et.al,2019; Suwono et.al, 2019; Andariana et.al, 2020), four were open ended test (Deshmukh & Deshmukh,2007; Deshmukh,2011; Silva & Almeida, 2017 & Seo et.al, 2017) three were diagnostic test (Kose, 2007; Galvin et.al 2015; Susanti, 2018), two were two-tier diagnostic test (Yenilmez & Tekkaya, 2006; Kilic & Saglam, 2009). Additionally, three of the studies used concept achievement test (Mustafa Urey, 2018), survey questionnaire (Rogayan & Albino, 2018), concept inventory (Roy & Mohapatra, 2022) too. Moreover, three studies (Kose, 2008; Kurt et.al, 2013 & Celikler & Aksan, 2013) applied drawing method to determine misconceptions.

❖ Findings related to research question no. 3:

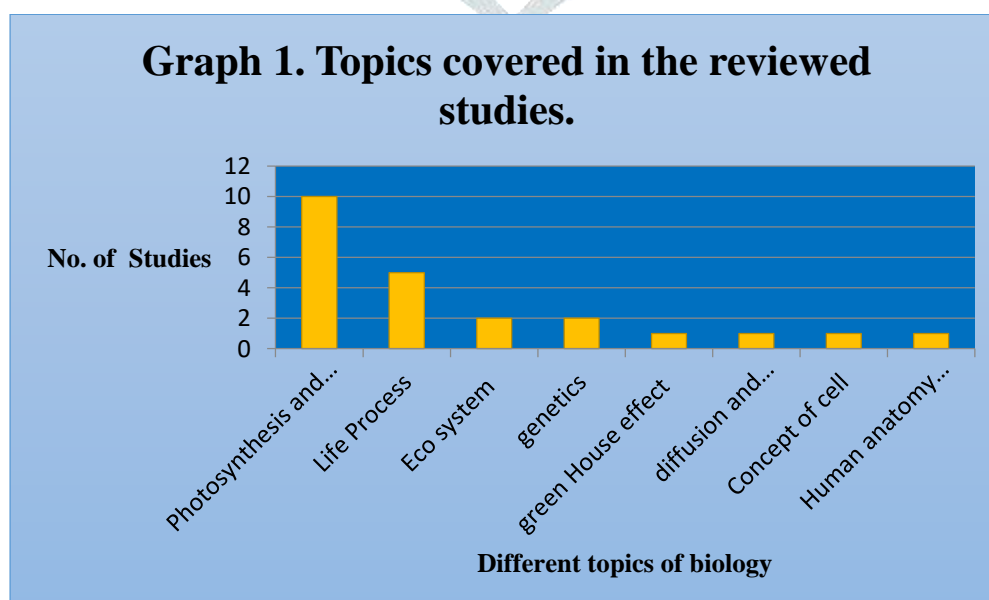
Techniques used to overcome misconceptions in Biology:

Conceptual change model was employed to overcome misconceptions in Biology in two research studies (Urey & Calik, 2008 & Tlala et.al, 2014) whereas rest of the studies adopted other techniques such as mind mapping and concept mapping (Guliz AYDIN et.al, 2009) and writing to learn assignments (Halim et.al, 2018).

❖ Findings related to research question no. 4:

Topics of Biology on which studies focussed:

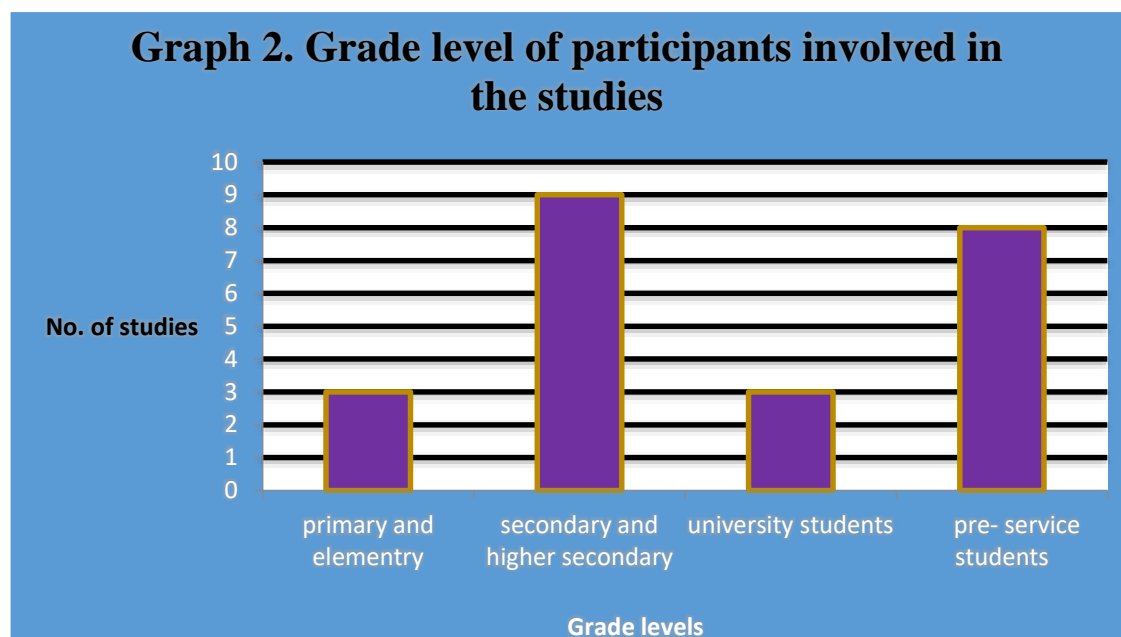
All the twenty-three studies examined the different areas of biology, but there are some common areas on which majority of the studies focussed. As shown in Graph 1, out of 23 studies, ten studies (43%) were conducted to identify misconceptions related to photosynthesis and respiration. In addition, five studies (21%) belong to the topic of life processes, two studies investigated the misconceptions in area of ecosystem. Other investigated topics were genetics (2), greenhouse effect (1), diffusion and osmosis (1), concept of cell (1), human anatomy and physiology (1).



❖ Other Findings:

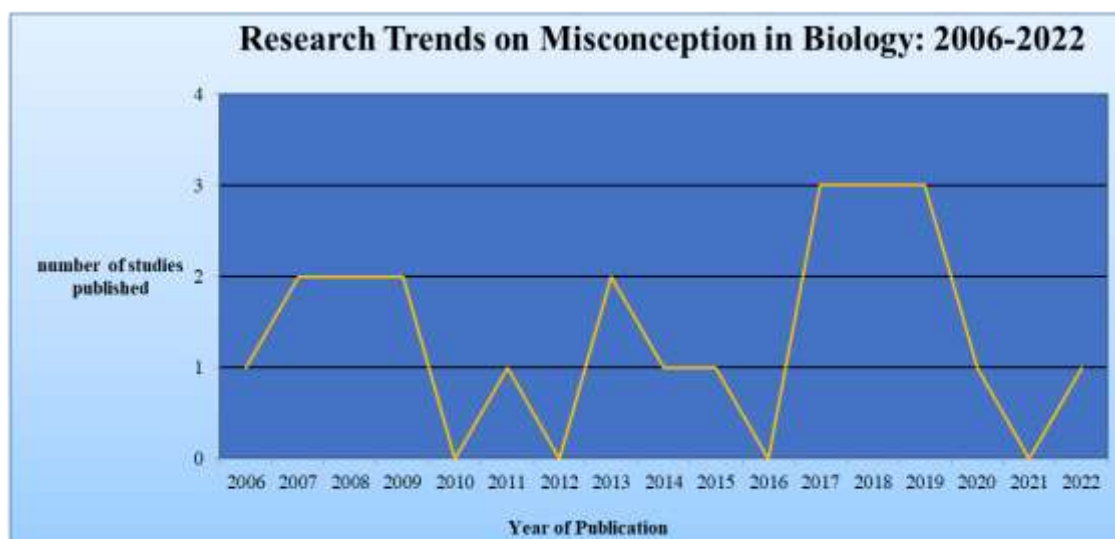
1. Related to Grade level of Participants-

All the studies between the year 2006-2022 having a variety of participants from primary to university students including pre-service teachers too. Graph 2, shows that most of the studies (39%) were conducted with secondary and higher secondary students (9 studies) along with 8 studies of pre-service & service teachers (34%) as well. The remaining studies were done on elementary (3) and university participants (3).



2. Trends-

The analysed studies were published between the years 2006 and 2022. According to Graph 3, it can be stated that there is an increase in the number of studies conducted on misconceptions in biology in recent years. We can clearly see that almost half of the studies (11) have been published especially in the last five years (2017-2022).

Graph 3.

Discussion and Conclusions

The systematic analysis of 23 studies conducted on misconception in Biology including both Indian as well as international studies shows many conclusions in terms of types of study, grade levels of participants, topics covered, data collection tools and techniques. Firstly, the review shows that in the recent years number of studies conducted on misconceptions in biology are enhanced (between the year 2017-2019). Second, large number of studies has been conducted with secondary and higher secondary students as well as with preservice teachers while very less has been conducted (less than 5) with primary and university students. In primary and elementary grade there are various basic concepts in every subject not only in biology so researchers should be more focussed towards selecting younger students as participants. Therefore, misconceptions can be resolved as soon as possible.

This study revealed that abundant work has been done related to the topic of photosynthesis and respiration. The topic of life processes is also one of the important areas of research to find misconceptions in biology. While limited researches have been done with other areas such as concept of cell (Urey & Calik, 2008), genetics (Kilic & Saglam, 2009), human anatomy & physiology (Andariana et.al, 2020), diffusion & osmosis (Kose, 2007). In biology there are some other challenging areas like cell division, classification, genetics etc. which must be explored from misconception point of view.

Most of the analysed studies showed that majority of research work aimed only to determine misconceptions among participants and few were found to eliminate them as well. Some researches done were more comprehensive as they started with the determination of misconceptions to its elimination. According to Comins (1998) people resist to change their ideas, thoughts and beliefs, it is not an easy task to change it. Further, as proved by many previous works (Tlala, Kibirige & Osodo, 2014) use of conceptual change strategy or method is more effective to address students' misconceptions in comparison to other conventional method.

The result of the review depicts that most of the studies used single data collection tool while two tier and three tier tests were most utilised tool. Open ended tests, multiple-choice diagnostic tests and drawing method were also used in a number of studies. Instead of using a single tool combination of tools & techniques is more effective in exploring misconceptions, since they provide in-depth information about students' knowledge. Likewise, studies were found using combination of methods such as drawing method with interview (Kose, 2008), analogy with conceptual change text & worksheet (Urey & Calik, 2008), two-tier test with interview (Kilic & Saglam, 2009), questionnaire with interview (Deshmukh, 2011). Further, to deal effectively with misconceptions studies also applied concept mapping, mind mapping and conceptual change model.

References:

1. Aydin & Balim (2009). Students' Misconceptions About the Subjects in The Unit "The Systems In Our Body". *Procedia Social and Behavioral Sciences*, 1, 2258–2263.
2. Andariana, A., Zubaidah, S., Mahanal, S., Suarsini, E. (2020). Identification of biology students' misconceptions in human anatomy and physiology course through three-tier diagnostic test. *Journal for the Education of Gifted Young Scientists*, 8(3), 1071-1085. DOI: <http://dx.doi.org/10.17478/jegys.752438>.
3. A. S. Halim et al. (2018). Identifying and Remediating Student Misconceptions in Introductory Biology via Writing-to-Learn Assignments and Peer Review. *CBE Life Sci Educ*, 17(2), doi: 10.1187/cbe.17-10-0212.
4. 'A Study of Students' Misconceptions in Biology at the Secondary School Level' (N. D. Deshmukh & Veena M. Deshmukh), *Proceedings of the HBCSE, epi-STEME-2, 2007*.
5. Barras, R. (1984). Some misconceptions and misunderstandings perpetuated by teachers and textbooks of biology. *Journal of Biological Education*, 18, 201-206.
6. Çelikler, D. and Aksan, Z. (2013). Determination of Knowledge and Misconceptions of Pre-Service Elementary Science Teachers About the Greenhouse Effect by Drawing. *Procedia - Social and Behavioral Sciences*, 136 (2014) 452 – 456.
7. Douglas Clerk & Margaret Rutherford (2000). Language as a confounding variable in the diagnosis of misconceptions. *International Journal of Science Education*, 22:7, 703-717.
8. Deshmukh, N. (2011). Students' Misconceptions and Cultural beliefs in Biology at the Secondary School Level'. *Vetri Education*. January 2011.
9. Galvin, E., Simmie, G. M., & O' Grady, A. (2015). Identification of Misconceptions in the Teaching of Biology: A Pedagogical Cycle of Recognition, Reduction and Removal. *Higher Education of Social Science*, 8(2), 1-8 DOI:10.3968/6519.
10. Gardner, R.I. and. Brown, D.I. (2013). A test of contemporary misconceptions in psychology, *Learning and Individual Differences*, 24, 211–215.
11. Hakan Kurt et. al (2013). Determining Cognitive Structures and Alternative Conceptions on the Concept of Reproduction (The Case of Pre-Service Biology Teachers). *Creative Education 2013*, 4(9), 572-587.
12. Helmi et al. (2019). Misconception Types Analysis on Mechanism of Evolution. *Journal of Physics: Conference series*. 1175 012169.
13. Haslam, F., & Treagust, D.F. (1987). Diagnosing secondary students' misconceptions of photosynthesis and respiration in plants using a two- tier multiple choice instrument. *Journal of Biological Education*, 21(3), 203-211.
14. Halim, A.S. et al. (2018). Identifying and Remediating Student Misconceptions in Introductory Biology via Writing-to-Learn Assignments and Peer Review, *CBE Life Sci Educ*. 2018 Summer; 17(2): ar28, doi: 10.1187/cbe.17-10-0212.
15. Kılıç, D. & Sağlam, N. (2009). Development of a two-tier diagnostic test concerning genetics concepts: the study of validity and reliability, *Procedia - Social and Behavioral Sciences*, 1(1), 2685-2686.
16. Kyungwoon, S., Soonhye, P. & Aeran, C. (2017). Science Teachers' Perceptions of and Approaches towards Students' Misconceptions on Photosynthesis: A Comparison Study between US and Korea. *EURASIA Journal of Mathematics, Science & Technology Education*, 13(1), 269-296.
17. Kusnick, J. (2002). Growing pebbles and conceptual prisms – understanding the source of student misconceptions about rock formation, *Journal of Geoscience Education*, 50 (1), 31-39.
18. Mustafa, Ü. & Muammer, Ç. (2008). Combining different conceptual change methods within 5E model: A sample teaching design of 'cell' concept and its organelles. *Asia-Pacific Forum on Science Learning and Teaching*, 9(2), 1-15.
19. M Desfandi, A W Abdi, A N Gadeng, and I Sofia. (2020). Identification of misconceptions in geography using the three-tier diagnostic test. *The International Conference of Science and Applied Geography IOP Conf. Series: Earth and Environmental Science* 561 (2020) 012040.

20. Oberoi, M. (2017). A Study of Misconceptions in Biology at Secondary School Level. *International Journal of Current Research*, 9(5), 50817-50819.
21. Ododo, O.M, (2014) Influence of cultural practice-related misconceptions on Achievement of Senior Secondary Biology Students in Zone C of Benue State, Nigeria. *British journal of Education, society and behavioural science*, 4(12), 1703-1705.
22. Osborne, R.J. (1983). Towards modifying children's ideas about electric current, *Research in Science and Technological Education*, 1, 73-82.
23. Orhun, N. (2001). Students' mistakes and misconceptions on teaching of trigonometry, *Proceedings of the International Conference: New ideas in Mathematics Education*, Palm Cove, Australia, 208-211.
24. Rogayan, D.V. Jr. & Albino, M.M. (2019). Filipino students' common misconceptions in biology: Input for remedial teaching. *Online Science Education Journal*, 4(2): 90- 103.
25. Roy, A., & Mohapatra, A. K. (2022). A Gender-based Investigation of Indian Senior Secondary Students' Misconceptions about Plant Reproduction through Concept Inventory. *Interdisciplinary Journal of Environmental and Science Education*, 18(4), e2287. <https://doi.org/10.21601/ijese/12089>.
26. Sacit Köse (2007). The Effects of Concept Mapping Instruction on Overcoming 9th Grade Students' Misconceptions About Diffusion and Osmosis. *Journal of Baltic Science Education*, 6(2), 16-25.
27. Sacit Köse (2008). Diagnosing Student Misconceptions: Using Drawings as a Research Method. *World Applied Sciences Journal*, 3(2), 283-293.
28. Silva, M. & Almeida, A. (2017). Primary school pupils' misconceptions of the human respiratory system in primary school students: From identification to destruction. *ICERI2017 Proceedings 10th International Conference of Education, Research and Innovation*, 1205-1210.
29. Susanti, R. (2018). Misconception of biology education student of teacher training and education of Sriwijaya University to the concept of photosynthesis and respiration. *J. Phys.: Conf. Ser.* **1022** 012056.
30. Suwono, Prasetyo, Lestari, Lukiati, Fachrunnisa, Kusairi, Saefi, Fauzi & Atho'illah (2019). Cell Biology Diagnostic Test (CBD-Test) portrays pre-service teacher misconceptions about biology cell. *Journal of Biological Education*, <https://doi.org/10.1080/00219266.2019.1643765>
31. Tlala, Kibirige & Osodo (2014). Investigating grade 10 learner's achievements in photosynthesis using conceptual change model. *Journal of Baltic Science Education*, 13(2), 155-164.
32. 'Textbook: A Source of Students' Misconceptions at the Secondary School Level', (N. D. Deshmukh & Veena M. Deshmukh), *Proceedings of episteme-4*, 2011, India.
33. Urey, M. (2018). Defining the relationship between the perceptions and the misconceptions about photosynthesis topic of the preservice science teachers. *European J Ed Res.*,7(4),813-826. doi: 10.12973/eu-jer.7.4.813.
34. Yenilmez and Tekkaya (2006). Enhancing students' understanding of photosynthesis and respiration in plant through conceptual change approach. *Journal of Science Education and Technology*, 15(1), 81-87.
35. Yusmina Hala, U A Syahdan, Halifah Pagarra and S Saenab (2018). Identification of Misconceptions on Cell Concepts among Biology Teachers by Using CRI Method, *Journal of Physics: Conference Series*, 1028 (2018) 012025 doi :10.1088/1742- 6596/1028/1/012025.
36. Yates, TB, & Marek, EA. (2013). Is Oklahoma really OK? A regional study of the prevalence of biological evolution-related misconceptions held by introductory biology teachers. *Evolution Education and Outreach*, 6, 1-20.