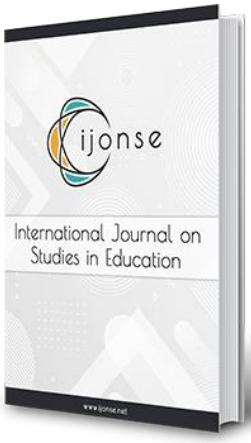

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Abstract

It is of great importance to examine and organize the misconceptions researches in biology education at regular intervals and to determine the trends. The aim of this study is to examine the studies on misconceptions in biology education in terms of different variables. Bibliometric network analysis method was used in the research. Here, firstly, reports on misconceptions in biology education were obtained by using “biology and misconception” in the “Social Sciences” category from SCOPUS. Accordingly, 410 publications was recorded. The documents were exported to CSV form and in turn subjected to the bibliometric analysis using VOSviewer Software. According to the results obtained, it was determined that the most studies were carried out in 2013. It showed that the most frequently used keywords in articles were “evolution” and other related words. Looking at the most frequently used terms, the terms "respiration" and “photosynthesis” are respectively according to their high relevance scores. In conclusion, we must state that misconception studies on the subjects that students have the most difficulty with in biology have remained up-to-date for many years.

Introduction

Biology education is a complex process. Misconceptions are a troubling issue for students and teachers in science education. This is especially due to the abstract nature of science subjects. In its simplest form, this process requires teacher instruction, student learning, and a science program. The focus of research on the education of the field and the field in the last two decades has produced fruitful results in terms of science teaching and learning methods. With these methods, biology education took a new shape and became more effective (Yağbasan & Gülçiçek, 2003).

Biology education is extremely important for the individuals of a society. Along with all these developments, one of the most important issues that biology educators focus on is the students' prior knowledge. Students bring this knowledge with them when they attend science classes for the first time. Students learn about some science concepts from previous teaching processes or they have preliminary knowledge gained from their observations in their lives. One of the main goals of biology education is to enable students to understand and apply the concepts in biology subjects correctly. For this reason, before teaching biology subjects, it is necessary to reveal the concepts that students have about the subject. Because students' prior knowledge researches aimed at inference revealed that students have misconceptions about many biology concepts (Yağbasan & Gülçiçek, 2003). These

misconceptions are valuable and indispensable for students as they are developed by their individual experiences (Öztap, Özay and Öztap, 2003). Therefore, students are reluctant to correct their misconceptions. In order to make biology teaching effective with the developed strategies, first of all, students' misconceptions about science concepts should be identified and eliminated. As a result of this, many researchers have focused on the diagnosis and treatment of students' misconceptions (Riche, 2000). Students' misconceptions about science are one of the important issues brought up by academic studies, and science educators have many unanswered questions about students' misconceptions (Riche, 2000).

Concepts are the foundation of the science of biology. If the concepts are defined in an easy-to-understand, clear language and supported with materials prepared in the visual and auditory virtual environment that will best explain them, solid foundations are created. In many studies on science teaching since the last quarter of the twentieth century, it has been observed that students have too much difficulty in some science subjects. Science educators, who are aware that the most negative effect on science education is the misconceptions that students have, have to determine how these subjects should be taught, the most effective teaching methods and techniques to ensure meaningful and permanent learning and to eliminate misconceptions (Kendirli, 2008).

Among the reasons for studying so much in biology are (a) students' misconceptions are one of the most important factors affecting students' success, (b) an effective biology course needs to reveal the misconceptions that students bring with them when they come to biology class, and (c) it will improve these misconceptions various findings such as containing information and activities, can be counted. Cell biology (Marek, 1986; Suwono et al., 2021), evolution, adaptation and natural selection (Anderson et al., 2002; Beardsley et al., 2012; Shtulman and Calabi, 2012; Ozay Kose, 2010; Keskin and Ozay Kose, 2017), structure of the human body, identification of various organ systems (Svandova , 2014), photosynthesis and respiration (Marmaroti and Galanopoulou, 2006; Özay and Öztaş, 2003), osmosis and diffusion (Friedler et al., 1987; Tekkaya et al., 1999; Artun and Coştu, 2011), ecology, plant biology (Tekkaya et al., 2000), genetics (Lewis and Robinson, 2000) are among the misconceptions frequently encountered in biology education.

Considering that misconceptions are an educational problem; It is foreseen that the results of a study in which studies published on misconceptions in biology education will be examined within the framework of various parameters will contribute to academicians by providing useful information. As in other science fields, studies in the field of biology education aim to reveal current trends in the field, to determine which subjects are saturated or what kind of new research is needed, and thus to increase the quality of education (Karamustafaoğlu, 2009; Şimşek et al. 2008). In addition, new researchers get an idea of what previous research is, thanks to published scientific articles and research (Henson, 2001; Tsai & Wen, 2005). Because, people who do research should first seek answers to questions such as "what are the previous studies in the literature", "what issues and problems will be needed to work on" and "what are the ways to meet these needs and how to solve them" (Karamustafaoğlu, 2009; Şimşek. et al., 2008). However, organizing and examining the studies on science education at certain times and determining the trends are important in terms of helping people who want to work on this subject (Çiltaş et al., 2012). For this reason, content analysis of the studies should be done (Gül and Köse, 2018).

There are studies published in peer-reviewed journals regarding the content of articles and theses related to biology

education (Altınışık, 2015; Köse, Çetin and Yünkül, 2018; Erdoğan, Marcinkowsky and Ok, 2009; Erdoğan, Uşak and Bahar 2013; Köse, Gül and Konu, 2014; Umdu-Topsakal, Çalık and Çavuş, 2012; Ünlü, Sever and Akpınar, 2011; Gül and Sözbilir, 2015; Gül and Sözbilir, 2016, Gül and Ozay Kose, 2018). No study has been found in the international literature to examine articles directly related to misconceptions in the field of biology and the bibliometric analysis to be conducted on this subject will be a first.

Within the framework of the stated reason, in this study, it is aimed to identify the research articles published on the misconceptions in the field of biology education in peer-reviewed journals published and to examine these researches in terms of certain criteria. This study is important in order to direct the studies on misconceptions in biology education and to design more comprehensive new studies. In this context, the articles scanned in the Scopus database were subjected to bibliometric network analysis.

Bibliometric analysis is a method that provides the most accurate data about the historical developments and trends of a subject in the literature and helps researchers who want to study in the relevant literature from where they should start (Özay, 2022). With bibliometric analysis, various features of academic publications are evaluated using quantitative analysis. In this way, it is possible to create a general framework related to a certain discipline by examining the statistical data of the studies such as author, subject, cited studies and authors (Bozkurt and Çetin, 2016; Akcan et al., 2023).

Scholars have suggested that the bibliometric technique is an interdisciplinary method that enables effective mapping of aspects and themes addressed during the development of a research field (Khanra et al., 2020, 2021; Liao et al., 2018; Martínez-L´opez et al., 2018; Tandon et al., 2021). However, bibliometric method-based compilations that include analyzes such as research productivity, citation rankings, and coexistence of concepts or citations have the potential to make significant contributions to the literature (Gordon et al., 1984). When the literature is examined, bibliometric analysis has been applied by many researchers from different disciplines to detect trends in research (Azer, 2017; Çelik et al., 2021; Çetinkaya and Çetin, 2016; Gülmez, Özteke and Gümüş, 2020; Karagöz and Ardıç, 2019; Kulak 2018; Kulak and Çetinkaya 2018; Kumar et al., 2021; Moral-Muñoz et al.,2020; Polat et al., 2013; Zhang et al., 2022).

The current study differs from other studies in that it uses a bibliometric method and focuses on misconception research in biology education. In addition, it has been understood that current mapping methods are not used in bibliometric studies that generally focus on biology education research. In this context, the current study contributes to the literature by revealing the general status of misconception research in biology education published in internationally indexed (Scopus) educational journals with the help of basic bibliometric analyzes and visual maps. The aim of this study is to make bibliometric analyzes of misconceptions studies in biology education within the framework of various parameters. During the research process, answers were sought to the following questions:

1) What is the distribution of studies on misconceptions in the field of biology education between 1970-2022 by years?
2) What is the distribution of studies on misconceptions in the field of biology education between 1970-2022

according to keywords?

3) What is the distribution of studies on misconceptions in the field of biology education between 1970-2022 by terms?

Method

This research is a review study and a descriptive research design was followed. Descriptive research is carried out with the aim of identifying and explaining existing and experienced situations (Karasar, 2009). The bibliometric method was chosen to discover which years, keywords and terms were most focused on in hundreds of misconception studies conducted in biology education. This method was preferred because it is possible to analyze hundreds or even thousands of studies in depth with the bibliometric method and because graphical definitions are included with the visual mapping technique for the research field (Börner et al., 2003; Zupic and Cater,2015).

Data Collection Process

The articles containing the misconceptions about biology within the scope of the research were accessed through the Scopus database. Scopus is an Elsevier organization that includes many journals from many publishers that offers abstracts, citations, full documents to the user, and also includes author features (Özgirgin, 2010). In addition, Scopus is a heterogeneous database that offers publications from many sources to the service of researchers (Ramalho et al., 2020). The reason for using Scopus database instead of Web of Science or Google Scholar for bibliometric analysis is that Scopus database is the largest database in the literature, producing information with better decisions and results, a valuable resource for bibliometric studies, technology, science, art, medicine and social science. It is preferred more because it provides a comprehensive and broad perspective in that fields (Ekinci & Özsaatçi; Işın, 2022; Martín et al., 2018).

First of all, “Article title, Abstract, Keywords” section was selected in order to get the most results from the Search within search button in the Scopus database. Then, the search was carried out by typing "biology and misconception" in the section of the scopus where the "search documents" search button is located. The reason for searching in this way is; misconception is expressed in different ways by different scientists in the literature (Gülev, 2008; Helm, 1980; Sutton, 1980). For example; According to Novak (1977), prejudices are in the form of naive concepts, intuitive beliefs, faulty ideas, underlying sources of error, persistent difficulty traps, and personal models of reality. Although these terms generally express the same concept, the term "misconception" is used more in the literature.

About thirty years ago, alternative concepts were used instead of the concept of Misconception. However, although alternative concepts were used, the concept of misconception was also mentioned. In fact, since we found the same studies when we scanned with the alternative concepts mentioned during the analysis, we used the concept of misconception, which is now the most frequently used and accepted as the most general concept in the studies. It is seen that the concept of misconception was used in previous studies to be comprehensive (Gül and Sözbilir, 2015; Gül and Sözbilir, 2016, Gül and Ozay Kose, 2018; Köse, Gül and Konu, 2014; Umdu-Topsakal,

Çalık and Çavuş, 2012; Ünlü, Sever and Akpınar, 2011). For this reason, the term “biology and misconception” was preferred while searching. Therefore, the limitation of this study is that the search was made only as "biology and misconception". 751 publications were found as a result of the search. Then, the Social Sciences section of Scopus was selected and filtered, and as a result, 410 publications were included in the research. The reason for filtering is that not all of the accessed publications are related to the subject, so the Social Sciences section has been selected. The search was carried out on 13.09.2022. Since the years of accessed publications start in 1970, studies between 1970 and 2022 were included in the research. Language discrimination was not made in the research. the publications were then exported to CSV form and in turn subjected to the bibliometric analysis using VOSviewer (Visualization of Similarities) Software.

Data Analysis

Bibliometrics is a measurement method used to describe and analyze the progress of a particular discipline or a particular field of research, using computer technology to display visual literature analysis results in a simple and clear graph (He et al., 2022; Merigó et al., 2015). The bibliometric network analysis used in the bibliometric method, on the other hand, is an approach technique used in the context of analyzing the relationships between research subjects, authors and institutions in a discipline, and showing and interpreting how these relationships are (Buonocore et al., 2018; Taddeo et al., 2019). In order to summarize the temporal and holistic plane that is not easily understood due to the ever-increasing development of literature on misconceptions in biology, the bibliometric network analysis method was preferred in this study. Another reason we prefer this method is to visualize scientific research with this method and to determine the relationships between certain topics, authors, journals, countries or institutions (Van Eck and Waltman, 2010).

VOSviewer is software that can be used in mapping for bibliometric data analysis (Al Husaeni & Nandiyanto, 2022; Al Husaeni et al., 2023; Hamidah et al., 2020; Mulyavati & Ramazan, 2021). This software enables us to collect literature efficiently and to establish interrelationships between selected publications within options (Kuzior & Sira, 2022). VOSviewer software visualizes bibliometric networks for easier analysis. With the VOSviewer program, analysis of certain subject areas, analyzes to determine the word density in the studies, analysis of the contents of the websites, analysis of the theses and co-authorship, the determination of the related words in the field can be provided and with which words the words used in the literature have closer coordinates can be provided. At the same time, it can be made more possible to detect meaningful relationships in big data (Artsın, 2020). In this research, VOSviewer v.1.61 program was used.

Findings and Discussion

Examination of Publications in terms of Years

When the trend of publications containing 410 misconceptions on biology is examined in Figure.1; it is seen that the studies on the subject started in 1970, there were fluctuations in the form of increases and decreases in the studies from 1970 to 2006, and studies between 1970 and 2006 constitutes 17% of the total studies. The increasing number of articles devoted to studies on misconceptions in biology education after 2006 can be explained as proof

that this subject has an important place among academics and needs to be examined. Although the number of publications reached its peak with a total of 31 studies (7.5%) in 2013, a decrease by almost half was observed in 2014. In the following years, although there are fluctuations in the number of publications again, it is seen that the number of publications isclose to each other in the ten-year period between 2011 and 2021, constituting 68% of the total studies. It is thought that this situation stemmed from the search for the reasons that prevented a new, modern and effective science education program throughout the world in those years. Considering the results obtained from the analysis of misconceptions in science education by Kurtuluş and Tatar (2021), it was observed that the highest number of publications was observed in 2013, which is in line with the resultsof this study.

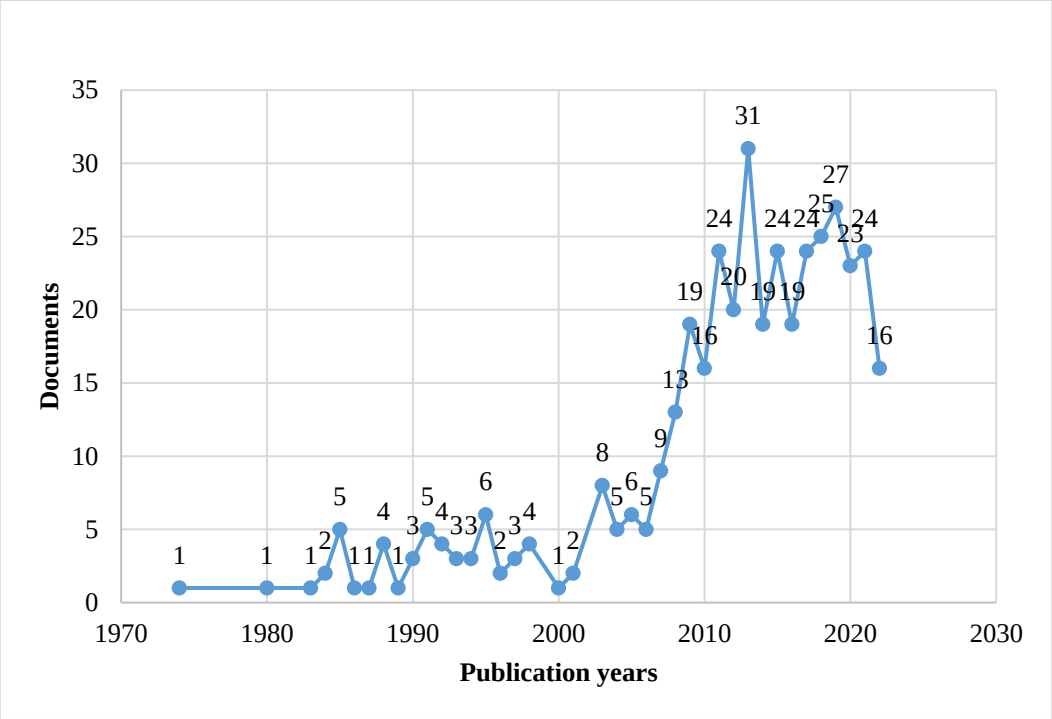


Figure 1. Number of Documents published between Years

Most Used Keywords in Publications

Keywords are one of the critical points of research. In this context, core keywords were revealed by performing keyword analysis. Threshold value shows at least how many times a reference is repeated (Akpınar and Atak, 2017). Figures for threshold values can take different forms in different datasets. When the threshold value is increased, the number of keywords to be included in the analysis decreases. When the threshold value is lowered, the number of keywords to be included in the analysis increases (Öztürk and Gürler, 2021).

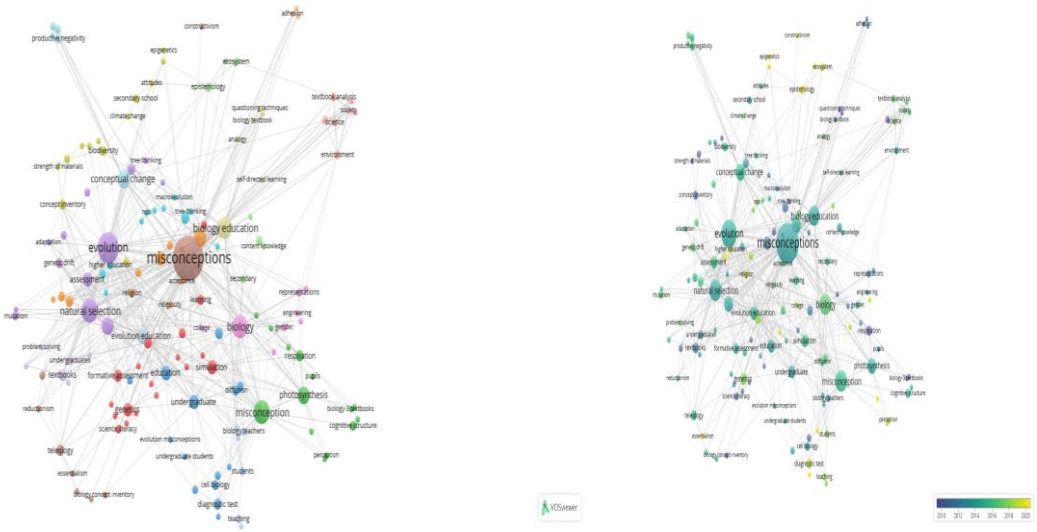
In this study, the threshold value was set as 2. For the analysis to determine the most common keywords related to the subject, 2 keywords were accepted as the minimum repetition of a keyword. 156 of 853 keywords reached the threshold. If this threshold value is set to 3, the number of keywords to be included in the analysis decreases to 71. Therefore, the threshold value was set as 2 in order to include more keywords in the analysis. The image created with Vosviewer for keyword analysis is given in Figure 2.

Table 1. Examining the Publications in terms of Keywords

Keyword	Occurrences	Total Link Strength	Keyword	Occurrences	Total Link Strength
Acceptance	2	8	Motivation	2	6
Active learning	12	27	Mutation	3	6
Adaptation	2	9	Natural selection	22	79
Adhesion	2	7	Nature of science	6	10
Analogy	2	5	Nos	2	2
Anatomy	2	1	Oklahoma	2	11
Assessment	8	23	Osmosis	4	13
Attitudes	2	5	Pedagogical content knowledge	2	2
Biodiversity	4	6	Pedagogy	2	5
Biological evolution	2	8	Perception	2	3
Biology	20	44	Photosynthesis	12	31
Biology concept ınventory	2	4	Phylogeny	5	11
Biology education	19	50	Plant respiration	2	4
Biology teacher education	2	6	Population genetics	3	4
Biology teachers	3	12	Pre-service biology teachers	4	11
Biology teaching	5	8	Pre-service teacher	2	5
Biology textbook	2	5	Pre-service teachers	4	4
Biology-3 textbooks	2	5	Preconceptions	2	5
Cell biology	4	7	Preservice science teachers	2	3
Cellular respiration	2	6	Prior knowledge	2	4
Charles darwin	2	2	Problem solving	2	4
Circulatory system	2	5	Productive negativity	4	11
Climate change	2	3	Professional development programme	2	4
Cognitive structure	4	3	Professional knowledge	2	8
Cohesion	2	7	Protein synthesis	2	3
College	2	2	Public high school	2	11
Common ancestor	2	4	Pupils	2	3
Concept inventory	4	14	Questioning techniques	2	6
Concept map	3	3	Randomized	3	10

Keyword	Occurrences	Total Link Strength	Keyword	Occurrences	Total Link Strength
			controlled trial		
Concept ınventory	2	4	Reasoning	2	8
Conceptual change	14	39	Reductionism	2	6
Conceptual development	2	4	Religion	3	9
Constructivism	2	1	Religiosity	2	7
Content knowledge	2	2	Representations	3	9
Context	2	10	Reproduction	2	4
Cooperative/collaborative learning	2	2	Respiration	5	14
Creationism	8	27	Science	3	16
Curriculum support materials	2	8	Science education	13	33
Darwin	3	11	Science literacy	3	4
Diagnostic assessment	3	10	Science misconception	2	1
Diagnostic test	5	7	Scientific content	2	5
Diffusion	4	13	Scientific literacy	3	17
Ecology	2	5	Secondary	3	8
Ecosystem	3	8	Secondary education	3	4
Education	9	24	Secondary school	3	3
Engineering	2	5	Secondary science	2	2
Environment	3	18	Self-directed learning	2	2
Epigenetics	2	2	Serious game	2	8
Epistemology	4	12	Simulation	8	21
Essentialism	2	6	Society	2	14
Evolution	37	113	Sorting process	2	6
Evolution education	9	37	Strength of materials	2	4
Evolution misconceptions	2	4	Stse issues	2	14
Evolutionary biology	5	11	Student misconceptions	3	6
Evolutionary mechanisms	3	12	Students	3	9
Formative assessment	6	8	Students' understanding	2	0
Gender	3	3	Surface tension	2	7
Genetic drift	4	16	Teacher beliefs	2	6
Genetic engineering	2	2	Teacher education	2	3
Genetics	7	17	Teacher preparation	2	9
Genetics learning	2	2	Teaching	3	4
Greenhouse effect	2	3	Teaching evolution	4	12

Keyword	Occurrences	Total Link Strength	Keyword	Occurrences	Total Link Strength
Higher education	3	8	Teaching/learning strategies	2	2
Human evolution	3	12	Technology	2	14
Knowledge	5	17	Teleology	5	14
Learning	4	17	Textbook analysis	3	16
Learning approach	2	6	Textbooks	6	21
Learning cycle	2	5	Theory of evolution	2	4
Learning progressions	2	5	Tree of life	2	4
Macroevolution	2	3	Tree thinking	2	6
Meiosis	3	4	Tree-thinking	2	4
Mental models	2	3	Undergraduate	8	25
Middle school	2	6	Undergraduate education	3	4
Misconception	22	51	Undergraduate students	2	3
Misconceptions	78	182	Undergraduates	4	17
Modeling	2	6	Understanding	3	6
Models	2	8	Intelligent design	3	10
Molecular biology	3	8			



A B

Figure 2. Keyword Network Analysis (A) and Temporal Trend of These Clusters (B)

When Figure 2 is evaluated in the context of cluster formation, many clusters have been identified. However, misconception of the terms has been addressed on “evolution and its related terms, natural selection, genetic drift,

mutation, adaptation, population genetics, phylogeny etc. (Figure2–A). The theory of evolution is very important for the biology course. So much so that Gould (1982) compared a biology education without evolutionary theory to chemistry without a periodic table. The evolution is of the most discussed topics among researchers and community since Galapagos Island visit of Charles Darwin.

The misconceptions observed in studies on evolution based on the literature are mostly "evolution happened by chance, there is no evidence to support the theory of evolution, it is irreligious to accept evolution, there are no transitional fossils between species, changes in living things have occurred since ancient times, so they cannot be observed, and species are a common phenomenon." each species has its own ancestor, not an ancestor" (Asghar et al., 2007; BouJaoude et al., 2011; Deniz et al., 2008; Fahrenwald, 1999; Graf & Soran, 2011; Keskin & Özay, 2017; Kim & Nehm, 2010; Pazza et al., 2010; Smith, 2010; van Dijk & Reydon, 2010).

When the subject is the theory of evolution, religion and science intersect and a contradictory situation arises (İnan and İrez, 2021). Darwinian theory is no longer just a scientific revolution, but a theory of revolution that includes religious beliefs and thoughts about human status and hopes for an ideal life (Ruse, 2007). Natural selection is the core issue of evolution, being one of the misconceptionalized for some yet. When we look at the literature, it is seen that students have a lot of misconceptions about adaptation and natural selection. (Anderson et al., 2002; Beardsley et al., 2012; Bishop ve Anderson, 1990; Clough ve Wood-Robinson, 1985; Demastes et al., 1995; Fahrenwald, 1999; Grant, 2009; NRC, 1995; Özay ve Keskin,2015Shtulman, 2006; Shtulman ve Calabi, 2012).

The most common misconceptions about evolution and natural selection in the literature are: Natural selection involves organisms trying to adapt. Natural selection gives organisms what they need. These concepts are considered biologically incorrect because the adaptation of species over time does not involve effort, desire, or need. Natural selection acts on genetic variation in a population where some variants may leave more offspring than others in the next generation. While intent and need do not play a role in the process of natural selection, the logic underlying this misunderstanding is a logical extension of what we experience in our own personal lives (Maskiewicz & Lineback, 2013). According to Darwin, the fundamental problem of evolutionary biology is adaptation. Two problems arise here. First, by what process (dynamics) does biological adaptation occur? Second, what is the purpose of adaptation: What organisms appear to be designed to do. At this point, Darwin's theory of natural selection explains both the process and the purpose of adaptation (Gardner, 2009; West, 2011). For Darwin, natural selection is a long-running, complex process involving multiple interrelated causes (Darwin, 1859; Gildenhuys, 2019). The adaptation process takes place through the action of natural selection driven by the differential reproductive success of individual organisms. These heritable traits associated with greater reproductive success tend to accumulate in natural populations (Darwin, 1859; Friedman, 1953). For the process to work, at least some of the variation must be inherited and somehow passed on to the descendants of organisms (Darwin, 1859; Gildenhuys, 2019).

Another example of misconceptions is that mutation is random. Natural selection, by definition, is not random in fitness. In general, this means that it is a serious misconception to think that adaptation happened “by chance” (Gregory,2009). In another example, students often attribute agency to trait changes in populations as if an

organism's need would cause a trait to change even during that organism's lifetime. The misconception is that the source of genetic variation is not random and is instead the result of external pressures. Many students also struggle with the idea of evolution as changes in the frequency of an allele or trait within a population, and instead think that populations gradually change their traits as a whole (Abraham et al., 2009).

The fact that teachers do not have sufficient knowledge about evolution seriously causes misconceptions in students (Keskin & Özay Köse, 2017; Özdeş et al., 2020). In addition, when the literature is examined, the main causes of misconceptions are the deficiencies about the concepts related to the nature of science such as law and hypothesis (epistemological = epistemological deficiencies), as well as the deficiencies in the content information of the theory of evolution (natural selection, adaptation, mutation, variation concepts, etc.) and scientific it is seen that there are deficiencies in perceiving the differences between knowledge and non-scientific knowledge (traditional and religious beliefs) (Apaydın & Sürmeli, 2009; Baker & Piburn, 1997; Lawson, 1995; NRC, 1998). The second misconceptionalized terms is linked to photosynthesis and respiration (Figure.2-A). This finding from the study is not surprising at all. Because the subjects of photosynthesis and respiration are biology subjects that are difficult to understand (Marmaroti ve Galanopoulou, 2006; Özay and Öztaş, 2003).

Some of the misconceptions identified in the literature related to photosynthesis and respiration are as follows; “Sunlight is converted into food in photosynthesis”, “The purpose of photosynthesis is to produce energy”, “Respiration is the process by which animals take oxygen and turn it into carbon dioxide”; “The dark reactions of photosynthesis happen at night”; “Green plants get the metabolic energy they need from insects and maggots”; “The most important task of the leaves is to release carbon dioxide”, “the nutrients of the plants are minerals taken from water and soil”, “plants produce oxygen day and night”, “the most important food source for the plant is water containing dissolved substances absorbed by the root system”, “the oxygen emitted from the photosynthesis process is for respiration, plants are not used by themselves but only by animals” etc. (Jayanti,2020; Kaya, 2010; Keleş and Kefeli, 2010; Keleş and Köse, 2004; Svandova,2014).

When the literature is examined, it is stated that some of these misconceptions are most likely due to students trying to understand the definition of photosynthesis and respiration by memorizing only the formula (Bacanak et al., 2004; Köse et al., 2005; Köse at al., 2006; Töman et al., 2016). Cho (1988) stated that photosynthesis is a chemical process necessary for the production of glucose, that CO_2 from the air and H_2O from the soil is taken during this process, that photosynthesis takes place with the help of solar energy in the chlorophylls found in the green parts of the plants. stated that it may be the reason. In addition, another reason why students have misconceptions about photosynthesis and respiration in science lessons is that while the concrete concepts in the subjects can be learned more easily by the students, the subjects in which abstract concepts are intensely involved and the subjects in which micro or macro natural events are explained remain more difficult in the minds of the students. (Oren et al., 2012).

Recognizing students' misconceptions is an important component of effective science teaching. In order to improve science education, educators should realize how misconceptions occur and what kind of misconceptions students have about a particular subject (Kestler, 2014). For this reason, students' initial understandings should be

carefully considered by teachers. One of the ways is to identify misconceptions that students already have from time to time, so that teachers can plan more effective lessons in the teaching and learning process (Lim & Poo; 2021).

According to the time trend, which is the second dimension of the analysis, recent studies on the misconception in biology have focused on epigenetics (Figure 2-B). This finding can be considered as an indicator of new research interests of academics working on misconceptions in biology. Regarding the subject, Lynch et al. (2022) state that the field of epigenetics is currently one of the fastest expanding fields in biology due to the increasing interest of the public in applications for human health. Epigenetics is the changes in gene function that cannot be explained by changes in the DNA sequence and can be inherited by mitosis and/or meiosis (Orcan, 2006; Semenderoğlu, 2012). When examining the literature, the most glaring misconception about epigenetics is that chromatin modifications are a separate layer of gene editing that responds directly to the environment and can potentially be inherited between generations. This view ignores the fact that environmental factors influence gene expression mainly through activation or repression of transcription factors that recruit chromatin regulators. The epigenome is mainly shaped by DNA sequence and transcription (Horsthemke, 2022).

Also, when we look at the keyword time trend analysis, in the researches on misconception in biology, the topics such as genetics, simulation, green house effect in the time period between 2010-2012; in the time period between 2014-2016, subjects such as photosynthesis, respiration, evolution, protein synthesis; in the time period between 2016-2018, topics such as difussion, osmosis, cell biology; can be said to come to the fore. The reason for this ranking may be related to the fact that the related topics are both abstract and difficult to understand, and that they are popularly spoken in daily life (global warming, GMO products, genetic engineering, protein synthesis, cell biology etc.). It can be said that epigenetics is the most up-to-date subject in research on misconceptions in biology education.

Most Used Terms in Publications

In studies on misconceptions in biology education, 8172 terms were used. In the research, 10 documents were taken into account as the minimum number of passes for a period. Of the 8172 terms, 225 met the relevant threshold. A relevance score was calculated for each of the 225 terms. Accordingly, the most relevant terms were selected. Here the default selection was to select 60% of the most relevant terms. Finally, 135 terms were selected for further analysis of the visualization and networks between terms (see Table 2).

Table 2. Examining the Publications in terms of Terms

Term	Occurrences	Relevance Score	Term	Occurrences	Relevance Score
Acceptance	14	15	Life	34	12.066
Animal	16	0.6748	Light	16	11.876
Answer	28	14.679	Majority	16	0.5411
Article	43	0.6022	Measure	12	0.6415

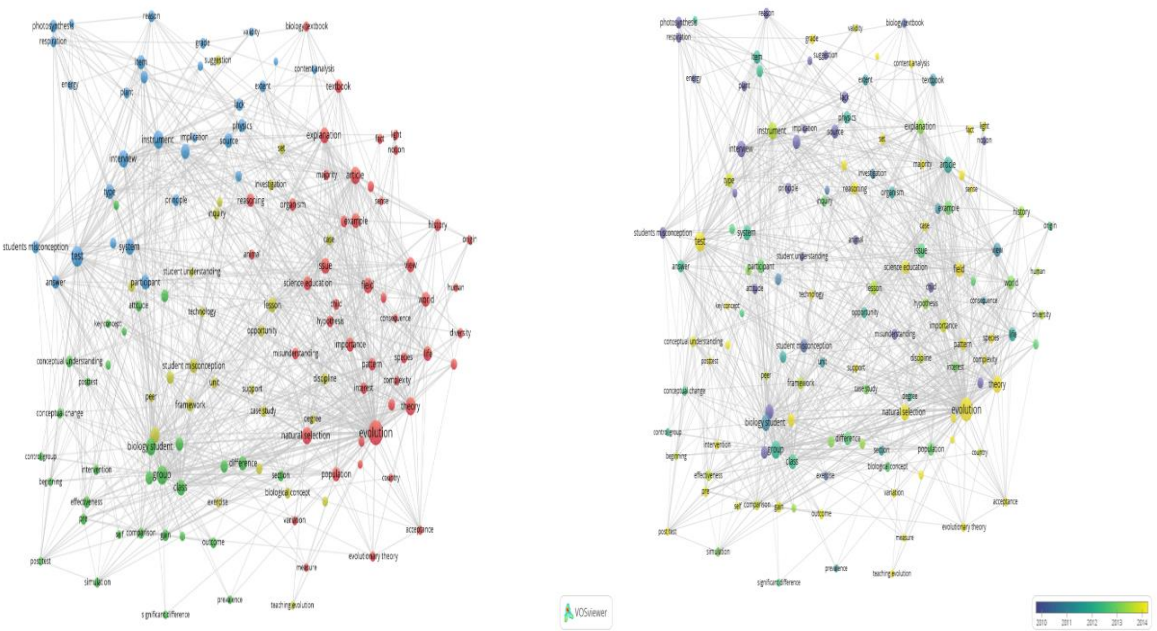
Term	Occurrences	Relevance Score	Term	Occurrences	Relevance Score
Attitude	17	0.7572	Misunderstanding	22	0.3484
Author	20	0.7074	Multiple choice question	12	34.259
Beginning	12	21.913	Natural selection	44	0.416
Biological concept	17	0.5593	Notion	14	12.885
Biology student	42	0.4784	Opportunity	20	0.8433
Biology textbook	16	16.076	Organism	23	0.4136
Case	17	0.6473	Origin	14	18.273
Case study	19	0.4889	Outcome	19	0.4844
Cell	14	12.292	Participant	32	0.7211
Chemistry	32	0.9313	Pattern	23	0.5273
Child	17	0.5613	Peer	13	0.757
Class	37	0.4284	Performance	28	0.5253
Comparison	19	0.9735	Person	21	12.082
Complexity	13	10.682	Perspective	18	0.778
Conceptual change	16	17.047	Photosynthesis	24	46.464
Conceptual understanding	22	15.594	Physics	27	0.8592
Consequence	12	0.8782	Plant	19	16.148
Content analysis	14	0.605	Population	30	0.4473
Control group	12	28.397	Post test	11	37.572
Country	12	0.9433	Posttest	11	14.802
Degree	14	0.5224	Pre	19	16.683
Detail	11	0.6415	Preservice teacher	10	0.8604
Difference	30	0.4122	Presence	15	0.6495
Diffusion	13	10.222	Present study	16	0.6502
Discipline	21	0.5773	Prevalence	11	0.8149
Diversity	15	16.571	Principle	21	0.691
Effectiveness	21	16.583	Reason	22	14.075
Energy	13	34.952	Reasoning	27	0.5274
Environment	28	0.5549	Resource	18	0.6464
Evolution	91	0.6687	Respect	13	0.826
Evolutionary biology	19	11.269	Respiration	19	51.694
Evolutionary theory	16	12.703	Sample	24	0.5656
Example	34	0.7556	Science education	29	0.455
Exercise	14	14.581	Scientific knowledge	12	0.7356

Term	Occurrences	Relevance Score	Term	Occurrences	Relevance Score
Experiment	14	0.8688	Section	19	0.3843
Explanation	38	0.4013	Self	11	0.9863
Extent	22	0.5607	Sense	12	0.7534
Fact	16	1.022	Set	19	0.5652
Field	37	0.5868	Significant difference	11	10.386
Framework	25	0.7135	Simulation	15	1.435
Frequency	23	0.357	Skill	35	0.5552
Function	23	12.402	Source	34	0.3788
Gain	22	0.6348	Species	18	0.9695
Grade	19	0.9449	Student misconception	31	0.3894
Group	54	0.6385	Student understanding	13	11.389
Hand	17	0.5638	Students misconception	25	17.754
High school student	18	0.7187	Suggestion	15	10.862
History	25	1.603	Support	14	0.4028
Human	11	17.696	System	37	0.592
Hypothesis	20	0.4894	Teaching evolution	11	10.982
İmportance	30	0.4505	Technology	15	0.4818
İnquiry	21	0.603	Test	60	1.369
İnstructor	24	0.8088	Textbook	27	10.632
İnstrument	48	0.9092	Theory	49	0.9795
İnteraction	14	0.7968	Type	32	0.8338
İnterest	22	0.6844	Undergraduate	18	0.7226
İntervention	15	14.968	Undergraduate student	16	0.5619
İnterview	44	0.8189	Unit	19	0.4563
İnvestigation	19	0.5038	Validity	12	10.959
İssue	36	0.3662	Variation	13	0.6332
İtem	29	16.086	View	34	0.9055
Key concept	12	0.6391	World	32	11.278
Lack	23	0.5422	Implication	14	0.4809
Lesson	33	0.559			

Accordingly, the most frequently used word in this study was determined as "evolution" (f=91). This is followed by the terms “test” (f=60), “group” (f=54) and “theory” (f=49). When evaluated in terms of affinity relationship,

it was determined that the term “respiration” (R.Sc:51,694) had the highest relevance score. This is followed by the terms "photosynthesis" (R.Sc:46,464), “conceptual change” (R.Sc:17,047), “Conceptual understanding” (R.Sc:15.594) and "Biology textbooks" (R.Sc: 16,076) (see Table.2).

Among the terms removed from the study, respiration was found to be the most frequently used term with a high relevance score. This finding is not at all surprising. Because respiration is one of the fundamental subjects of general biology. In addition, due to the fact that it is an abstract subject, it is thought that students have a lot of misconceptions about this subject. As a matter of fact, in various studies, it has been stated that students have misconceptions that may prevent the acquisition of new information on the "Respiratory System" (Aydın & Balım, 2009; Bacanak et al., 2004; Crawley & Arditzoglou, 1988; Lazarowitz & Lieb, 2006; Yazıcı and Sözbilir, 2020; Yürük & Çakır, 2000). According to the relevance score, photosynthesis is also among the most frequently used terms. While explaining the subject of photosynthesis, the necessity of explaining the subject of respiration can be considered as the reason why the relevance score of respiration is higher than that of photosynthesis. Respiration and photosynthesis are interconnected issues. The coupling between respiration and photosynthesis plays an important role in the energetic physiology of green plants and some secondary-red photosynthetic eukaryotes (Gain et al., 2021). In addition, studies reveal that students encounter some difficulties in understanding photosynthesis, and that talking about respiration and energy production while explaining photosynthesis makes the subject more complex for students (Mikkila-Erdmann, 2001).



A B

Figure 3. Term Analysis (A) and Temporal Trend of These Clusters (B)

Another term with high relevance scores in the research is “conceptual change” and “conceptual understanding”. In order to get rid of misconceptions, meaningful learning methods should be used (Karakuyu & Tüysüz, 2011).

The conceptual change approach aims to learn concepts in a meaningful way instead of encouraging students to memorize (Koray Cansungü and Honey, 2002). Conceptual understanding shows that the subject is learned at a meaningful level (Uzunhasanoğlu et al., 2020).

"Biology textbooks" are among the terms with high relevance scores in the research. Bennour (2021) stated that textbooks continue to be a mandatory reference document especially for students and teachers, however, they can be a source of misunderstandings. Again, Öztaş and Özay (2004) stated in their studies that misconceptions may arise from the textbooks taught to the students, from the teachers, or from the fact that the current knowledge level of the students about a subject is not sufficiently known by the teacher.

When we look at Figure.3-A, size of circle is the most used term, colors show clusters and lines show unity. Accordingly, it is seen that the terms used with clustering are mostly concentrated in the terms biology student, student misconception, evolution, and the association between terms is high. Looking at the analysis made according to the time trend, it is seen that the terms used in recent years again focus on evolution (Figure.3-B).

Conclusions

In this study, studies on misconceptions in biology education are included. Bibliometric analyzes of the published studies were made using various parameters such as year, keywords and terms. The dataset used in this study was created based on 410 works indexed in the Scopus database between 1970 and 2022. In this respect, the study is considered to be the study with the most comprehensive data set, aiming to reveal the general situation regarding misconceptions in the field of biology education, where similar methods are used. As a result of this study; it is seen that studies on the subject started in 1970, there were fluctuations in the studies until 2006, and after 2006, the studies gained serious momentum. The number of publications reached its peak in 2013, and although there were fluctuations in the number of publications again in the following years, it seems that the number of publications was close to each other in 2013. When evaluated in the context of keywords and terms, concepts related to evolution took the first place, and concepts related to photosynthesis and respiration took the second place.

Recommendations

This is the first study providing a bibliometric analysis of research trends in documents on the effects of misconceptions in biology education. This situation creates a unique field for new studies on the subject. This study provides an overview of and an effective understanding of the current status of the literature on misconceptions in biology education and offers interesting insights into the development of the field. We believe that the results of this study are important for the future developments of misconceptions in the biology education. Although the research is a study on misconceptions in particular, it is generally related to biology education as a research area. Therefore, it gives ideas about how the issue can be handled in related disciplines. In addition, ideas about how and which studies can be conducted in other fields can be obtained from this study. From this point of view, biology education research will fill the gaps in the literature and provide the opportunity to follow new

trends closely. Also, more detailed bibliometric studies can be conducted in different fields of education, taking into account the macro data presented in this research. Bibliometric studies are important for researchers to closely follow the studies and developments in that field. The research is also to include a method applicable to different fields of science. For this reason, it directs new researches' interests as a method how to follow and it may be recommended to conduct bibliometric studies in different fields. Researchers who will conduct a literature review in this field may be advised to consider the most commonly used keywords in publications obtained from our research and make use of these expressions while scanning. According to keyword analysis, the most relevant keywords are evolution, photosynthesis and respiration. Studies containing other keywords regarding biology misconceptions should also be given greater emphasis. We believe that new studies are needed in this field. In addition, researchers who will conduct new studies on misconceptions in biology education may be advised to choose field-specific terms that express the details most effectively as keywords, so that their studies can be easily found by a wide audience. In this study, Scopus, which is considered the most comprehensive database in the literature, was preferred. However, it may also be recommended to use different databases in similar studies. Finally, it is recommended to continue research with an emphasis on identifying and correcting misconceptions in biology.

Limitations

Research data was provided only from the Scopus database. Since publications in other databases such as ERIC are not included in the analysis, it cannot be said to include all publications regarding misconceptions in biology education. In addition, other types of publications such as theses, conference papers or books were not included in the analysis, and the type of publication included in the sample of the research was limited to articles. Moreover, while data are examined according to many parameters in bibliometric analysis, in this study the analysis is limited to three parameters. In the research, the date of analysis was taken as 13.09.2022. The year 2022 will not be completed during this process and the databases will be visible in the relevant database after a few months. Therefore, there may be data loss for 2022.

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