

Features of the formation and development of biophysical concepts among biology students

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Abstract

The purpose of this research; The aim is to get the opinions of biology teachers in determining the formation and development of biophysical concepts among biology students with concept maps. This research is in the case study model, which is one of the qualitative research designs. The participant group of the research consists of 40 biology teachers who are teaching at various high schools in Kazakhstan in the 2021-2022 academic year. The data of the study were collected with a semi-structured interview form created by the researchers. As a result of the research; the vast majority of biology teachers; They stated that they sometimes benefited from concept maps while providing the formation and development of biophysical concepts in their students. Again, the majority of biology teachers; They stated that they often found it necessary to benefit from concept maps while providing the formation and development of biophysical concepts in their students. Biology teachers participating in the research, while providing the formation and development of biophysical concepts in their students, the positive aspects of benefiting from concept maps; They categorized the subject as providing better learning, improving the thought system, establishing relationships between concepts, making the lesson more enjoyable and

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facilitating the learning of key concepts. While biology teachers participating in the research ensure the formation and development of biophysical concepts in their students, the negative aspects of using concept maps are; They categorized it as difficulty of preparation, not being a very effective method and not appealing to every student.

Keywords: Biophysical concepts, concept map, biology teachers

1. Introduction

Biological science has an important place among other sciences and forms a bridge between other sciences (Ceyhan, 2022). For this, it is an important requirement for the individual to have knowledge of basic biological concepts. In addition, developments in fields such as medicine, biotechnology, ecology, environment, agriculture and genetic engineering, which are closely related to biology, affect individuals closely. It is a known situation that biological developments affect all living and non-living environments significantly (Allen and Tanner, 2003).

1.1. Theoretical and conceptual framework

Biology course has a very important place in understanding the world we live in and our relationship with living and non-living things (Liu & Lee, 2013). Many of the answers to the questions in our minds are included in the content of the biology course. The most important thing is that this course is one of the courses that gives students the ability to ask questions. In this way, it enables us to know the universe we live in and ourselves better (Tsui and Treagust, 2013).

One of the most important goals of biology teaching is to effectively learn and use biology concepts, many of which are abstract and difficult to learn. Effective teaching methods are needed to achieve this goal. One of the methods applied in biology teaching is to teach the subjects with the "Concept Maps" method (Nunez et al., 2012). In biology teaching, concepts are of great importance for learning new subjects and associating them with old subjects and providing meaningful learning (Nogerbek et al., 2022). For this reason, concepts should be given a great place in biology teaching and for this, contemporary methods should be used rather than traditional methods (Kelkay and Sitotaw, 2019).

The biology curriculum consists of units covering the acquisitions related to the concepts, principles and theories in biology, as well as the acquisitions related to skills, understanding, attitudes and values (Daily et al., 2019). Concept maps can be used in different ways at different levels of the course (initial, development, explanation, development and evaluation stages) according to different educational purposes (Tripto et al., 2013). Concept maps are generally used in science education as an educational strategy to increase students' success by improving their conceptual perception levels and to evaluate students' conceptual understanding as a measurement and evaluation tool (Zulfiani et al., 2018; Sahin et al., 2021).

However, the Concept map also reveals mistakes. Misconception refers to information about the connection between two concepts or the ignoring of critical features of the concept (Dabbagh, 2001). Concept maps; It can be thought of as planning mechanisms that show what the concepts students need to learn are and how there is a connection between these concepts (Karadag et al., 2017).

Concepts form the building blocks of knowledge, and relations between concepts constitute scientific principles. Concept maps, on the other hand, help students to clarify the basic ideas to be learned and the relationships between them, and to make connections between previous knowledge and new knowledge (Hafeez, 2021).

Concept maps that help to realize meaningful learning are given to teachers; it gives the opportunity to organize concepts, decide ways of discussion with students, and reveal misconceptions (Kinchin et al ., 2005; Chou et al., 2022).

this way, students are able to discover the meanings of the concepts and remember what they have learned for a longer period of time (Schwendimann , 2015). Although the biology course is quite high in terms of both subject content and terminology, it includes many abstract concepts. This makes it difficult for students to understand biological concepts and terms. Therefore, in this research; It is considered important to investigate the level of biology teachers' use of concept maps in order to create biophysical concepts in students (Schaal , 2010).

1.2. Related research

Rao (2004) used a quasi-experimental design with pretest-posttest control group in his study named "The Effect of Concept Mapping in Science on Students' Science Achievement, Cognitive Skills and Attitudes". The sample of the research consists of eight classes determined from two local schools. Concept mapping technique was used in the experimental group (47 students) and traditional teaching was used in the control group (42 students). The developed achievement test was given to the students as a pre-test and post-test; In the pre-test, no significant difference was determined between the groups, but in the post-test, a significant difference was found in favor of the experimental group taught with the concept mapping technique.

In Okebukola (1990), "Achieving Meaningful Learning of Concepts in Genetics and Ecology; In his study titled "Using Concept Map Technique", the effect of using concept maps on meaningful concept learning was examined. The results showed that the experimental group who applied the concept maps technique increased their success by providing meaningful learning. Aykanat et al. (2005) examined the effect of science teaching on student achievement using computer-aided concept maps. As a result of the findings obtained from the study, it was revealed that the computer aided concept maps teaching method was more effective than the traditional teaching method in teaching the "Cell" subject of the "Journey to the Internal Structure of Living Being" unit.

Chang et al. (2002) investigated the students' ability to understand and summarize the subjects in their research titled "The Effect of Concept Maps on Increasing Subject Understanding and Summarizing". The study was carried out with 126 students. As a result of the research, it has been concluded that the concept map method increases the ability of understanding and summarizing the subject. Djanette and Fouad (2014) aimed to determine the misunderstandings of 1st grade students about light propagation (GO) by using concept maps before and after teaching. Boumerdes' work University of Algiers (Algeria) with 52 students studying at the Faculty of Science. In the study, they reached the conclusion that students revealed their wrong meanings by using concept maps.

1.3. Purpose of the research

The purpose of this research; The aim is to get the opinions of biology teachers in determining the formation and development of biophysical concepts among biology students with concept maps. In line with this purpose, the research seeks answers for the following sub-objectives.

1. Biology teachers; Does it make use of concept maps while providing the formation and development of biophysical concepts in students?
2. Biology teachers; Do they find it necessary to benefit from concept maps while providing the formation and development of biophysical concepts in their students?
3. Biology teachers; How does it determine the positive and negative aspects of using concept maps while providing the formation and development of biophysical concepts in students?

2. Methods and Materials

2.1. research method

This research is in the case study model, which is one of the qualitative research designs. The case study is a research approach that is close to qualitative research designs and is one of the research approaches used to obtain detailed information about a situation for the researcher, relevant persons, decision makers or institutions, and sometimes to explain the accuracy and effectiveness of the theory according to the context (Fidel, 1984). The case study model helps to explore and reveal the holistic and meaningful features of real-life events. In addition, researchers have the opportunity to closely examine the data obtained with the help of case studies in a specific context (Yin , 2003). Based on this, the opinions of the teachers in this study were transformed into findings in accordance with the case study.

2.2. Participants

The participant group of the research consists of 40 biology teachers who are teaching at various high schools in Kazakhstan in the 2021-2022 academic year. Teachers who participated in the study reported that they participated voluntarily. Of the biology teachers participating in the study, 21 were female and 19 were male. 16 of the biology teachers have less than 10 years of professional experience and 24 of them have more than 10 years of professional experience.

2.3. Data collection tools

The data of the study were collected with a semi-structured interview form created by the researchers. During the creation phase of the data collection tool, the opinions of 3 experts in the field were taken. Afterwards, the research questions were directed to 2 biology teachers and the comprehensibility of the questions was tested. biology teachers; They found the questions clear and understandable. Thus, the semi-structured interview form was given its final form. Table 1 shows the semi-structured interview form prepared for biology teachers.

Table 1

Semi-Structured Interview Form

Demographic Information of Biology Teachers

Gender:

Professional Experience:

Semi-Structured Interview Questions

1. Do you make use of concept maps while providing the formation and development of biophysical concepts in your students?

Always () Often () Sometimes () Rarely () Never ()

2. Do you find it necessary to use concept maps while providing the formation and development of biophysical concepts in your students?

Always () Often () Sometimes () Rarely () Never ()

3. How do you evaluate the positive and negative aspects of using concept maps while providing the formation and development of biophysical concepts in your students?

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In Table 1, a semi-structured interview form prepared to be used in the research is given. There are 2 demographic questions on the gender and professional experience of biology teachers in the form. In the semi-structured interview form; There are 3 questions about the use of concept maps in the formation and development of biophysical concepts in students of biology teachers. 2 of the questions are closed-ended questions and 1 of them is designed to be open-ended.

2.4. Data collection process

During the data collection phase, face-to-face interviews were conducted with teachers studying at various high schools in Almaty, Kazakhstan. After obtaining the necessary permissions with the schools where the teachers teach, interviews were held to determine the date and time of the meeting. Interviews with teachers in 6 different schools were carried out in groups. Biology teachers were first given information about the ethical principles and content of the research. Afterwards, semi-structured interview forms were distributed, and they were asked to examine the questions and ask if there was anything that was not understood. Then, the teachers filled in semi-structured interview forms and handed them over to the researchers. It took approximately 3 weeks to complete the interview process with all of the teachers who constituted the study group of the research.

2.5. Data collection analysis

Descriptive analysis method was used in the analysis of the research data. The purpose of descriptive analysis is to bring together the data collected as a result of interviews and observations with the reader in an organized and interpreted way. In most descriptive analyzes, the data are classified according to predetermined themes, the findings related to the classified data are summarized, and the summaries are interpreted with the subjective knowledge of the researcher (

Kvale , 1994). The answers given by the biology teachers to the semi-structured interview form were transformed into findings by the researchers using the descriptive analysis method.

3. Results

In this section, the answers given by the biology teachers to the semi-structured interview form developed to collect the research data are given in frequency and percentage tables.

In Table 2, biology teachers participating in the research; The students were given the opportunity to benefit from concept maps while providing the formation and development of biophysical concepts.

Table 2

Biology Teachers' Use of Concept Maps While Ensuring the Formation and Development of Biophysical Concepts in Their Students

Category	F	%
Always	4	10
Often	6	15
Sometimes	22	55
Rarely	5	12.5
Never	3	7.5
Total	40	100

In Table 2, the biology teachers participating in the research benefiting from concept maps while providing the formation and development of biophysical concepts in their students are categorized. 10% of biology teachers answered always, 15% often, 55% sometimes, 12.5% rarely and 7.5% never.

In Table 3, biology teachers participating in the research; It is given that students find it necessary to benefit from concept maps while providing the formation and development of biophysical concepts.

Table 3

Biology Teachers Finding It Necessary to Use Concept Maps While Ensuring the Formation and Development of Biophysical Concepts in Their Students

Category	F	%
Always	7	17.5
Often	26	65
Sometimes	5	12.5
Rarely	2	5
Never	-	-
Total	40	one hundred

In Table 3, the biology teachers who participated in the research find it necessary to use concept maps while providing the formation and development of biophysical concepts in their students . 17.5%

of the biology teachers answered always, 65% often, 12.5% sometimes, 5% rarely. Among the biology teachers participating in the research, ; There is no teacher who answered that I do not find it necessary to use concept maps while providing the formation and development of biophysical concepts in their students.

In Table 4, biology teachers participating in the research; The students' views on the positive and negative aspects of using concept maps while providing the formation and development of biophysical concepts were evaluated.

Table 4

Biology Teachers on the Positive and Negative Aspects of Using Concept Maps While Ensuring the Formation and Development of Biophysical Concepts in Their Students

Category	Subcategory	F	%
Positive sides	Provides a better understanding of the subject	31	77.5
	Develops the thinking system	23	57.5
	It enables the establishment of relations between concepts	10	25
	Makes the lesson more enjoyable	8	20
	Makes learning key concepts easier	5	12.5
Negative Sides	It is difficult to prepare	21	52.5
	It is not a very effective method.	13	32.5
	Does not appeal to all students	9	22.5
	There is no downside	8	20

In Table 4, the views of biology teachers participating in the research on the positive and negative aspects of using concept maps while providing the formation and development of biophysical concepts in their students are categorized. For the positive aspects; 77.5% of the teachers enable the subject to be learned better, 57.5% develop the thought system, 25% ensure the establishment of relations between concepts, 20% make the lesson more enjoyable and 12.5% key They answered that it facilitates the learning of concepts. As for the negative aspects; 52.5% of the teachers answered that it is difficult to prepare, 32.5% is a very effective method, and 22.5% answered that it does not appeal to every student. 20% of the biology teachers participating in the research; They stated that there is no negative side of using concept maps while providing the formation and development of biophysical concepts in their students.

4. Discussions

The majority of biology teachers participating in the research; They stated that they sometimes benefited from concept maps while providing the formation and development of biophysical concepts in their students. Kurnaz and Pektas (2013), in their research on Science and Technology teachers' use of concept mapping technique in measurement-evaluation; teachers stated that they use the concept mapping technique and have their students prepare concept maps; however, it has been revealed that teachers are insufficient in how to score concept maps. The majority of biology teachers participating in the research; They stated that they often found it necessary to benefit from concept maps while

providing the formation and development of biophysical concepts in their students. Wallace and Mintzes (1990) stated that concept maps are a valid and appropriate method for identifying conceptual changes in biology, and Kinchin (2000, 2001) stated that concept maps are a helpful tool in biology learning.

Biology teachers participating in the research, while providing the formation and development of biophysical concepts in their students, the positive aspects of benefiting from concept maps; They categorized the subject as providing better learning, improving the thought system, establishing relationships between concepts, making the lesson more enjoyable and facilitating the learning of key concepts. While biology teachers participating in the research ensure the formation and development of biophysical concepts in their students, the negative aspects of using concept maps are; They categorized it as difficulty of preparation, not being a very effective method and not appealing to every student. Roth (1994) also revealed in his study that concept maps are a useful tool for students. It was stated that maps gave students an idea about what they learned and why, and increased in-class communication. However, it was underlined that this situation is not valid for every student. In their study, Guastello et al. (2000) stated that the method of teaching with concept maps in terms of academic success of students revealed more successful results than traditional teaching methods. Kilic and Saglam (2004) in their research; investigated the effect of concept maps on learning success and permanence in biology education. As a result of the research; It has been revealed that the permanence of the lesson in which the concept mapping technique is used is higher than the lesson in which the traditional approach is used.

5. Conclusion

The coming years will be the age of biological sciences. Within this dynamism, in institutions such as primary, secondary and higher education in biology, students should be taught both biological and cultural issues that occur from birth to death, within the framework of their personal abilities, and it should be ensured that they grow up in a versatile way and gain a good character. In this general perspective, biology, as a living science, constitutes an inevitable part of our culture. For this reason, teaching the concepts in biology has an important place in the education process. It is thought that the use of concept maps in teaching these concepts has positive effects on learning. Starting from here, in this research; In determining the formation and development of biophysical concepts among biology students with concept maps, the views of biology teachers were taken. As a result of the research; the vast majority of biology teachers; They stated that they sometimes benefited from concept maps while providing the formation and development of biophysical concepts in their students. Again, the majority of biology teachers; They stated that they often found it necessary to benefit from concept maps while providing the formation and development of biophysical concepts in their students. Biology teachers participating in the research, while providing the formation and development of biophysical concepts in their students, the positive aspects of benefiting from concept maps; They categorized the subject as providing better learning, improving the thought system, establishing relationships between concepts, making the lesson more enjoyable and facilitating the learning of key concepts. While biology teachers participating in the research ensure the formation and development of biophysical concepts in their students, the negative aspects of using concept maps are; They categorized it as difficulty of preparation , not being a very effective method and not appealing to every student.

6. Recommendations

The results obtained from the research are that biology teachers, their students shows that they sometimes benefit from concept maps while providing the formation and development of biophysical concepts. In addition, teachers; They stated that concept maps should be used frequently in the teaching of biophysical concepts. This situation puts the teachers' lack of ability to prepare and use concept maps. In this direction, in-service training programs are organized for biology teachers at regular intervals in the schools where they study, resulting in the necessity of acquiring the ability to prepare and use concept maps. In addition, teachers; The negative aspects of using concept maps while providing the formation and development of biophysical concepts; The difficulties of the preparation were stated as not being a very effective method and not appealing to every student. Changing the perceptions of biology teachers regarding the negative aspects stated in the in-service training programs can also be presented as a suggestion.

REFERENCES

- Allen , D. , & Tanner , K. (2003). Approaches to cell biology teaching : mapping the journey — concept maps as signposts of developing knowledge structures _ *Cell Biology Education* , 2 (3), 133-136.
<https://doi.org/10.1187/cbe.03-07-0033>
- Aykanat , F. , Right, M., & Kalender, S. (2005). The effect of science teaching with computer aided concept maps on student achievement. *Gazi University Kastamonu Education Journal* , 13 (2), 391-400. <https://search.trdizin.gov.tr/yayin/detay/117175/>
- Ceyhan, B. (2022). Assessing the ethical concerns of science and biology teachers regarding regarding animal experimentation _ *Contemporary Educational Researches Journal* . 12(3), 167–176.
<https://doi.org/10.18844/cerj.v12i3.6931>
- Chang , K. E. , Sung , YT, & Chen , ID (2002). The effect of concept mapping to enhance text comprehension and summarization . *The Journal of Experimental Education* , 71 (1), 5-23.
<https://doi.org/10.1080/00220970209602054>
- Chou , Y.Y. , Wu , PF, Huang , CY, Chang , SH, Huang , HS, Lin, WM, & Lin, ML (2022). Effect of digital learning using augmented reality with multidimensional concept map in elementary science course _ *The Asia -Pacific Education Researcher* , 31 (4), 383-393.
<https://link.springer.com/article/10.1007/s40299-021-00580-y>
- Dabbagh , N. (2001). concept mapping as a mindtool for critical thinking . *Journal of Computing in Teacher Education* , 17 (2), 16-23. <https://doi.org/10.1080/10402454.2001.10784410>
- Daily, S. M. , Mann, MJ, Kristjansson , AL, Smith, ML, & Zullig , KJ (2019). School climate and academic achievement in middle and high school students . *Journal of School Health* , 89 (3), 173-180.
<https://doi.org/10.1111/josh.12726>

- Orazkul, T., Saltanat, I., Aitmagambet, U., Mentay, D., Aizhakhhan, A. & Yerzhan (2022). Features of the formation and development of biophysical concepts among biology students. *Cypriot Journal of Educational Science* . 17(9), 3091-3102 <https://doi.org/10.18844/cjes.v17i9.8036>
- Djanette , B. , & Fouad , C. (2014). Determination of university students ' misconceptions about light using concept maps . *Procedia -Social and Behavioral Sciences* , 152 , 582-589. <https://doi.org/10.1016/j.sbspro.2014.09.247>
- Fidel, R. (1984). the case study method : A case study _ *Library and Information Science Research* , 6 (3), 273-288. <https://eric.ed.gov/?id=EJ308770>
- Guastello , E. F. , Beasley , TM, & Sinatra, RC (2000). concept mapping effects on science content comprehension of low-achieving inner city seventh graders _ *Remedial and special education* , 21 (6), 356-364. <https://doi.org/10.1177/074193250002100605>
- Hafeez , M. (2021). Assessment of academics achievements and memorization power of students by concept map strategy and traditional lecturer approach . *International Journal of Learning and Teaching* , 13 (3), 133-145. <https://doi.org/10.18844/ijlt.v13i3.5922>
- Montenegro , M. (2017). The effect of concept map based education on the problem solving skills of students . *New Trends and Issues Proceedings on Humanities and Social Sciences* , 3 (1), 506-513. <https://doi.org/10.18844/gjhss.v3i1.1813>
- Kelkay , A. D. , & Sitotaw , C. (2019). The effect of practical work to enhance ninth grade achievement in biology class : The case of diaspora secondary school , Ethiopia . *Global Journal of Guidance and Counseling in Schools: Current Perspectives* , 9 (3), 95-105. <https://doi.org/10.18844/gjgc.v9i3.4253>
- Kilic , D. , & Saglam, N. (2004). The effect of concept maps on learning achievement and retention in biology education. *Hacettepe University Faculty of Education Journal* , 27 (27). <https://avesi.hacettepe.edu.tr/yayin/fd2bc105-f061-4668-b219-6c8579c0ca3d/biology-egitiminde-kavram-haritalarinin-ogrenme-basarisina-ve-kaliciligina-etkisi>
- Kinchin , IM (2001). if concept mapping is so helpful to learning biology , why aren't we all doing it ? . *International Journal of Science Education* , 23 (12), 1257-1269. <https://doi.org/10.1080/09500690010025058>
- Kinchin , I. M. , De -Leij , FA, & Hay, DB (2005). The evolution of a collaborative concept mapping activity for undergraduate microbiology students . *Journal of Further and Higher Education* , 29 (1), 1-14. <https://doi.org/10.1080/03098770500037655>
- Kurnaz, M. , & Pektas, M. (2013). Concept map use cases of science and technology teachers in assessment and evaluation. *Mersin University Faculty of Education Journal* , 9 (1). <https://dergipark.org.tr/en/pub/mersinefd/issue/17382/181563>
- Kvale , S. (1994). *Interviews : An introduction to qualitative research interviewing* _ Sage Publications , Inc. <https://psycnet.apa.org/record/1996-97829-000>

- Orazkul, T., Saltanat, I., Aitmagambet, U., Mentay, D., Aizhakhhan, A. & Yerzhan (2022). Features of the formation and development of biophysical concepts among biology students. *Cypriot Journal of Educational Science* . 17(9), 3091-3102 <https://doi.org/10.18844/cjes.v17i9.8036>
- Liu , S. H. , & Lee, GG (2013). using a concept map knowledge management system to enhance the learning of biology . *Computers & Education* , 68 , 105-116. <https://doi.org/10.1016/j.compedu.2013.05.007>
- Nogerbek , A. , Sumatokhin , S., Maimatayeva , A., Ziyayeva , G., & Childibayev , D., (2022). future biology teachers ' opinions on technological pedagogical content knowledge . *World Journal on Educational Technology: Current Issues*. 14 (2), 369-379. <https://doi.org/10.18844/wjet.v14i2.6971>
- Nunez , E. E. , Pringle , RM, & Showalter , KT (2012). Evolution in the Caribbean classroom : A critical analysis of the role of biology teachers and science standards in shaping evolution instruction in Belize. *International Journal of Science Education* , 34 (15), 2421-2453. <https://doi.org/10.1080/09500693.2012.700529>
- Okebukola , PA (1990). attaining meaningful learning of concepts in genetics and ecology : An examination of the potency of the concept mapping technique _ *Journal of research in science teaching* , 27 (5), 493-504. <https://doi.org/10.1002/tea.3660270508>
- Rao , MP (2004). Effect of concept-mapping in science on science achievement , cognitive skills and attitude of students . *epiSTEME-1* , 2 , 130. <https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.116.9295&rep=rep1&type=pdf#page=138>
- Roth , W. M. (1994). Student views of collaborative concept mapping : An emancipatory research project . *Science Education* , 78 (1), 1-34. <https://psycnet.apa.org/doi/10.1002/sce.3730780102>
- Sahin, F. , Adiguzel, S., & Nibat , GC (2021). Examining pre -service science teachers ' diagnostic question preparation skills on Seasons , climate , and weather movements . *International Journal of Innovation Research in Education* , 8 (2), 54-77. <https://doi.org/10.18844/ijire.v8i2.5411>
- Schaal , S. (2010). Enriching traditional biology lectures — Digital concept maps and their influence on achievement and motivation . *World Journal on Educational Technology* , 2 (1), 42–54. <https://psycnet.apa.org/record/2012-24282-004>
- Schwendimann , BA (2015). concept maps as versatile tools to integrate complex ideas : From kindergarten to higher and professional education _ *Knowledge Management & E-Learning: An International Journal* , 7 (1), 73-99. <http://www.kmel-journal.org/ojs/index.php/online-publication/article/view/271>
- Trypto , J. , Assaraf , OBZ, & Amit, M. (2013). mapping What they Know : Concept Maps as an Effective tool for Assessing Students ' Systems thinking . *American Journal of Operations Research* , 3 , 245-258. https://file.scirp.org/pdf/AJOR_2013013015111311.pdf

- Orazkul, T., Soltanat, I., Aitmagambet, U., Mentay, D., Aizhakhhan, A. & Yerzhan (2022). Features of the formation and development of biophysical concepts among biology students. *Cypriot Journal of Educational Science* . 17(9), 3091-3102. <https://doi.org/10.18844/cjes.v17i9.8036>
- Tsui , C. Y. , & Treagust , DF (2013). Introduction to multiple representations : Their importance in biology and biology education _ Of *Multiple representations in biological education* (pp . 3-18). Springer , Dordrecht. https://link.springer.com/chapter/10.1007/978-94-007-4192-8_1
- Wallace, J. D. , & Mintzes , JJ (1990). The concept map as a research tool : Exploring conceptual change in biology . *Journal of research in science teaching* , 27 (10), 1033-1052. <https://doi.org/10.1002/tea.3660271010>
- Yin , RK (2003). Design and methods . *case study research* , 3 (9.2). <https://doc1.bibliothek.li/acc/filmf044149.pdf>
- Zulfiani , Z. , Suwarno , IP, & Miranto , S. (2018). Science education adaptive learning system as a computer-based science learning with learning style variations . *Journal of Baltic Science Education* , 17 (4), 711. http://www.scientiasocialis.lt/jbse/files/pdf/vol17/711-727.Zulfiani_JBSE_Vol.17_No.4.pdf