

Concept Mapping as a Strategy for Addressing Misconceptions in Biology: A Scholarly Review

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Abstract

Misconceptions are persistent barriers to meaningful learning in Biology because students often enter classrooms with ideas formed through everyday experience, previous instruction, language and informal sources. Some of these ideas conflict with scientifically accepted explanations and can interfere with subsequent learning. Concept mapping provides a practical means of making students' thinking visible by requiring them to identify concepts and represent relationships among them. This narrative review synthesizes empirical studies and meta-analytic evidence published primarily between 2020 and 2025 on concept mapping in Biology and related STEM education. Searches were conducted using ERIC, Google Scholar and accessible journal/publisher databases, with bibliographic details cross-checked against journal and indexing records. Studies were included when they reported empirical outcomes or directly examined misconceptions, conceptual understanding, achievement or retention. The evidence indicates that concept mapping can improve Biology achievement and retention and can help identify and reduce misconceptions. For example, Ogundare et al. (2020) reported remediation of 61.9% of identified Ecology misconceptions, while Demirci and Oktay (2021) found significant improvements in achievement and the elimination of misconceptions in protein synthesis. A 2025 meta-analysis of 37 STEM studies found a moderate overall effect of concept mapping on achievement ($g = 0.630$). The review concludes that concept mapping is not a universal cure, but a useful diagnostic, instructional and formative-assessment strategy. Its effectiveness is likely to be greatest when combined with questioning, discussion, practical activities and other conceptual-change approaches.

Keywords: concept mapping, misconceptions, Biology education, conceptual change, meaningful learning, retention, achievement

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Introduction

Teaching Biology is not simply a matter of helping students remember names, definitions and processes. The deeper challenge is helping learners understand how biological ideas fit together. A student may, for example, correctly define a gene, chromosome and DNA and still be unable to explain how the three are related. Another learner may know that dominant and recessive alleles exist but assume that a dominant trait must be the most common trait in a population. Such responses are important because they reveal the structure of the learner's thinking, not merely a missing fact. The central problem addressed by this review is that, although concept mapping is widely recommended for meaningful learning, the evidence specifically connecting it with the diagnosis and remediation of Biology misconceptions is scattered across different topics, learner groups and research designs. Without a transparent synthesis of this evidence, teachers and researchers may overgeneralize positive findings from achievement studies and overlook the conditions under which concept mapping actually helps learners change inaccurate conceptions.

Misconceptions can be particularly persistent in Biology because many biological processes are microscopic, abstract, dynamic or difficult to observe directly. Genetics, cell division, photosynthesis, respiration, ecology, evolution and molecular biology require learners to coordinate several concepts at once. When an existing explanation is internally meaningful to a learner, simply telling the learner the 'correct answer' may not be enough to dislodge it. What is needed is an approach that allows students to express what they think, examine relationships among ideas, encounter evidence and reconstruct their understanding.

Concept mapping is well suited to this purpose. It is a visual knowledge-representation technique in which concepts are connected by labelled relationships to form meaningful propositions. Its roots are commonly traced to Novak's work in the 1970s and to Ausubel's theory of meaningful learning, which emphasizes the importance of relating new knowledge to relevant prior knowledge (Novak & Cañas, 2008). In recent years, empirical work has continued to examine its value in Biology and STEM education, including its influence on achievement, retention and misconceptions (Ahmed et al., 2021; Demirci & Oktay, 2021; Wang et al., 2025).

Objectives

The review had four objectives: (1) to examine empirical evidence on the use of concept mapping in Biology and related science education; (2) to identify evidence that concept mapping can diagnose or remediate misconceptions; (3) to examine reported effects on achievement and retention; and (4) to identify practical conditions and limitations that should guide classroom use of concept mapping.

Methodology

This article used a narrative review design. The search strategy was developed around the terms concept mapping, concept maps, misconceptions, conceptual change, Biology education, Biology achievement, and retention, used singly and in combinations. Searches were conducted through ERIC, Google Scholar and accessible journal/publisher databases, and records were cross-checked against journal, DOI and indexing pages where available. The search prioritized studies published from 2020 to 2025 so that the synthesis reflected recent evidence. Foundational works and high-relevance synthesis studies outside this period were retained only where they were necessary to explain the theoretical basis or the broader evidence base.

Eligibility and selection

Studies were considered eligible when they (a) addressed concept mapping as an instructional, diagnostic or assessment strategy; (b) involved Biology or a closely related science/STEM learning context; and (c) reported empirical findings on misconceptions, conceptual understanding, achievement, retention or related learning outcomes. Purely theoretical papers, opinion pieces and studies unrelated to the review objectives were excluded. Because the evidence was methodologically heterogeneous, the review did not combine the primary studies statistically. Instead, findings were synthesized narratively, while the 2025 STEM meta-analysis by Wang et al. (2025) was used as a higher-level quantitative source. This approach is consistent with a narrative review rather than a systematic review or de novo meta-analysis.

Data extraction and methodological appraisal

For each included empirical study, information was extracted on year, country, Biology topic, participants, design, major outcome and principal finding.

Methodological quality was appraised narratively rather than with a formal risk-of-bias instrument, focusing on clarity of design, sample description, data-collection procedures and appropriateness of the reported analysis. Quasi-experimental studies were interpreted with caution because many used intact classes or pre-existing groups. The appraisal was intended to improve transparency, not to assign a validated numerical quality score.

Results

Evidence from Nigeria

The Nigerian evidence provides several relevant empirical examples. Ahmed et al. (2021) used a quasi-experimental design with two intact SS II classes in Lagos and reported higher achievement and retention in the concept-mapping group. Akintola and Odewumi (2023) studied 267 SS II students in four intact classes in Ogbomoso South and found a significant achievement difference favoring concept-map instruction in Ecology. Ugwoke and Ude (2022) used a quasi-experimental design with 241 students in three schools in Enugu Education Zone and reported higher Biology achievement for students taught with concept mapping than for those taught by lecture.

The evidence also extends to specialized Biology topics. Magaji et al. (2024) used a pre-test/post-test non-equivalent control-group design with 103 SS II students from two coeducational schools in Katagum Zonal Education, Bauchi State, and reported significantly better Genetics performance and retention in the concept-mapping group than in the lecture group. Oyeyemi et al. (2024) used a quasi-experimental design with 77 students to examine retention in Cell Division and reported a significant effect of concept mapping. These findings are important because Genetics and cell division require learners to coordinate several interrelated concepts.

Konyeme and Alordiah (2024) conducted a pre-test/post-test control-group quasi-experimental study involving 133 SS II students in six public schools in Delta State. The concept-mapping group comprised 46 students; a visual-imagery group comprised 38; and a control group comprised 49. The study examined achievement and practical skills and found that the concept-mapping group outperformed the control group on the reported achievement measure, although the visual-imagery group had the highest mean achievement. This is a useful reminder that concept mapping should not automatically be assumed to be superior to every alternative strategy.

Evidence beyond Nigeria

Evidence from outside Nigeria also supports the use of concept mapping. Demirci and Oktay (2021) conducted a pre-test/post-test quasi-experimental study with 60 Biology teacher candidates in Turkey and reported a significant post-test advantage for the concept-map group, together with evidence of reduced misconceptions in protein synthesis. Manas (2023) used a pre-test/post-test quasi-experimental design with 40 secondary-school students in Iran and reported significant effects on achievement and higher delayed retention for the concept-mapping group. Kusumawardani et al. (2025) used a qualitative descriptive design with 12 purposively selected students in Indonesia and showed that concept maps, supplemented by clarification interviews, could uncover misconceptions in human reproductive-system concepts.

At the synthesis level, Wang et al. (2025) conducted a meta-analysis of 37 studies published between 2004 and 2023. They reported a moderate overall effect of concept mapping on STEM achievement ($g = 0.630$, 95% CI [0.469, 0.790]). The analysis found stronger effects in science and at the secondary level, while independent student construction of concept maps produced the largest effect among the construction modes examined. The authors also reported comparable moderate effects for paper-based and digital concept mapping. These findings strengthen the broader evidence base but should not be interpreted as proof that concept mapping eliminates misconceptions in every Biology context. The results of the review are presented in Table 1.

Table 1

Summary of the Results of the Review

Study	Context/ topic	Sample	Design	Main outcome	Misconception evidence	Narrative appraisal
Ogundare et al. (2020)	Nigeria; Ecology	114	Quasi-experimental	61.9% of identified misconceptions remediated	Direct	Moderate; clear sample/design and outcome reported
Ahmed et al. (2021)	Nigeria; Biology	2 intact SS II classes;	Quasi-experimental	Higher achievement and	Indirect	Moderate; design and outcomes

		exact no not stated in accessibl e abstract		retention with concept mapping		clear, sample size not stated in abstract
Demirci & Oktay (2021)	Turkey; protein synthesis	60 Biology teacher candidat e	Pre- /post- test quasi- experim ental	Significa nt post- test advantage ; reduced misconce ptions	Direct	Moderate; sample, instruments and analysis reported
Ugwoke & Ude (2022)	Nigeria; Biology	241	Quasi- experim ental; 3 schools	Higher achievem ent than lecture group	Indirect	Moderate; sample/design/ analysis reported
Akintola & Odewumi (2023)	Nigeria; Ecology	267; 4 intact classes	Quasi- experim ental	Significa nt achievem ent difference favoring concept maps	Indirect	Moderate; large sample and design reported
Manas (2023)	Iran; Biology	40	Pre- /post- test quasi- experim ental	Higher achievem ent and delayed retention	Indirect	Moderate; sample/design and delayed post-test reported
Magaji et al. (2024)	Nigeria; Genetics	103; 2 coeducat ional schools	Pre- /post- test non- equivale nt control group	Higher performa nce and retention	Indirect	Moderate; sample, design, reliability and analysis reported
Konyeme & Alordiah (2024)	Nigeria; Biology achievement/ practical skills	133; 6 public schools	Pre- /post- test control- group quasi- experim ental	Concept- mapping group exceeded control; visual imagery had highest mean achievem ent	Indirect	Moderate; groups, intervention and outcomes reported
Oyeyemi et al.	Nigeria; Cell Division	77	Quasi- experim	Significa nt	Indirect	Moderate; sample/design

(2024)			ental	retention effect		and outcome reported
Kusumaw ardani et al. (2025)	Indonesia; human reproductive system	12	Qualitati ve descripti ve	Concept maps uncovere d multiple misconce ptions	Direct	Descriptive; small purposive sample, useful diagnostic evidence

Note: “Direct” indicates that misconception identification or remediation was an explicit outcome; “Indirect” indicates that the study primarily assessed achievement or retention rather than misconceptions. “Narrative appraisal” is an author-level appraisal for transparency and is not a validated risk-of-bias score.

Discussion

Understanding Concept Mapping

A concept map is more than a decorative diagram. A useful map shows concepts and the relationships connecting them, usually with linking words that explain what one concept does to, causes, includes or relates to another. The learner therefore has to make decisions: Which concepts matter? Which concepts belong together? What is the nature of their relationship? Are there missing links? These decisions make the learner's thinking visible.

This feature distinguishes concept mapping from simply copying notes. A teacher can present a finished map, but the greater learning opportunity comes when students construct, explain and revise their own maps. In this process, students are encouraged to retrieve prior knowledge, connect ideas and notice gaps or contradictions. The resulting map can then become a shared object for classroom discussion.

The approach also fits naturally with constructivist views of learning. Learners actively interpret new information in relation to what they already know. When a new explanation does not fit an existing understanding, the learner has an opportunity to revise the existing structure. Recent research on concept mapping combined with conceptual change instruction similarly emphasizes reflection, self-questioning and peer discussion as mechanisms for addressing misconceptions (Sarwar et al., 2024).

Misconceptions as a Problem in Biology Learning

A misconception is not simply an absence of knowledge. It is an idea or explanation that differs from scientifically accepted understanding and is sufficiently meaningful to the learner that it influences how new information is interpreted. This distinction matters pedagogically. If a student has never heard the term 'allele,' the teacher can introduce it. If the student believes that an allele is a complete chromosome, however, the teacher must address an existing relationship that is inaccurate.

Recent research continues to show that misconceptions occur across Biology topics. Ogundare et al. (2020) reported multiple misconceptions among senior school students studying Ecology and found that concept-mapping instruction remediated 61.9% of those identified. Demirci and Oktay (2021), working with 60 Biology teacher candidates, found that concept-map-based teaching was more effective than rote learning for achievement and for eliminating misconceptions in protein synthesis. Their findings are particularly instructive because protein synthesis requires learners to coordinate concepts such as DNA, RNA, genes, chromosomes, transcription, translation, codons, ribosomes and amino acids.

More recent work has extended the diagnostic use of concept maps. Kusumawardani et al. (2025), for instance, used concept maps and clarification interviews to uncover misconceptions about the human reproductive system, including areas related to reproductive organs, gametogenesis, fertilization, pregnancy, menstruation and breastfeeding. The study illustrates an important point: students may appear to know a topic while still holding inaccurate connections among its component ideas.

Why Concept Mapping Can Help Reduce Misconceptions

The first advantage of concept mapping is that it makes students' thinking visible. In a conventional written test, an incorrect answer may tell the teacher that something went wrong but not necessarily what the student believes. A concept map can show the relationship that produced the error.

Second, concept mapping encourages meaningful learning. Instead of treating Biology as a collection of isolated facts, students are asked to connect ideas. This is particularly useful in Genetics, where the distinction and relationship

among DNA, genes, chromosomes, alleles, genotype and phenotype are central to understanding.

Third, the strategy creates opportunities for dialogue. Students can compare maps, explain why they connected two concepts, listen to alternative explanations and revise their maps. The teacher can use an incorrect link as a starting point for a question rather than immediately labelling the student 'wrong.' This small change in classroom interaction can make conceptual correction less threatening and more productive.

Fourth, concept mapping supports formative assessment. A teacher can ask students to draw a map before a lesson, revisit it during instruction and redraw it afterwards. The changes provide evidence of what has been learned, what remains unclear and which misconceptions may still require attention.

Finally, concept mapping can support retention because information organized into meaningful relationships is easier to revisit and reconstruct. The findings of Ahmed et al. (2021), Manas (2023), Magaji et al. (2024) and Oyeyemi et al. (2024) provide empirical support for this dimension.

Making Concept Mapping Work in the Biology Classroom

For concept mapping to become a genuine learning experience, teachers should avoid reducing it to a drawing exercise. A practical classroom sequence can begin with a focus question, followed by elicitation of students' prior ideas. Students then identify key concepts, arrange them from more general to more specific where appropriate, connect them with labelled relationships, discuss questionable links and revise the map after instruction or practical experience.

For example, before teaching Genetics, students might be asked: 'How are DNA, genes, chromosomes and inherited traits related?' Their initial maps may contain incomplete or inaccurate relationships. Instead of correcting the maps immediately, the teacher can use questioning, examples, genetic diagrams, chromosome models and problem-solving tasks to create opportunities for students to reconsider their explanations. Students then revise their maps. The revised map becomes evidence of conceptual development rather than simply a finished classroom product.

Teachers should also consider collaborative mapping. Working in pairs or small groups gives learners a reason to explain their thinking. However, group maps should not replace individual thinking completely. Students can first construct individual maps and then negotiate a group version. This approach allows the teacher to see both personal and shared understandings.

Digital concept-mapping tools can be useful where facilities are available, but technology is not a prerequisite. Paper, pencils, cards and a classroom board can support the same essential cognitive activity. The 2025 meta-analysis by Wang et al. found moderate effects for both digital and paper-based approaches, suggesting that the quality of the learning design matters more than the medium itself.

Limitations

No single teaching strategy can remove every misconception. Students' ideas are influenced by prior schooling, language, textbooks, culture, everyday experiences and information encountered outside school. Some misconceptions are deeply held and may require repeated evidence and carefully designed conceptual-change experiences.

There is also a learning curve. Ahmed et al. (2021) noted that both teachers and students may experience difficulties when using concept mapping. Students who have never constructed maps may initially focus on the appearance of the diagram rather than the accuracy of the propositions. Teachers therefore need to model the process, provide examples, use clear focus questions and give feedback on the relationships represented.

Finally, concept maps should not be assessed only by their visual neatness. A simple-looking map may contain scientifically accurate propositions, while an elaborate map may contain many incorrect relationships. Assessment should therefore consider the accuracy, relevance and quality of relationships among concepts.

Implications for Biology Education

The evidence reviewed has implications for classroom practice, teacher education and research. Biology teachers should be encouraged to use concept maps not only as a summary at the end of a lesson but as a diagnostic tool at the beginning and a formative assessment tool throughout instruction. Teacher

education programs should provide prospective teachers with practical experience in constructing, interpreting and scoring concept maps.

For curriculum planners, concept mapping offers a way of shifting emphasis from memorization toward connected understanding. This is consistent with the growing emphasis on learner-centered and inquiry-oriented science teaching. The 2025 meta-analysis by Wang et al. suggests that concept mapping can be especially effective when combined with contextual and inquiry-based approaches.

For researchers, future studies should move beyond achievement scores alone and investigate the specific misconceptions that change, those that remain stable and the classroom processes responsible for the change. Longitudinal studies could also examine whether conceptual improvements identified through revised maps persist months after instruction.

Conclusion

Misconceptions are not simply empty spaces in students' minds; they are often coherent explanations built from prior experience and earlier learning. That is why they can be surprisingly difficult to change. Concept mapping offers Biology teachers a practical way of entering that cognitive world. By asking students to show how concepts are connected, the teacher can see not only what students know but also how they are making sense of what they know.

Recent evidence provides encouraging support for this approach. Studies in Nigeria have reported improvements in Biology achievement, retention and practical learning outcomes, while research in other contexts has demonstrated direct benefits for the remediation of misconceptions. The recent STEM meta-analysis by Wang et al. (2025) provides broader quantitative support, showing a moderate overall effect of concept mapping on achievement and a similarly moderate effect in Biology.

The strongest conclusion, therefore, is not that concept mapping can solve every problem in Biology education. Rather, it brings together several elements of effective Biology teaching: attention to prior knowledge, active engagement, visible reasoning, meaningful connections, formative assessment and opportunities for conceptual change. Used thoughtfully alongside practical work, discussion, questioning and other evidence-based strategies, concept

mapping is a valuable pedagogical response to the persistent problem of misconceptions in Biology.

Recommendations

Based on the evidence reviewed, Biology teachers should use concept mapping as part of a broader conceptual-change approach, particularly when teaching abstract and highly interconnected topics such as Genetics, Ecology, protein synthesis and cell division. Teachers should first elicit students' prior ideas, allow individual or collaborative map construction, discuss incorrect or incomplete links, and provide opportunities for students to revise their maps after instruction and practical evidence. Teacher-education programs should include practical training in concept-map construction, interpretation and assessment. Researchers should also report sample characteristics, intervention duration, instruments, effect sizes where appropriate and the specific misconceptions that changed, so that future reviews can compare findings more rigorously.

Reference

- Ahmed, M. A., Shittu, F. A., Yahaya, L., & Dada, A. O. (2021). Effects of concept-mapping instructional strategy on senior school students' achievement in Biology, Lagos State, Nigeria. *Malaysian Online Journal of Educational Sciences*, 9(1), 14–23. <https://eric.ed.gov/?id=EJ1283930>
- Akintola, D. A., & Odewumi, M. O. (2021). Effects of concept maps on senior secondary school students' achievement in ecological concepts in Ogbomoso South, Nigeria. *Journal of Education*, 203(1). <https://doi.org/10.1177/0022057421991867>
- Demirci, T., & Oktay, M. (2021). The effectiveness of concept teaching using concept maps on academic achievement and elimination of misconceptions: Protein synthesis case. *Science Education International*, 32(4), 390–399. <https://doi.org/10.33828/sei.v32.i4.15>
- Konyeme, J. E., & Alordiah, C. O. (2024). Concept mapping and visual imagery techniques as determinants of senior secondary school students' achievement and practical skills in Biology in Delta State,

- Nigeria. *Studies in Education*, 22(1), 91-103.
<https://sie.com.ng/index.php/journal/article/view/25>
- Kusumawardani, A. F., Noor, M. F., & Amaliyah, S. (2025). Utilizing concept maps to uncover misconceptions in human reproductive system material. *Journal BIOEDUIN*, 15(2), 1-11.
<https://doi.org/10.15575/bioeduin.v15i2.46470>
- Magaji, S., Duwan, I. A. J., & Salisu, A. (2024). Effect of concept-mapping strategy on academic performance and retention in Genetics among secondary Biology students in Katagum Zonal Education, Bauchi State-Nigeria. *Journal of Education Research and Library Practice*, 5(8), 29-38. <https://africanscholarpub.com/ajerlp/article/view/293>
- Manas, G. E. (2023). The effect of concept map strategy on academic achievement and student retention in Biology education. *Studies in Educational Management*, 14, 1–10.
<https://doi.org/10.32038/sem.2023.14.01>
- Novak, J. D., & Cañas, A. J. (2008). *The theory underlying concept maps and how to construct and use them*. Institute for Human and Machine Cognition. <https://cmap.ihmc.us/docs/theory-of-concept-maps/>
- Ogundare, A. A., Bello, G., Adeoye, A. G., & Abimbola, I. O. (2020). Effects of concept-mapping instructional strategy in remediating senior school students' misconceptions in Ecology in Oyo, Nigeria. *Nigerian Online Journal of Educational Sciences and Technology*, 2(1), 1-9. <https://nojest.unilag.edu.ng/article/view/995>
- Oyeyemi, W. T., Olorundare, A. S., & Bolaji, H. O. (2024). Effect of concept mapping instructional strategy on senior secondary school students' retention level in Biology in Kwara State. *Assimilation: Indonesian Journal of Biology Education*, 7(2), 121–130.
<https://doi.org/10.17509/aijbe.v7i2.69120>
- Sarwar, M. N., Shahzad, A., Ullah, Z., Raza, S., Wasti, S. H., Shrahili, M., Elbatal, I., Kulsoom, S., Qaisar, S., & Nazar, M. F. (2024). Concept mapping and conceptual change texts: A constructivist approach to address the misconceptions in nanoscale science and technology.

Frontiers *in* *Education*, 9.
<https://doi.org/10.3389/feduc.2024.1339957>

Ugwoke, A. O., & Ude, V. C. (2022). Effect of concept mapping instructional strategy on senior secondary school students' achievement in Biology in Enugu Education Zone, Enugu State, Nigeria. *Asian Journal of Education and Social Studies*, 26(1), 24–35. <https://doi.org/10.9734/AJESS/2022/v26i130613>

Wang, X.-M., Wang, J.-L., Xu, S.-Y., & Xu, S.-J. (2025). Concept mapping in STEM education: A meta-analysis of its impact on students' achievement (2004–2023). *International Journal of STEM Education*, 12, 30. <https://doi.org/10.1186/s40594-025-00554-2>