VOLUME 10 Issue 1
JULY 2025

E-ISSN: 2622-3384
P-ISSN: 2527-9939

JURNAL MEdu Mangifera Edu

Teaching techniques for genes, DNA, and chromosomes: An inventory of 12th-grade high school practices in Pontianak

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ABSTRACT

Genetic concepts are complex and often lead to student misconceptions due to difficult textbooks and ineffective teaching strategies. Widespread misunderstandings highlight the need for effective instructional techniques to enhance comprehension. This study examine the teaching techniques employed by Biology teachers in 20 high schools in Pontianak City to evaluate their implementation, strengths, and limitations in genetics instruction. This study used a qualitative survey approach to examine teaching techniques for genes, DNA, and chromosomes in 12th-grade classes across 20 high schools in Pontianak City. Data were collected through validated questionnaires and observation sheets, focusing on learning activities, instructional approaches, and challenges faced by teachers. Responses were summarized in tables, analyzed descriptively, and presented to highlight technique variations, selection criteria, and implementation. A total of 20 teaching techniques were identified, with most schools using a combination of 2 to 5 methods, while only three schools applied a single technique, and discussion was the most frequently integrated approach. Teaching techniques for Genes, DNA, and Chromosomes in Pontianak high schools vary, with most teachers combining multiple methods to enhance understanding, interaction, and engagement. The selection and combination of techniques are influenced by student needs, classroom conditions, and learning objectives, highlighting the importance of a balanced approach between student-centered, teacher-led, and objective-driven strategies.

ARTICLE INFO

Keywords
Active learning strategies, Genetics education, Instructional methods, Learning process, Teaching techniques

Received
March 6, 2025

Revised
May 31, 2025

Accepted
June 30, 2025

Published
July 31, 2025

How to cite
Muftifah K.N., Candramila W., & Yuniarti A. (2025). Teaching Techniques for Genes, DNA, and Chromosomes: An Inventory of 12th-Grade High School Practices in Pontianak. *Jurnal Mangifera Edu*, *10*(1), 64-75. https://doi.org/10.31943/mangiferaedu.v10i1.220.

INTRODUCTION

The abstract and complex nature of genetic concepts makes it challenging for students to understand, often leading to misconceptions or incomplete comprehension (Mocan, 2021). The difficulties in learning genetics may arise from textbooks that present material beyond students' comprehension levels and from teachers who lack effective instructional strategies, resulting in improper concept delivery (Ojo, 2024; Mocan, 2021). Similarly, Adebimpe et al. (2024) identified genetics as one of the most challenging concepts in biology, highlighting the need for teachers to adopt appropriate teaching methods. Furthermore, conceptual understanding is crucial in biology education, as it enables students to develop competencies and apply their knowledge to problem-solving (Dahlan et al., 2020). This understanding involves not only grasping individual concepts but also making meaningful connections between related ideas (Adhani & Rupa, 2020).

Misconceptions among students regarding genetic material have been widely documented in research. For instance, Waskito et al. (2020) found that conceptual misunderstandings are a significant factor contributing to students' difficulty in grasping genetic material, particularly among 12th-grade science students in Pontianak City. These findings are consistent with studies conducted among 12th-grade students in other regions (Mulya & Zulyusri, 2022; Maysyaroh & Noor, 2025; Hidayat & Kasmiruddin, 2020). Similarly, Jannah (2023) identified widespread misconceptions across nearly all topics related to genetic material in 12th-grade high school classes. The prevalence of these misconceptions highlights the need for improved lesson planning. Additionally, teaching strategies for students with misconceptions should be adapted to their specific learning needs, differentiating them from those with a more complete understanding. Furthermore, teachers' mastery of diverse instructional techniques plays a crucial role in identifying the most effective approach for addressing students' learning challenges.

The high rates of conceptual misunderstandings (39.2%) and misconceptions (33.21%) about genetic material among 12th-grade high school students in Pontianak City, as reported by Waskito et al. (2020), highlight the need for an inventory of teaching techniques used in classroom instruction. Given the complexity of genetic material concepts, a focused inventory of instructional strategies can offer valuable insights for teachers in lesson planning. This inventory should encompass various aspects, including learning activities, instructional approaches, models, methods, specific teaching techniques, criteria for selecting techniques, the sequence of concepts taught, student responses, and the challenges faced by teachers. Such comprehensive information is expected to serve as a valuable reference for evaluating the strengths and limitations of different teaching techniques.

This study conducted an inventory of teaching techniques employed by Biology teachers across 20 high schools in Pontianak City. It aims to describe the identified teaching techniques, with a particular focus on their implementation in the learning process. The study is expected to provide valuable insights into the strengths and weaknesses of each teaching technique, serving as a reference for teachers, particularly those teaching genetics. Additionally, the findings can serve as a reflection for teachers who regularly use the same techniques yet continue to encounter suboptimal student learning outcomes.

METHOD

This study employed a qualitative survey approach to examine the teaching techniques used by teachers in delivering lessons on genes, DNA, and chromosomes in 12th-grade high school classes in Pontianak City. Participants were selected through a purposive sampling approach, with data collected only from schools that granted permission for the research. Out of 56 public and private high schools in Pontianak City, only 20 schools approved participation, as indicated by official permission letters from school principals and consent statements from 12th-grade Biology teachers.

Data were collected through questionnaires that included questions on types of learning activities, instructional approaches, models, methods, teaching techniques, considerations for selecting teaching techniques, the sequence of concepts taught, student responses, and challenges faced by teachers when teaching genes, DNA, and chromosomes in 12th-grade classes. In addition to the questionnaire, data were collected using observation sheets to assess the inclusion of key

components in lesson plans (RPP), as suggested by Hudha et al. (2017). Before implementation, the questionnaire was validated by two faculty members from the Biology Education Study Program at FKIP Universitas Tanjungpura. Once deemed suitable, it was completed by 12th-grade Biology teachers at participating schools. To ensure data validity, participating teachers signed the questionnaire after verifying the consistency of their responses with actual classroom conditions based on their professional judgment.

Data analysis was conducted in the following steps:

1. The questionnaire responses were entered into a summary table to facilitate data organization and summarization. The table contained columns corresponding to the questionnaire items, with each column populated based on the data obtained from each school.
2. Responses that were identical across two or more schools were summarized. The data were reorganized into a more concise summary table, where the frequency of each response was recorded as the number of schools (n) out of the 20 high schools analyzed. This summarization process facilitated the presentation and analysis of descriptive data.

Data were presented in tables to enhance clarity and facilitate the interpretation of results. Each teaching technique was explained to highlight its distinguishing features, particularly when similar techniques were used in different ways. A recapitulation was also conducted to document instances where teaching techniques were combined with other methods. Additional data obtained from the questionnaires and observation sheets were also summarized and presented descriptively to elaborate on the concepts, selection criteria, and implementation of the teaching techniques used by teachers.

RESULTS AND DISCUSSION

A total of 20 teaching techniques were identified in 20 high schools in Pontianak City for delivering lessons on genes, DNA, and chromosomes (see Table 1). Most schools (13 schools) implemented a combination of two to five teaching techniques, while only three schools applied a single technique: discussion (2 schools) and student-centered learning (1 school). The discussion method was the most frequently used, either independently or in combination with other methods, such as question-and-answer sessions, assignments, presentations, lectures, problem-solving exercises, and the use of media like mind mapping and crossword puzzles. One school even combined discussion with various other approaches, including focused material, repetition of key concepts, questionnaires, information technology, and the give-and-receive method. Other combinations observed included presentations with lectures and demonstrations, as well as literature studies with role-playing. In addition, Al Mumtaz Private High School developed three innovative teaching techniques specifically for the topics of genes, DNA, and chromosomes: TERPADU, ADLX, and Introflex, which reflect a contextual and integrative approach to biology education.

Teaching techniques for Genes, DNA, and Chromosomes in 20 Pontianak high schools vary, with most teachers combining multiple methods. Using more than two techniques is more common than just two. Single techniques promote student independence, while combined techniques enhance understanding, engagement, and interaction. They also cater to the needs of students, school facilities, and classroom conditions. Some schools have established guidelines for selecting teaching techniques. Teachers' reasons for choosing teaching techniques vary, even when using the same methods (see

Table 1). For instance, discussion was used for independent concept discovery in one school and for PBL in another. Similarly, a combination of discussion, Q&A, and assignments served different purposes across schools, from enhancing understanding to encouraging engagement. While some schools shared identical reasoning, most had unique considerations.

Table 1. Teaching techniques and teachers' considerations for their selection in teaching genes, DNA, and chromosomes in 20 high schools in Pontianak City.

Types and Combinations of Teaching Techniques	Considerations for Selecting Teaching Techniques	N
Discussion	To enable students to engage in independent learning by discovering the concepts of genes, DNA, and chromosomes.	1
	To facilitate Problem-Based Learning (PBL)	1
Discussion and Question & Answer	To clarify the material being taught	1
	To encourage active participation from all students during the discussion	1
Discussion and Assignments	To help students stay energized and focused	2
Discussion and Problem-Solving	To enable students to interact, share experiences and information, solve problems, and actively participate	1
Discussion and Presentation	1. To ensure that students are actively engaged and capable of identifying the structure of DNA, RNA, and chromosomes, along with all related processes 2. To align with the learning objectives and available school facilities	1
Discussion, Question & Answer, and Assignments	To facilitate students' understanding of the taught material	1
	To promote a two-way learning process	1
	To encourage students to be actively engaged in learning	1
Discussion, Presentation, and Question & Answer	Utilizing diverse teaching techniques to boost student engagement, recognizing that students learn in different ways	1
Discussion, Presentation, and Lecture	To adapt to students' abilities, the availability of learning facilities, and classroom conditions	1
Discussion, Question & Answer, and Lecture	To adapt to the learning objectives and classroom conditions	1
Discussion, Presentation, Mind Map, and Crossword Puzzle	To evaluate students' understanding through material explanation	1
Discussion, Focus on Learning Material, Repeat Things Hard, Questionnaire, Information Technology and Giving & Receiving	To adapt to students' abilities, the availability of learning facilities, and classroom conditions	1
Presentation, Lecture, and Demonstration	To make learning more meaningful and enjoyable while encouraging student engagement	1
Presentation, Literature Study, and Role Play	To help students better understand the material through a more engaging process	1
Student-centered	To make learning more active and engaging, avoiding monotony	1
TERPADU, ADLX, and Introflex	1. To follow the standardized template used at the school 2. To make learning more meaningful by relating the concept of genes to real-life applications	1
	Total Number of Schools	20

ADLX = Active Deep-Learner Experience; TERPADU = *Telaah, Eksplorasi, Rumuskan, Presentasikan, Aplikasikan, Duniawi dan Ukhrawi* (Study, Exploration, Formulation, Presentation, Application, Worldly, and Hereafter); Introflex = *Individualisasi, Interaksi, Observasi, Refleksi* (Individualization, Interaction, Observation, Reflection); N = number of schools using.

The following is an explanation of the implementation of each teaching technique identified in 20 high schools in Pontianak City.

1. Discussion

   Among 20 teachers, two used discussions as their sole technique. Teacher A guided students from prior knowledge exploration to group discussions, concluding with reinforcement. Teacher B assigned worksheets to the groups, followed by presentations and a Q&A session, during which the teacher facilitated the discussion and drew conclusions. Proctor (2020) highlights group problem-solving as a collaborative decision-making approach; however, if teachers finalize conclusions, students may miss opportunities for independent learning. To enhance learning, teachers should allow students to summarize discussions (Sutiyarni, 2023).

2. Question and Answer

   Seven of twenty teachers use Q&A alongside other techniques, mainly discussions, but do not consider it a standalone method. Q&A typically follows discussions, assignments, or presentations to reinforce understanding. Nephawe & Lambani (2022) highlight its role in achieving learning objectives and fostering student engagement, while Juliangkary & Pujilestari (2022) note its benefits in enhancing concentration, critical thinking, and confidence.

3. Presentation

   Six of twenty teachers use presentations in conjunction with other techniques, primarily discussions. Presentations typically follow assignments, with students presenting their work. (Cesarria et al., 2025)This technique highlights its ability to foster teamwork and independent learning, while Sanjaya (2020) notes its role in promoting open discussions and knowledge exchange.

4. Assignments

   Six out of twenty teachers use assignments, but always in conjunction with other techniques to reinforce understanding. Graham et al., (2023) state that well-designed assignments enhance achievement. Fitriani et al. (2020) found that individual tasks yield better outcomes than group work, as students take more responsibility for their work.

5. Problem-Solving

   One of twenty teachers uses problem-solving, always combined with discussion. Problem-solving involves structured thinking to resolve real-world issues (Zuhriyah, 2022) and is more effective with teacher feedback (Anam et al., 2021). In this study, group discussions helped students visualize the structure of chromosomes, thereby improving their understanding.

6. Lecture

   Three out of twenty teachers use the lecture technique, always in combination with other methods. Lectures typically include visual aids, such as PowerPoint slides or videos (Tuma, 2021), to explain complex topics like genes, alleles, and chromosomes. While lectures are efficient and cost-effective, Susanti et al. (2024) note that they can be monotonous and hinder engagement. To improve effectiveness, teachers must vary delivery and encourage interaction (Sipahutar et al., 2023).

7. Mind Mapping

   One out of 20 teachers uses mind mapping in combination with discussion, presentation, and crossword puzzles. This technique helps students organize complex concepts, such as genes and DNA, and visualize the connections between terms. Ridho & Imron (2023) note that mind mapping, through the use of structured diagrams, helps students focus on central topics and understand abstract concepts more clearly.

8. Crossword Puzzle

   One out of 20 teachers uses crossword puzzles, integrated with discussion, presentation, and mind mapping. These puzzles, focused on topics such as genes and DNA, help review material and improve retention (Bheke et al., 2021). They also make learning more engaging and interactive, with the competitive aspect boosting student motivation and participation (Agustin et al., 2021; Ritonga et al., 2021; Bawazeer et al., 2022). This technique supports learning across cognitive, emotional, and psychomotor domains.

9. Focus on Learning Material

   One out of the 20 teachers applies a 'focus on learning material' technique, integrated with discussion, repetition, questionnaires, information technology, and feedback. This comprehensive approach is considered effective in achieving learning objectives (Siswondo & Agustina, 2021).

10. Repeat Things Hard

    One out of the 20 teachers employs the 'Repeat Things Hard' technique, in combination with discussion, focus on learning material, questionnaires, information technology, and feedback. The use of repetition reinforces key concepts and enhances retention, particularly among students who face challenges with memorization (Purba & Zuraidah, 2021).

11. Questioner

    One out of the 20 teachers utilizes the 'Questioner' technique, integrated with discussion, focus on learning material, repetition, information technology, and feedback. To maximize its effectiveness, questioning should align with learning objectives, and teachers are encouraged to scaffold students' thinking by providing simpler or guiding questions when they encounter difficulty or respond incorrectly (Salmon & Barrera, 2021).

12. Information Technology

    One out of the 20 teachers integrates information technology into discussions, focusing on learning materials, repetition, questioning, and feedback. In this approach, students utilize tools such as Google to access supplementary materials, complete assignments, and actively participate in discussions (Carstens et al., 2021).

13. Giving and Receiving

    One out of the 20 teachers implements the 'giving-and-receiving' technique, in combination with discussion, focus on learning material, repetition, questioning, and the use of information technology. Through peer tutoring, students engage in knowledge exchange and collaborative problem-solving, fostering the development of critical thinking skills. To support this process, feedback should be descriptive, grounded in classroom observations, and aligned with competency standards to promote mutual understanding (Gan et al., 2021)

14. Demonstration

    One out of 20 teachers uses the demonstration technique, combined with presentation and lecture methods. It serves as an assessment of both skill performance and the final product (Nugroho et al., 2021), with tasks or worksheets assigned for evaluation.

15. Literature Study

    One out of 20 teachers uses literature study, combined with role-playing. This technique involves using videos to spark student interest, followed by questions to stimulate curiosity, literature study, and discussions to gather relevant data (Wahyuningsih et al., 2024).

16. Role Play

    Role-playing is used by 1 out of 20 teachers to teach Protein Synthesis, enhancing student understanding by assigning roles as objects or organisms, which stimulates imagination and comprehension (Hadiawati et al., 2023). This interactive technique fosters talent development and collaboration but requires more time and space (Rokmanah et al., 2024).

17. Student-centered

    One out of 20 teachers uses the student-centered technique, where students lead the learning process with the teacher acting as a facilitator. This approach encourages interaction and problem-solving, with the teacher guiding and motivating students (Juhra, 2023).

18. TERPADU

    One out of 20 teachers uses the Integrated (TERPADU) technique, combining it with ADLX and Introflex methods. This approach integrates the curriculum to provide meaningful learning experiences (Utami, 2023).

19. ADLX

    One out of 20 teachers uses ADLX, often in combination with other techniques. ADLX integrates active learning with deep learning, promoting meaningful behavioral changes and encouraging students to apply positive values (Alqarny & Mujiburrohman, 2023).

20. Introflex

    Introflex, used by one out of 20 teachers, focuses on individualization, interaction, observation, and reflection to accommodate students' unique needs (Utami et al., 2024).

According to Siregar (2021), techniques are methods used to achieve a goal, often involving a combination of multiple approaches. The findings of this study indicate that teachers employ various combinations of techniques to deliver concepts related to Genes, DNA, and Chromosomes. Two to six teaching techniques are combined with multiple considerations. However, some teaching techniques are more appropriately categorized as approaches or models. For example, problem solving and student-centered learning are better described as approaches, while TERPADU, ADLX, and Introflex are learning models. Bonnes & Hochholdinger (2020) explain that an approach is a philosophical framework or basic intent in teaching, a model or method is a systematic representation of that approach, and a technique is the practical action carried out by the teacher in the classroom as the implementation of the process. Misunderstandings in interpreting teaching techniques, approaches, and models suggest that teachers have not yet been able to differentiate among them. On the other hand, understanding these distinctions helps educators select and apply methods more effectively to achieve learning goals.

However, the most commonly used combination of two teaching techniques involves discussion paired with another method to enhance students' understanding, two-way interaction, and active participation. The combinations used include discussion with question-and-answer to facilitate interaction and improve comprehension, discussion with assignments to clarify material and ensure student engagement, discussion with presentations to encourage students to present material, identify unclear points, and discuss them further, or debate with problem-solving to enhance interaction, information exchange, and active student involvement in solving problems.

The combination of three teaching techniques is also used to enhance students' understanding, two-way interaction, and active participation. The most common combination is discussion, question-and-answer, and assignments. Other combinations include discussion with presentation and question-and-answer to accommodate different learning styles, discussion with presentation and lecture based on available facilities, and discussion with question-and-answer and lecture according to learning objectives and classroom conditions. Additionally, the combination of presentation, lecture, and performance demonstration is effective in increasing students' motivation and understanding of concepts related to Genes, DNA, and Chromosomes.

In addition to combinations of two and three techniques, some teachers also implement combinations of four or even six techniques to optimize learning outcomes. A combination of four teaching techniques—discussion, presentation, mind mapping, and crossword puzzles—is used to assess students' understanding of concepts related to Genes, DNA, and Chromosomes. Meanwhile, a combination of six teaching techniques—discussion, focusing on learning material, repetition of complex concepts, questioning, the use of information technology, and giving and receiving feedback—is implemented based on students' abilities, available learning facilities, and classroom conditions.

Among the 13 combinations of teaching techniques, teachers' considerations can be categorized into three perspectives.

- The first perspective views students as active participants. This is evident in combinations such as discussion and presentation, discussion and problem-solving, and discussion, presentation, and Q&A. Here, students are encouraged to identify unclear concepts, interact, exchange ideas, and engage actively rather than passively listening. According to Romiyansah et al. (2020), learning models that position students as subjects, such as inquiry-based learning, allow them to explore and discover new concepts.
- The second perspective focuses on the teacher as the central figure in the learning process. This is the most commonly used approach, where teachers aim to facilitate understanding, promote two-way interaction, and assess student comprehension. According to Maulani et al. (2021), teacher-centered learning often involves conventional methods, such as lectures and Q&A sessions. However, Nawafil & Junaidi (2020) argue that this approach can limit students' ability to develop and innovate due to the teacher's dominant role as the sole knowledge provider.
- The third perspective prioritizes learning objectives. This is reflected in combinations such as discussions, Q&A sessions, lectures, presentations, and demonstrations, chosen based on their alignment with lesson goals and classroom conditions. Jannah (2023) notes that some teachers still struggle to create effective learning environments, despite being expected to foster

engagement and optimize student outcomes. However, Abdulla & Woods (2021) caution that focusing solely on learning objectives may reduce student involvement in the learning process.

Ultimately, a balanced approach is crucial—considering students as active learners, the teacher's role as a facilitator, and the alignment with learning objectives. While teachers must manage the classroom effectively, students should also take an active role in the process. Selecting appropriate teaching techniques requires careful consideration of learning objectives, content, and classroom conditions, as a single technique may not be universally effective (Siregar, 2021). This is because a single teaching technique may not be equally effective across different types of learning materials. By integrating varied techniques, teachers can create an engaging learning environment, making the study of Genes, DNA, and Chromosomes more interactive and enjoyable.

CONCLUSION

This study identified 20 variations of teaching techniques employed by biology teachers in Pontianak City for the topic of Genes, DNA, and Chromosomes. The findings reveal a strong tendency to combine multiple approaches, resulting in 13 distinct combinations that reflect deliberate adaptation to specific learning objectives, student needs, and institutional resources. The integration of innovative strategies, such as role-playing and mind mapping, underscores a growing emphasis on enhancing student engagement and conceptual understanding. These results highlight the pedagogical importance of aligning teaching methods with the contextual demands of both the subject matter and the learners.

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