

# Teaching techniques inventory for explaining gene, DNA, and chromosome concepts in senior high school

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## ABSTRACT

Genetics is a fundamental topic in Biology, yet its abstract nature presents challenges in the learning process. Effective teaching of genetics concepts requires appropriate instructional approaches to facilitate student understanding. The success of learning outcomes depends on various components, including teachers, students, learning objectives, content, teaching methods, and assessment strategies. The integration of suitable teaching techniques and instructional media is essential, particularly when addressing specific learning difficulties faced by students. This study employed a survey method with a qualitative approach to explore the teaching techniques used by teachers in delivering the concepts of genes, DNA, and chromosomes to 12th-grade students. The findings revealed that teachers implement 20 distinct teaching techniques, which are combined into 13 different instructional strategies to enhance student comprehension. This study provides teachers with insights into various teaching techniques to address the learning difficulties that students often encounter in understanding genetics.

**Keywords:** biology teachers, genetics, learning approach, learning process, teaching techniques

## INTRODUCTION

The abstract and complex nature of genetic concepts makes it challenging for students to interpret and process in their thinking, often leading to misconceptions or incomplete understanding (Haskel-Ittah & Yarden, 2018). According to Ojo (2024), difficulties in grasping genetics may stem from textbook content that is not suited to students' cognitive levels, as well as teachers' lack of effective instructional strategies, which can result in improper presentation of the concepts. Similarly, Saenab et al. (2016) emphasized that genetics is one of the most challenging topics in biology, necessitating the use of appropriate teaching methods. Furthermore, conceptual understanding plays a crucial role in biology education, as it enables students to develop competencies and apply their knowledge to solve simple problems (Dahlan et al., 2020). Adhani and Rupa (2020) highlighted that conceptual understanding involves both grasping individual concepts and linking them with related ideas.

Student misconceptions about genetic material have also been widely studied. For instance, Waskito et al. (2020) found that a lack of understanding of concepts and misconceptions are factors causing high levels of misunderstanding of genetic material among 12th-grade science students in Pontianak City. Similar findings were observed among 12th-grade high school students in various regions (Hidayat & Kasmiruddin, 2020; Madukubah et al., 2018; Mulya & Zulyusri, 2022). Machová and Ehler (2023) found that despite being taught in biology curricula for decades, genetics remains a subject where students continue to hold various misconceptions. The prevalence of these misconceptions in genetics indicates the need for better lesson planning. Additionally, the teaching techniques applied to students with misconceptions might need to differ from those for students who need more or have complete knowledge. Furthermore, the variety of teaching techniques teachers master will significantly assist in finding the most appropriate technique for each student's learning challenges.

Waskito et al. (2020) found that 12th-grade high school students in Pontianak City exhibited a high rate of conceptual misunderstandings (39.2%) and misconceptions (33.21%) regarding genetic material. These findings highlight the importance of assessing the teaching methods employed by educators in classroom instruction. In the context of genetic material concepts, the rates of misunderstanding and misconceptions are also high, at 39.6% and 31.5%, respectively. An inventory of teaching techniques for a single material or concept can provide valuable insights and information for teachers to consider in lesson planning. In this regard, teachers' inventory of teaching mechanisms should encompass the forms of learning activities, learning approaches, models, methods, teaching techniques, considerations for selecting teaching techniques, the sequence of concepts taught, student responses, and the challenges teachers face while teaching. This comprehensive information is expected to provide a thorough basis for consideration and highlight each teaching technique's advantages and disadvantages.

In this study, an inventory of teaching techniques used by Biology teachers in 20 high schools in Pontianak City was conducted. This research aims to describe each teaching technique identified, mainly how teachers use them in the learning process. This study is expected to provide important information about the advantages and disadvantages of each teaching technique used, thus serving as a guide for teachers, especially those teaching genetic material. The results of this study can also provide helpful reflection for teachers who have frequently used the same techniques but have consistently achieved suboptimal student learning outcomes.

## MATERIAL AND METHODS

This study used a qualitative survey method to describe the teaching techniques used by teachers in teaching the concepts of genes, DNA, and chromosomes in 12th-grade high school classes in Pontianak City. The sampling of participants in this study employed a participatory technique, where data collection was conducted only in schools that granted permission for the research. Out of the 56 public and private high schools in Pontianak City, only 20 schools granted permission, as evidenced by response letters for research permission from the school principals and statements of willingness to participate from each Biology teacher teaching 12<sup>th</sup> grade.

Data collection in this study was carried out by distributing questionnaires containing questions about the forms of activities, approaches, models, and methods of learning, teaching techniques, considerations for selecting teaching techniques, the sequence of concepts taught, student responses, and the challenges faced by teachers when teaching the material on genes, DNA, and chromosomes in 12th-grade classes. In addition to the questionnaire, data was collected using observation sheets to observe the presence or absence of each component in the lesson plans (RPP), according to Hudha et al. (2017). Before use, the questionnaire was validated by two lecturers from the Biology Education Study Program at FKIP Universitas Tanjungpura. Once deemed suitable for use, the questionnaire was completed by the 12th-grade Biology teachers at each school that agreed to participate. As proof of data validity, the respective teachers signed the questionnaire after checking the consistency of their answers with the actual conditions according to the teachers' opinions.

Data analysis was conducted in the following steps:

1. The questionnaire responses were recorded in a reference table to streamline data compilation. The reference table contains columns corresponding to the questions in the questionnaire. Each column is filled out based on the findings of each school.
2. Based on the distribution of questionnaire responses from all schools, a recapitulation was conducted for similar answers from two or more schools that provided the same response. The data was rearranged into a more concise aid table where the appearance of the same answer is presented in the form of the number of schools using (n) out of the 20 high school samples analyzed. The recapitulation process was carried out to facilitate the presentation and analysis of descriptive data.
3. Data presentation was made on tables to facilitate understanding of the results. Each teaching technique was described descriptively to differentiate them from one another, especially if there were similar teaching techniques but different in usage and utilization. Recapitulation was also carried out to note the use of teaching techniques combined with other types. Other data revealed in the questionnaire and observation sheets were also recapitulated and presented descriptively to elaborate on the concepts, considerations, and ways of using the teaching techniques chosen by the teachers.

## RESULTS

There are 20 teaching techniques used by teachers in 20 high schools in Pontianak City to deliver material on Genes, DNA, and Chromosomes (**Table 1**). Among the twenty teaching techniques, 13 schools use a combination of 2-5 teaching techniques. The single teaching technique found is discussion (2 schools) and student-centered (1 school). In addition to being used singly, the discussion teaching technique is also most commonly combined with other teaching techniques, namely problem-solving (1 school), question and answer (2 schools), assignments (2 schools), presentation (1 school), question and answer and assignments (3 schools), presentation and question and answer (1 school), presentation and lecture (1 school), question and answer and lecture (1 school), presentation, mind map, and crossword puzzle (1 school), as well as focus on learning material, repeat things hard, questionnaire, information technology, and giving & receiving (1 school). Other combinations of teaching techniques are presentation, lecture, and demonstration (1 school), presentation, literature study, and role play (1 school), and TERPADU, ADLX, and Introflex (1 school). Furthermore, unique teaching techniques were found, independently developed by the school itself, namely Study, Exploration, Formulation, Presentation, Application, Worldly, and Hereafter (TERPADU), Active Deep-Learner Experience (ADLX), and Individualization, Interaction, Observation, Reflection (Introflex), all of which are developed and used at Al Mumtaz Private High School. These three teaching techniques are even used to teach the material on genes, DNA, and chromosomes in the respective schools.

Teachers' considerations in choosing teaching techniques can vary even if the teaching techniques are the same (**Table 2**). For example, in selecting the discussion technique, there are two different considerations from two schools: School A uses it so that students can experience the learning process by discovering concepts themselves, according to Teacher A, while teacher B from School B uses it to activate Problem-Based Learning (PBL). Another example is the same combination of discussion, question and

**Table 1.** Types and combinations of teaching techniques used by teachers in teaching Genes, DNA, and Chromosomes material in 12th-grade high school classes in Pontianak City

Types and Combinations of Teaching Techniques	Total of Schools Using (n)
Discussion	2
Discussion and Question & Answer	2
Discussion and Assignments	2
Discussion and Problem-Solving	1
Discussion and Presentation	1
Discussion, Question & Answer, and Assignments	3
Discussion, Presentation, and Question & Answer	1
Discussion, Presentation, and Lecture	1
Discussion, Question & Answer, and Lecture	1
Discussion, Presentation, Mind Map, and Crossword Puzzle	1
Discussion, Focus on Learning Material, Repeat Things Hard, Questionnaire, Information Technology and Giving & Receiving	1
Presentation, Lecture, and Demonstration	1
Presentation, Literatur Study, and Role Play	1
Student-centered	1
TERPADU, ADLX, and Introfex	1

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)

**Table 2.** Teaching techniques and the considerations for their selection by teachers in 20 high schools in Pontianak City in teaching Genes, DNA, and Chromosome material

Types and Combinations of Teaching Techniques	Considerations for Choosing Teaching Techniques	(n)
Discussion	So that students can experience the learning process independently by discovering the concepts of genes, DNA, and chromosomes.	1
	To activate Problem-Based Learning (PBL).	1
Discussion and Question & Answer	To clarify the conveyed material.	1
	So that during the discussion activity, all students can actively participate in learning.	1
Discussion and Assignments	So that students feel energized.	2
Discussion and Problem-Solving	So that students can interact and exchange experiences/information, solve problems, and be active.	1
Discussion and Presentation	1. So that students are active and capable of identifying the structure of DNA, RNA, and chromosomes, as well as all related processes.	1
	2. To adjust to the learning objectives and school facilities.	
Discussion, Question & Answer, and Assignments	To facilitate students' understanding of the material taught.	1
	To create two-way learning.	1
	So that students are active.	1
Discussion, Presentation, and Question & Answer	Using varied techniques to increase student engagement because of different learning methods from different students.	1
Discussion, Presentation, and Lecture	Adjust to students' abilities, the availability of learning facilities, and classroom conditions.	1
Discussion, Question & Answer, and Lecture	To adjust to the learning objectives and classroom conditions.	1
Discussion, Presentation, Mind Map, and Crossword Puzzle	To assess the level of student understanding through material explanation.	1
Discussion, Focus on Learning Material, Repeat Things Hard, Questionnaire, Information Technology and Giving & Receiving	Adjust to students' abilities, the availability of learning facilities, and classroom conditions.	1
Presentation, Lecture, and Demonstration	So that learning is more meaningful and enjoyable, and students are more active.	1
Presentation, Literatur Study, and Role Play	So that students can better understand the material through a more interesting process.	1
Student-centered	So that learning is more active and not monotonous.	1
TERPADU, ADLX, and Introfex	1. To adjust to the template used at the school.	
	2. To make learning meaningful by connecting the concept of genes with lessons or applications in daily life.	1

\*n = total of schools using

answer, and assignment techniques but with different considerations found in three schools. In School A, the teacher uses this combination to facilitate students' understanding of the material, while in the other two schools, the purpose is to create two-way learning and to keep students active during the lessons. The same teaching technique chosen with the same rationale by two different schools was also found. For the rest, the choice of teaching technique was based on one consideration that differed from one school to another.

## DISCUSSION

The techniques used in teaching Genes, DNA, and Chromosomes material in 20 high schools in Pontianak City vary. The number of teachers using only one type of teaching technique is fewer than those who combine it with one or more other teaching techniques. The combination of more than two teaching techniques is found more frequently than the combination of two. The considerations for using single and combinative teaching techniques are somewhat different, especially in making students more active or allowing them to experience learning by discovering concepts independently, particularly in encouraging student engagement. Considerations for selecting combinative teaching techniques different from single teaching techniques are to clarify and enhance understanding of the conveyed material, provide more varied learning so that students do not feel bored, give students opportunities to interact more with each other, enhance two-way interaction between teachers and students, and provide more meaningful and enjoyable learning. Additionally, considerations for selecting combinative teaching techniques are also aimed at adapting to the conditions of students, school facilities, and classroom conditions. In one of the schools in the sample, the school has already established considerations for selecting teaching techniques and implemented by the respective teachers.

Here is an explanation of each teaching technique found in 20 high schools in Pontianak City.

### Discussion

Two out of twenty teachers exclusively use discussion as their teaching method. Teacher A's discussion method involves students first exploring their prior knowledge, followed by group discussions with other students. At the end of the lesson, the teacher provides reinforcement or aligns perceptions with the students. Meanwhile, Teacher B's discussion method involves dividing the class into several groups, with each group receiving a worksheet. Each group discusses and presents the results of their discussion, followed by a Q&A session, and the teacher then facilitates a discussion and draws conclusions. According to Proctor (2020), group problem-solving techniques focus on finding solutions collectively to a specific problem and making simple decisions as one type of problem-solving. The ultimate goal is for students to be able to make decisions. However, if the discussion process ends with the teacher making the final decision, the students' learning process to find solutions or conclusions regarding the topic discussed remains incomplete. Teachers should still provide opportunities for students to make or summarize the decisions/conclusions from the discussion process (Osman et al, 2018).

### Question and Answer

Seven out of twenty teachers incorporate the question-and-answer technique alongside one or more other teaching methods. The question-and-answer technique is always combined with discussions, where the Q&A activity is not considered a part of the discussion itself. In this context, discussions are always the primary teaching technique, followed immediately by Q&A or another teaching technique, and then Q&A. Thus, teachers do not consider Q&A as the main teaching technique. This is also evident where Q&A is conducted after assignments and group presentations. The Q&A is aimed at clarifying the material being discussed. This condition aligns with the opinion of Nephawe and Lambani (2022), who state that using the question-and-answer technique serves to achieve goals and brings about changes in student behavior, as well as motivating them to ask questions during lessons or when the teacher poses questions. Q&A can also improve concentration on the lesson, stimulate critical thinking, and enhance the courage to express opinions (Juliangkary & Pujilestari, 2022).

### Presentation

Six out of twenty teachers integrate the presentation technique with other teaching methods. Teachers combine presentations with one or more other teaching techniques. Presentations are most frequently used alongside discussions but not as the primary technique. This activity always begins with the teacher assigning tasks, such as completing worksheets or group assignments, and then students present their work. According to Remsburg and Hagar (2019), using the presentation technique allows students to work in teams and explore material from various learning sources, fostering independence in the learning process. Additionally, Sanjaya (2020) adds that the presentation technique can also stimulate students to engage in open discussions, thereby expanding their knowledge based on information obtained from their classmates.

### Assignments

Six out of twenty teachers incorporate the assignment technique, always in combination with one or more other teaching methods rather than using it independently. Assignments are used by teachers to help students better understand the material being taught. According to Graham et al. (2023), optimal assignments can improve student achievement. These assignments are given by teachers as individual or group tasks. Fitriani et al. (2020) state that the learning outcomes from group tasks are lower than those from individual assignments. This may be due to decreased student responsibility when completing group assignments. Conversely, the learning outcomes from individual assignments are higher because students feel more motivated to complete their tasks (Fitriani et al., 2020).

### Problem-Solving

One in twenty teachers incorporates the problem-solving technique, but always in combination with discussions rather than as a standalone method. Problem-solving is an effort to resolve everyday issues using specific thinking processes and steps (Zuhriyah, 2022). Learning through problem-solving is more effective when teachers facilitate the activity by providing feedback (Kelly et al., 2016). The combination of problem-solving and discussion involves group discussions to solve problems. In this study, the problem chosen by the teacher for group discussion was about chromosome structure, considering that chromosomes cannot

be seen with the naked eye. The discussion steps are expected to help students visualize the abstract concept of chromosomes, making it easier to understand.

### **Lecture**

The lecture method is used by 3 out of 20 teachers and is not used as a sole technique but combined with two other teaching techniques. The lecture technique involves the teacher explaining the material. For example, two of the three teachers start by asking introductory questions and then provide a general explanation of the concepts of genes, alleles, and chromosomes with the assistance of PowerPoint (PPT) slides. Meanwhile, another teacher explains the material with the help of PowerPoint (PPT) slides and instructional videos sourced from common platforms like YouTube. This aligns with Fernando and Marikar (2017), who state that a lecture is an effort to deliver learning orally to students and use PowerPoint slides to provide visual support during the process. This technique is selected based on learning objectives, classroom conditions, and the availability of school facilities. According to Aina (2017), if teachers only use lectures to deliver concepts of genes, DNA, and chromosomes without combining them with other appropriate teaching models and without the use of instructional media, the teaching-learning process may be perceived as boring, and students may have difficulty understanding the concepts presented by the teacher. On the other hand, lectures can be more efficient (in terms of time, equipment, and costs) because they can reach many students simultaneously and are easier to conduct than other techniques. However, the downside is minimal students response, one-way communication, and it requires teachers to be skilled in explaining to make it more engaging, such as using intonation and rhythm in their voice, as well as clear articulation (Nainggolan et al., 2023; Sipahutar et al., 2023).

### **Mind Mapping**

One out of twenty teachers incorporates the mind mapping technique. Teachers do not use this technique solely but combined it with discussion, presentation, and crossword puzzle techniques. Difficulties encountered when teaching the concepts of genes, DNA, and chromosomes include new terms that students find hard to understand and the extensive use of scientific/Latin terminology. Therefore, in applying these concepts, teachers provide opportunities for students to create mind maps. According to Yang et al. (2018), mind mapping visualizes thoughts through a tree diagram. With this technique, students are expected to focus on the main topic and develop subtopics connected to the main topic in a diagram. Thus, the entire content of the topic and subtopics can be examined more systematically and comprehensively.

### **Crossword Puzzle**

The crossword puzzle technique is used by one out of 20 teachers. This technique is not only used alone but also combined with discussion, presentation, and mind mapping techniques. The crossword puzzles created by the teacher are completed by students on topics such as Genes, DNA, and Chromosomes. According to Bheke et al. (2021), this technique can be used to review material previously taught to students. This review is beneficial as it helps students more easily remember the information presented. Through completing crossword puzzles, students are expected to find the learning process more enjoyable, active, and participative, while also fostering a sense of competition, thereby providing greater meaning in the learning process (Agustin et al., 2021; Bawazeer et al., 2022; Ritonga et al., 2021). Thus, the achievement of learning objectives in cognitive, emotional, and psychomotor aspects is more likely.

### **Focus on Learning Material**

The focus on learning material technique is used by 1 out of 20 teachers, often combined with discussion, repetition, questionnaires, information technology, and giving and receiving feedback techniques. The learning process is considered effective if it can achieve the predetermined learning objectives (Siswondo & Agustina, 2021). Teachers play a crucial role in ensuring the accomplishment of these learning objectives (Siswondo & Agustina, 2021).

### **Repeat Things Hard**

The Repeat Things Hard technique is used by 1 out of 20 teachers. This technique is also combined with discussion, focus on learning material, questionnaires, information technology, and giving and receiving feedback techniques. According to Purba and Zuraidah (2021), repeating material is quite effective during the learning process because it helps students who have difficulty memorizing the material, thus enabling understanding through repetition and periodic delivery of the material, accompanied by questions to measure their level of understanding (Purba & Zuraidah, 2021).

### **Questioner**

The Questioner technique is used by 1 out of every 20 teachers. This technique is combined with discussion techniques, focusing on learning materials, repeating difficult concepts, utilizing information technology, and giving and receiving. According to Sivarajah et al. (2019), questioning students is done based on learning objectives. If students show no response or answer incorrectly, teachers can ask simpler questions or questions at a lower cognitive level to guide students to answer the initial question.

### **Information Technology**

Information technology is used by 1 out of every 20 teachers, combined with discussion techniques, focusing on learning materials, repetition of difficult concepts, questioning, and giving and receiving. Students can use the internet to obtain additional information. These activities utilize Google optimally to search for additional materials, complete assigned tasks, and discuss various topics (Habsy, 2017).

## Giving and Receiving

One in twenty teachers employ giving and receiving technique. This technique is also combined with discussion techniques, focusing on learning materials, repeating difficult concepts, questioning, and information technology. With peer tutoring, students can mutually give and receive, or share understanding of concepts, enabling them to independently find solutions to their challenges and become active and critical thinkers. Feedback should be descriptive and based on direct observations. To be more effective, observations of student behavior should be compared against established competency levels. Both teachers and students should have a shared understanding of these activities. Furthermore, receiving feedback can be a challenging task depending on its message. Feedback providers must consider what needs to be delivered to the receiver. Such determinations are contextual and require emotional intelligence (Jug et al., 2019).

## Demonstration

Demonstration is used by 1 out of every 20 teachers. It combines presentation and lecture techniques. Student demonstration is a type of assessment that focuses on two activities: observing the process of skill performance and evaluating the products of students (Nugroho et al., 2021). In this activity, teachers ask students to complete worksheets or assignments, which are then assessed by the teacher.

## Literature Study

Literature study is used by 1 out of every 20 teachers and combined with another technique, which is role-playing. The teaching technique of literature study involves sparking students' interest through instructional video playback. Subsequently, the teacher poses questions that stimulate curiosity among students. Following this, students engage in literature study and participate in discussions. Literature study is an activity aimed at gathering data or sources related to the topic under discussion (Habsy, 2017).

## Role Play

The next technique is role-playing, used by 1 out of every 20 teachers. Role-playing is employed in teaching Protein Synthesis to facilitate students' understanding of the process. Assigning roles as inanimate objects or living organisms can help build students' imagination and comprehension (Hadiawati et al., 2023). Role-playing offers advantages such as creating a more engaging and entertaining learning environment, effectively developing and exploring students' talents and potentials, and enhancing collaboration among students to improve engagement and partnership in learning. However, it often requires more time and relatively larger space (Rohmanurmeta, 2017).

## Student-centered

One in twenty teachers solely employs the student-centered technique without integrating other methods. In its implementation, students are placed at the center of learning, allowing them to interact with each other. The teacher's role is to provide stimuli and guidance to help students find answers to the issues they encounter in the material. Lee and Hannafin (2016) emphasize that in student-centered learning, teachers serve as designers of learning experiences, enabling students to be more active, independent, and engaged in their own learning.

## TERPADU

One in twenty teachers incorporates the TERPADU technique in their teaching, combining it with other methods like ADLX and Introflex, which are learning models from the Integrated Islamic School Network of Indonesia. TERPADU involves integrated curriculum approaches aimed at realizing a relevant and meaningful learning process for students (Kurniawan, 2016).

## ADLX

ADLX, short for Active Deep Learner eXperience, is used by 1 out of every 20 teachers and is combined with other teaching techniques. According to Alqarny and Mujiburrohmah (2023), ADLX involves active learning, where students participate actively through activities such as discussions, problem-solving, and reflection. Meanwhile, deep learning emphasizes learning that has a better impact and can permanently change students' behavior. The goal of using this technique is for students to apply the positive values learned in their daily lives (Alqarny & Mujiburrohmah, 2023).

## Introflex

Introflex is an acronym for Individualization, Interaction, Observation, and Reflection (Utami et al., 2024). It is used by one out of every 20 teachers. Introflex learning requires teachers to understand the uniqueness of each student and to be able to accommodate these unique needs according to the differing requirements of students (Utami et al., 2024).

Specific actions or techniques are used by teachers to achieve immediate objectives in the classroom, such as the use of visual aids, games, or group activities to facilitate learning (Hasanova et al., 2021). As found in the results obtained, teachers combine several techniques in delivering concepts of Genes, DNA, and Chromosomes. The combination of these teaching techniques is outlined as follows:

1. The combination of discussion, question-and-answer, and assignments is the most commonly used teaching technique combination. Teachers consider using this combination to facilitate students' understanding of the taught material, promote two-way learning interactions, and encourage active participation from students in the learning process.



2. The most commonly used teaching technique combination is discussion and question-and-answer. Teachers choose this combination to facilitate students' understanding of the taught material, foster two-way learning interactions, and encourage active participation from students in the learning process.
3. The combination of discussion and assignments is also widely used. Teachers choose this combination to clarify the material being taught and ensure that during discussions, all students can actively participate in the learning process.
4. Teachers also use a combination of discussion and presentation techniques. Discussions are conducted through presentations by students either in groups or individually. Students are also given the opportunity to identify as many unclear points as possible, starting from factual questions to hypothetical ones, and then engage in discussions to align perceptions.
5. The combination of discussion and problem-solving is used by teachers with the consideration that students can interact and exchange experiences/information, solve problems, and all remain active without any passive listeners.
6. Teachers also combine discussion, presentation, and question-and-answer techniques, considering the selection of these varied techniques so that students can be more active due to their different learning methods.
7. Teachers also use a combination of discussion, presentation, and lecture techniques based on the facilities available and the students' needs.
8. The combination of discussion, question-and-answer, and lecture techniques is used based on learning objectives and classroom conditions.
9. The combination of presentation, lecture, and performance demonstration is used based on learning objectives and classroom conditions. This combination has been effective in enhancing student motivation in understanding concepts related to Genes, DNA, and Chromosomes. Teachers also find it easier to deliver information as reinforcement for these concepts.
10. Teachers combine presentation, literature study, and role-playing techniques to help students better understand the material in a more engaging process.
11. TERPADU, ADLX, and Introflex are combined based on the JSIT template, which incorporates the uniqueness of JSIT due to its spiritual approach, making learning meaningful by connecting concepts of Genes with moral lessons and their application in daily life.
12. Discussion, presentation, mind mapping, and crossword puzzles are combined with the consideration of assessing how well students understand explanations of concepts related to Genes, DNA, and Chromosomes.
13. The combination of discussion, focus on learning material, repetition of difficult concepts, questioning, information technology, and giving and receiving is used by teachers considering the students' abilities, the availability of learning facilities, and the classroom conditions.

Among the 13 combinations of teaching techniques and their selection considerations, three perspectives used by teachers were identified. The first perspective views students as active subjects, evident in three types of teaching technique combinations: discussion and presentation, discussion and problem-solving, and discussion, presentation, and Q&A. In this perspective, students have the opportunity to identify aspects they do not understand about the discussed material, interact and exchange experiences/information, solve problems, and are not just passive listeners but can be more active because each student's learning style can differ. According to Romiyansah et al. (2020), one of the learning models that position students as subjects is the inquiry model. By using the inquiry model, students engage in various activities during learning, enabling them to discover new concepts. These new concepts are those that previously existed but are newly understood by the students.

The second perspective is from the viewpoint of the teacher as the subject. This perspective is most commonly used by teachers and is based on considerations such as facilitating students' understanding of the material, creating two-way learning, encouraging students to be more active in learning, and allowing the teacher to assess students' comprehension of the explanations given. According to Maulani et al. (2021), teacher-centered learning is evident in the use of conventional methods like lectures and Q&A. The drawback of this perspective is that it positions the teacher as the main source of knowledge in the classroom, which can affect the development of students' knowledge by limiting change and innovation (Nawafil & Junaidi, 2020).

The third perspective is based on learning objectives and is evident in two combinations of teaching techniques: the combination of discussion, Q&A, and lecture techniques, and the combination of presentation, lecture, and demonstration techniques. The selection of these two combinations is considered to align with the learning objectives and classroom conditions. Buchari (2018) notes that some teachers still struggle to create effective learning conditions and situations. However, in teaching, teachers are expected to create a conducive environment to enhance learning outcomes. Additionally, if teaching focuses solely on learning objectives, it can negatively impact on student engagement in the learning process (Abdulla & Woods, 2021).

Essentially, it is crucial to consider all three perspectives: students as subjects, students as objects, and the alignment with learning objectives. The teacher as a subject is important because the teacher is the classroom manager, thus mastering teaching techniques is necessary for effective classroom management. However, students also need to have an active role in the learning process. Mastery of teaching techniques is required for classroom management. On the other hand, a process must be measurable in its success. Learning evaluation can be conducted if the learning outcomes align with the established learning objectives.

The use of varied teaching techniques based on considerations and lesson plans by teachers in delivering the concepts of Genes, DNA, and Chromosomes aims to create a more engaging and enjoyable teaching-learning process, allowing students to actively participate. Although technology is not predominantly mentioned in all teaching techniques, there are still elements of technology used in the learning process, particularly in the form of multimedia (PPT, videos), internet access, and online

information retrieval. Each teaching technique has its own strengths and weaknesses, so teachers should carefully consider which technique to use before delivering the material. The selection of teaching techniques should be based on learning objectives, content, situation, and conditions, as the same teaching technique may not be suitable for different learning materials (Babayeva, 2023). The provision of positive feedback, the implementation of student-centered teaching methods, and the creation of an inclusive learning environment are believed to enhance teaching effectiveness (Munna & Kalam, 2021).

## CONCLUSION

Teaching techniques for Gene, DNA, and Chromosomes in high schools vary, with most teachers combining multiple methods to enhance understanding and engagement. Common approaches include discussions, Q&A sessions, presentations, assignments, problem-solving, lectures, mind mapping, and unique methods like TERPADU, ADLX, and Introfex. Teachers consider student perspectives, ease of delivery, and curriculum alignment when choosing techniques. The study highlights that a varied and combined approach improves learning effectiveness.

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## REFERENCES

- Abdulla, A., & Woods, R. (2021). Obstacles vs. resources – Comparing the effects of a problem-focused, solution-focused and combined approach on perceived goal attainability and commitment. *International Journal of Applied Positive Psychology*, 6(2), 175-194. <https://doi.org/10.1007/s41042-020-00044-6>
- Adhani, A., & Rupa, D. (2020). Analisis pemahaman konsep mahasiswa pendidikan biologi pada matakuliah fisiologi tumbuhan [Analysis of biology education students' conceptual understanding in the plant physiology course]. *Quantum: Jurnal Inovasi Pendidikan Sains*, 11(1), 18-26. <https://doi.org/10.20527/quantum.v11i1.8035>
- Agustin, S., Sumardi, S., & Hamdu, G. (2021). Kajian tentang keaktifan belajar siswa dengan media teka teki silang pada pembelajaran IPS SD [Study on students' learning activeness using crossword puzzle media in elementary social studies learning]. *Pedadidaktika: Jurnal Ilmiah Pendidikan Guru Sekolah Dasar*, 8(1), 166-176. <https://doi.org/10.17509/pedadidaktika.v8i1.32917>
- Aina, M. (2017). Peningkatan kemampuan kognitif dan afektif siswa pada materi substansi genetik menggunakan model picture and picture dan media audiovisual serta papan tempel di kelas XII SMA Negeri 11 Muaro Jambi [Improving students' cognitive and affective abilities on genetic substance material using the picture and picture model, audiovisual media, and bulletin board in grade XII of SMA Negeri 11 Muaro Jambi]. *Biodik*, 3(2), 60-72. <https://doi.org/10.22437/bio.v3i2.5498>
- Alqarny, F. U., & Mujiburrohman. (2023). Desain kurikulum terpadu dengan pendekatan ADLX (Active Deep Learner eXperience) [Integrated curriculum design using the ADLX (active deep learner eXperience) approach]. *Didaktika: Jurnal Kependidikan*, 12(4), 719-730. <https://jurnaldidaktika.org/contents/article/view/290>
- Babayeva, Z. (2023). Determination of teaching strategies considered necessary in teaching biology. *International Journal of Educational Spectrum*, 5(2), 51-67. <https://doi.org/10.47806/ijesacademic.1273224>
- Bawazeer, G., Sales, I., Albogami, H., Aldemerdash, A., Mahmoud, M., Aljohani, M. A., & Alhammad, A. (2022). Crossword puzzle as a learning tool to enhance learning about anticoagulant therapeutics. *BMC Medical Education*, 22(1), Article 267. <https://doi.org/10.1186/s12909-022-03348-0>
- Bheke, E., Pritem, S., & Pujarih, S. (2021). The effect of application of crossword puzzle learning strategy on student learning outcomes. *Journal La Edusci*, 2(3), 10-15. <https://doi.org/10.37899/journallaedusci.v2i3.398>
- Buchari, A. (2018). Peran guru dalam pengelolaan pembelajaran [The teacher's role in learning management]. *Jurnal Ilmiah Iqra*, 12(2), 1693-5705. <http://doi.org/10.30984/jii.v12i2.897>
- Dahlan, D. R., Sunardi, O., & Munandar, R. R. (2020). Pengembangan media alat peraga papan genetika elektrik untuk meningkatkan penguasaan konsep siswa [Development of electric genetic board instructional media to improve students' concept mastery]. *Journal of Biology Education Research (JBER)*, 1(1), 17-24. <https://doi.org/10.55215/jber.v1i1.2632>
- Fernando, S. Y., & Marikar, F. M. (2017). Constructivist teaching/learning theory and participatory teaching methods. *Journal of Curriculum and Teaching*, 6(1), 110-122. <https://doi.org/10.5430/jct.v6n1p110>
- Fitriani, P. E., Uriemanda, R. A., Widiastuti, R., Yusup, I. R., & Listiwati, M. (2020). Perbandingan penugasan kelompok dan individu terhadap hasil belajar pada mata kuliah genetika mahasiswa pendidikan biologi semester 6B [Comparison of group and individual assignments on learning outcomes in the genetics course of sixth-semester 6B biology education students]. *Pedagonal: Jurnal Ilmiah Pendidikan*, 4(1), 21-25. <https://doi.org/10.33751/pedagonal.v4i1.1989>



- Graham, B. S., Ridder, G., Thiemann, P., & Zamarro, G. (2023). Teacher-to-classroom assignment and student achievement. *Journal of Business and Economic Statistics*, 41(4), 1328-1340. <https://doi.org/10.1080/07350015.2022.2126480>
- Habsy, B. A. (2017). Seni memehami penelitian kualitatif dalam bimbingan dan konseling: Studi literatur [The art of understanding qualitative research in guidance and counseling: A literature study]. *JURKAM: Jurnal Konseling Andi Matappa*, 1(2), 90. <https://doi.org/10.31100/jurkam.v1i2.56>
- Hadiawati, N. M., Munandar, K., & Prasetyo, W. G. (2023). Penerapan metode role playing berbasis masalah untuk meningkatkan hasil belajar biologi [Implementation of problem-based role playing method to improve biology learning outcomes]. *Education Journal: Journal Educational Research and Development*, 7(2), 202-208. <https://doi.org/10.31537/ej.v7i2.1249>
- Hasanova, N., Abdudzizov, B., & Khujakulov, R. (2021). The main differences between teaching approaches, methods, procedures, techniques, styles and strategies. *JournalNX - A Multidisciplinary Peer Reviewed Journal*, 7(2), 371-375. <https://www.neliti.com/publications/342865/the-main-differences-between-teaching-approaches-methods-procedures-techniques-s>
- Haskel-Ittah, M., & Yarden, A. (2018). Students' conception of genetic phenomena and its effect on their ability to understand the underlying mechanism. *CBE—Life Sciences Education*, 17(3), Article 36. <https://doi.org/10.1187/cbe.18-01-0014>
- Hidayat, T., & Kasmiruddin. (2020). Miskonsepsi materi genetika tentang ekspresi gen [Misconceptions of genetic material about gene expression]. *Bioedusains: Jurnal Pendidikan Biologi dan Sains*, 3(1), 59-65. <https://doi.org/10.31539/bioedusains.v3i1.1262>
- Hudha, M. N., Aji, S., & Rismawati, A. (2017). Pengembangan modul pembelajaran fisika berbasis problem based learning untuk meningkatkan kemampuan pemecahan masalah fisika [Development of physics learning module based on problem-based learning to improve physics problem-solving skills]. *SEJ (Science Education Journal)*, 1(1), 36-51. <https://doi.org/10.21070/sej.v1i1.830>
- Jug, R., Jiang, X. S., & Bean, S. M. (2019). Giving and receiving effective feedback: A review article and how-to guide. *Archives of Pathology and Laboratory Medicine*, 143(2), 244-250. <https://doi.org/10.5858/arpa.2018-0058-RA>
- Juliangkary, E., & Pujilestari, P. (2022). Kajian literatur metode tanya jawab pada pembelajaran matematika [Literature review of the question-and-answer method in mathematics learning]. *Jurnal Ilmiah Mandala Education*, 8(3), 2571-2575. <https://doi.org/10.58258/jime.v8i3.3839>
- Kelly, R., McLoughlin, E., & Finlayson, O. E. (2016). Analysing student written solutions to investigate if problem-solving processes are evident throughout. *International Journal of Science Education*, 38(11), 1766-1784. <https://doi.org/10.1080/09500693.2016.1214766>
- Kurniawan, R. (2016). Sistem pendidikan Islam terpadu dalam menyiapkan generasi rabbani dan generasi terdidik (Studi pada sistem pendidikan Islam terpadu di bawah jaringan Sekolah Islam Terpadu) [Integrated Islamic education system in preparing the rabbani generation and the educated generation (Study on the integrated Islamic education system under the Integrated Islamic School network)]. *International Conference on Islamic Epistemology*, 92-98. <https://publikasiilmiah.ums.ac.id/handle/11617/7969>
- Lee, E., & Hannafin, M. J. (2016). A design framework for enhancing engagement in student-centered learning: Own it, learn it, and share it. *Educational Technology Research and Development*, 64(4), 707-734. <https://doi.org/10.1007/s11423-015-9422-5>
- Machová, M., & Ehler, E. (2023). Secondary school students' misconceptions in genetics: Origins and solutions. *Journal of Biological Education*, 57(3), 633-646. <https://doi.org/10.1080/00219266.2021.1933136>
- Madukubah, F., Taiyeb, M., & Hartati. (2018). Identifikasi miskonsepsi siswa pada konsep substansi genetik dengan menggunakan three tier test di kelas XII Sekolah Menengah Atas [Identification of students' misconceptions on the concept of genetic substance using a three-tier test in grade XII high school]. *Proceeding Biology Education Conference*, 15(1), 236-242. <https://jurnal.uns.ac.id/prosbi/article/view/31766>
- Maulani, M., Maison, Kurniawan, D. A., & Jumiarti, H. (2021). Identifikasi kemampuan analisis siswa dengan menerapkan model pembelajaran berpusat pada guru (Teacher Center Learning) pada mata pelajaran fisika di SMA N 1 Lubuk Sikaping [Identification of students' analytical skills by applying the teacher-centered learning model in physics subject at SMA N 1 Lubuk Sikaping]. *1st E-Proceeding SENRIABDI 2021*, 53(2), 143-150. <https://jurnal.usahidsolo.ac.id/index.php/SENRIABDI/article/view/848>
- Mulya, M. S., & Zulyusri, Z. (2022). Meta-analisis miskonsepsi siswa pada mata pelajaran biologi SMA [Meta-analysis of students' misconceptions in high school biology subject]. *Biodidaktika: Jurnal Biologi dan Pembelajarannya*, 17(2), 159-168. <https://jurnal.untirta.ac.id/index.php/biodidaktika/article/view/16510>
- Munna, A. S., & Kalam, M. A. (2021). Teaching and learning process to enhance teaching effectiveness: Literature review. *International Journal of Humanities and Innovation (IJHI)*, 4(1). <https://doi.org/10.33750/ijhi.v4i1.102>
- Nainggolan, R. B. M., Sipahutar, M. A., Sihombing, L., & Sipahutar, M. (2023). Peningkatan kemampuan komunikasi yang empatik dan asertif remaja dan orang tua melalui bimbingan kelompok dengan teknik pemberian informasi (ceramah) [Improving empathetic and assertive communication skills of adolescents and parents through group counseling using the information-giving (lecture) technique]. *JKKP (Jurnal Kesejahteraan Keluarga dan Pendidikan)*, 10(2), 138-148. <http://doi.org/10.21009/JKKP.102.02>
- Nawafil, M., & Junaidi. (2020). Revitalisasi paradigma baru dunia pembelajaran yang membebaskan [Revitalization of a new liberating learning paradigm]. *Jurnal Pendidikan Islam Indonesia*, 4(2), 215-225. <https://doi.org/10.35316/jpii.v4i2.193>

- Nephawe, F. T., & Lambani, M. N. (2022). Use of question-and-answer method in teaching English prepositions to primary school learners. *International Journal of Language and Literary Studies*, 4(3), 109-125. <https://doi.org/10.36892/ijlls.v4i3.1000>
- Nugroho, W. A., Yudha, R. P., Sundari, S., & Praja, H. N. (2021). Analisis instrumen asesmen unjuk kerja pada pembelajaran PJOK di sekolah dasar Kota Cirebon [Analysis of performance assessment instruments in PJOK learning at elementary schools in Cirebon City]. *Gelanggang Olahraga: Jurnal Pendidikan Jasmani dan Olahraga (JPJO)*, 4(2), 126-141. <https://doi.org/10.31539/jpjo.v4i2.1795>
- Ojo, A. T. (2024). Examination of secondary school students' conceptual understanding, perceptions, and misconceptions about genetics concepts. *Pedagogical Research*, 9(1), Article em0185. <https://doi.org/10.29333/pr/14095>
- Osman, S., Che Yang, C. N. A., Abu, M. S., Ismail, N., Jambari, H., & Kumar, J. A. (2018). Enhancing students' mathematical problem-solving skills through bar model visualisation technique. *International Electronic Journal of Mathematics Education*, 13(3), 273-279. <https://doi.org/10.12973/iejme/3919>
- Proctor, T. (2020). Creative problem-solving techniques, paradigm shift and team performance. *Team Performance Management*, 26(7-8), 451-466. <https://doi.org/10.1108/TPM-06-2020-0049>
- Purba, I. A., & Zuraidah, Z. (2021). Efektivitas tanya jawab sebagai metode pengulangan materi dalam meningkatkan pemahaman siswa terhadap materi pelajaran saat daring [Effectiveness of the question-and-answer method as a material review strategy in improving students' understanding of lessons during online learning]. *Jurnal Abdikmas*, 1, 134-144. <https://doi.org/10.51158/abdikmas.v1i2.553>
- Remsburg, A. J., & Hagar, M. C. (2019). Can student presentations be an effective form of active learning for the student audience? *The Online Journal of New Horizons in Education*, 9(1). <https://tojnied.net/journals/tojnied/articles/v09i01/v09i01-01.pdf>
- Ritonga, A. W., Ritonga, M., Septiana, V. W., & Mahmud. (2021). Crossword puzzle as a learning media during the Covid-19 pandemic: HOTS, MOTS or LOTS? *Journal of Physics: Conference Series*, 1933(1), Article 012126. <https://doi.org/10.1088/17426596/1933/1/012126>
- Rohmanurmeta, F. M. (2017). Peningkatan hasil belajar bahasa Indonesia melalui metode role playing pada siswa sekolah dasar [Improving Indonesian language learning outcomes through the role playing method in elementary school students]. *Bahastra*, 37(1), 24-31. <http://dx.doi.org/10.26555/bahastra.v37i1.5960>
- Romiyansah, R., Karim, K., & Mawaddah, S. (2020). Analisis kemampuan koneksi matematis siswa pada pembelajaran matematika dengan menggunakan model pembelajaran inkuiri terbimbing [Analysis of students' mathematical connection ability in mathematics learning using the guided inquiry learning model]. *EDU-MAT: Jurnal Pendidikan Matematika*, 8(1), 88-95. <https://doi.org/10.20527/edumat.v8i1.8342>
- Saenab, S., B, N., L, H., & Futri, S. R. (2016). Pembelajaran genetika (susah) dengan strategi humor (mudah), apakah mempengaruhi minat siswa? [Genetics learning (hard) with humor strategy (easy), does it affect students' interest?] *Jurnal Nalar Pendidikan*, 4(2), 131-136. <https://doi.org/10.26858/jnp.v4i2.2414>
- Sanjaya, P. (2020). Efektivitas penggunaan teknik presentasi dan praktikum dalam pembelajaran acara agama Hindu pada mahasiswa program studi PGSD semester III tahun akademik 2019/2020 [Effectiveness of using presentation and practicum techniques in Hindu religious learning for third-semester PGSD students in the 2019/2020 academic year]. *WIDYACARYA: Jurnal Pendidikan, Agama dan Budaya*, 4(1), 44-47. <https://core.ac.uk/download/pdf/327190451.pdf>
- Siswondo, R., & Agustina, L. (2021). Penerapan strategi pembelajaran ekspositori untuk mencapai tujuan pembelajaran matematika [Implementation of expository learning strategy to achieve mathematics learning objectives]. *Himpunan: Jurnal Ilmiah Mahasiswa Pendidikan Matematika*, 1(1), 33-40. <https://jim.unindra.ac.id/index.php/himpunan/article/view/3155>
- Sivarajah, R. T., Curci, N. E., Johnson, E. M., Lam, D. L., Lee, J. T., & Richardson, M. L. (2019). A review of innovative teaching methods. *Academic Radiology*, 26(1), 101-113. <https://doi.org/10.1016/j.acra.2018.03.025>
- Utami, Y., Reistanti, A. P., & Elsanti, R. (2024). Implementasi pembelajaran berbasis ADLX dengan pendekatan terpadu untuk meningkatkan prestasi belajar PAI siswa [Implementation of ADLX-based learning with an integrated approach to improve students' learning achievement in Islamic Education (PAI)]. *Jurnal Ilmiah Pedagogi*, 23(1), 26-37. <https://doi.org/10.63889/pedagogy.v16i2.175>
- Waskito, P., Candramila, W., & Yokhebed. (2020). Analisis pemahaman siswa SMA di Kota Pontianak mengenai materi genetika [Analysis of high school students' understanding of genetics material in Pontianak City]. *EduNaturalia: Jurnal Biologi dan Kependidikan Biologi*, 1(1), 33-38. <https://doi.org/10.26418/edunaturalia.v1i1.36499>
- Yang, Y.-S., Lee, C.-Y., Cheng, T.-F., & Lou, S.-J. (2018). Effects of the life curriculum integrating the happiness teaching and the mind mapping teaching methods on the imagination for second graders. *International Journal of Information and Education Technology*, 8(2), 152-155. <https://doi.org/10.18178/ijiet.2018.8.2.1025>
- Zuhriyah, A. (2022). Model pembelajaran kolaboratif teknik pemecahan masalah untuk meningkatkan kemampuan kreativitas berpikir matematika siswa [Collaborative learning model using problem-solving techniques to improve students' mathematical creative thinking skills]. *Jurnal Ilmu Pendidikan (JIP) STKIP Kusuma Negara*, 13(2), 100-108. <https://doi.org/10.37640/jip.v13i2.1016>