

Genetics Research Trends on Science Learning in Junior High Schools: A Review

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Abstract. Genetics is a core topic in junior high school science, but its abstract, complex concepts lead many students to misconceptions and weak conceptual understanding. This study analyzes research trends in junior high school genetics learning through a Systematic Literature Review (SLR). We examined publication trends, learning models, research methods, learning materials, and key findings from studies published between 2021 and 2026. We searched Google Scholar, Scopus, SciSpace, and Semantic Scholar, screened the results following PRISMA with predetermined inclusion and exclusion criteria, and selected 16 of the 50 initially identified articles. We analyzed the selected studies descriptively through categorization, comparison, and thematic synthesis. Inheritance was the most researched topic, while DNA, allelic interactions, and molecular genetics received little attention. Guided inquiry was the most widely applied learning model, followed by cooperative learning and Problem-Based Learning (PBL). The studies report that active and technology-based approaches, including concept mapping, multimedia learning, and digital game-based learning, contribute to improved conceptual understanding, motivation, critical thinking skills, and student engagement. Misconceptions about Mendelian and non-Mendelian inheritance, cell division, and genotype-phenotype relationships persist across studies. Researchers also show growing interest in integrating digital learning technologies, multiple representations, and genomics-related perspectives into genetics instruction, but evidence on how well these work in junior high school remains limited. Current research trends support more active, inquiry-oriented, and technology-based genetics instruction and call for further empirical studies of innovative learning approaches in genetics education.

Keywords: Genetics Learning; Genomics Literacy; Inheritance; Junior High School; Science Education.

Introduction

Junior high science classes introduce genetics through the inheritance of traits, genes, DNA, chromosomes, mutations, and variation. Students use these concepts to explain biodiversity and to follow current issues in health, agriculture, and biotechnology. Learning genetics at this age builds the scientific literacy they need for later study [1]. Consequently, science education is expected not only to foster conceptual understanding but also to develop students' scientific inquiry skills, critical thinking abilities, and scientific literacy.

Despite its importance, genetics remains one of the most challenging topics for junior high school students. The abstract nature of genetic concepts, complex scientific terminology, and the need for analytical reasoning often lead to misconceptions and a lack of conceptual understanding. Previous research has reported persistent learning difficulties regarding DNA, chromosomes, inheritance patterns, and cell division; these difficulties are often exacerbated by teacher-centered teaching methods that prioritize rote memorization over conceptual understanding [2], [3].

To address these challenges, a number of learning approaches have been investigated. The use of genetics teaching aids and Punnett diagrams has been reported to improve students' motivation and understanding of inheritance concepts [4], [5]. Similarly, the use of science instructional videos [6], metacognitive approaches

[7] Mapping concept and the 5E Learning Cycle model have shown positive impacts on learning outcomes. Recent studies have also explored technology-based learning environments, including bioinformatics-based learning, to help students visualize abstract genetic concepts and relate them to real-world biological phenomena [8], [9]. These findings indicate a growing emphasis on active, inquiry-oriented, and technology-supported learning in genetics education.

Although research on genetics education has expanded rapidly, the existing evidence remains fragmented. Previous systematic reviews have largely examined genetics education within broader educational contexts or focused on specific themes such as visual media, contextual learning, learning difficulties, or classical genetics concepts [10], [11], [12]. Consequently, these reviews offer limited insight into the specific evolution of genetics learning in junior high school science education, including trends in research topics, instructional models, and research methods, as well as persistent learning challenges. Furthermore, few reviews have synthesized how digital learning technologies and emerging perspectives on genetics have been integrated into genetics instruction at the junior high school level.

Research Methods

A Systematic Literature Review (SLR) is conducted following the Preferred Reporting Items for Systematic

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Reviews and Meta-Analyses (PRISMA 2020) guidelines. We identified, screened, evaluated, and synthesized earlier studies on genetics learning in junior high school science education. We chose the SLR because its structured, transparent procedure lets us map research trends, identify dominant themes, and synthesize evidence from existing studies.

The literature was searched Google Scholar, Scopus, SciSpace, and Semantic Scholar using combinations of the keywords genetics, genetics learning, science learning, inheritance, science education, junior high school, and

systematic literature review. We included studies published between 2021 and 2026 in Indonesian or English.

The initial search returned 50 potentially relevant articles. We selected among them in the four PRISMA 2020 stages: identification, screening, eligibility, and inclusion. At screening, we excluded 21 articles that did not meet the indexing and relevance criteria. We assessed the remaining 29 full-text articles for eligibility and excluded 13 that did not satisfy the predefined inclusion criteria. That left 16 articles for the final review. The article selection process followed the PRISMA 2020 guidelines, as illustrated in Figure 1.

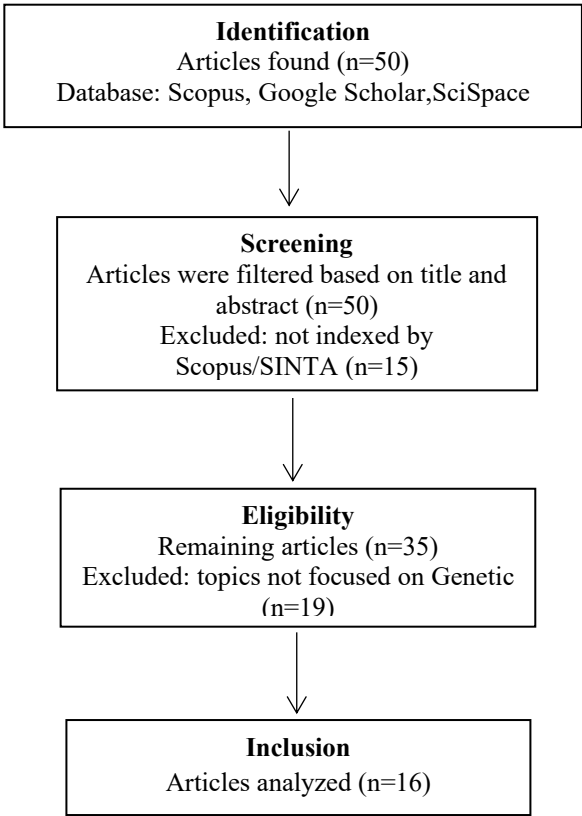


Figure 1. Flowchart Preferred Reporting Items for Systematic Review and Meta-Analysis

The inclusion criteria comprised five requirements: (1) the study focused on genetics learning within science education; (2) the participants were junior high school students or educational contexts directly relevant to junior high school genetics learning; (3) the article reported instructional models, research methods, or learning outcomes related to genetics education; (4) the study was published in a peer-reviewed national or international journal; and (5) the full text was available in either Indonesian or English. Studies were excluded if they were unrelated to genetics education, lacked sufficient methodological information, were not published in peer-reviewed journals, or consisted of conference abstracts, opinion papers, editorials, or other non-research publications.

To enhance the methodological rigor of the review, a quality assessment was conducted before data extraction. Each eligible article was evaluated using four criteria adapted from common SLR appraisal practices: (1) relevance to the research objectives, (2) clarity of research methodology, (3) completeness of reported findings, and (4)

credibility of the publication source. Only studies that satisfied the minimum quality requirements were retained for the final synthesis.

Data from the selected studies were collected using a standardized form that recorded publication year, genetics topic, instructional model, research method, learning media, and principal findings. We analyzed all 16 articles through qualitative descriptive thematic synthesis, categorising, comparing, and synthesising the findings against these predetermined aspects. The analysis let us map publication trends, identify dominant instructional approaches, examine recurring learning challenges, and determine future research directions in junior high school genetics education.

Results and Discussion

The literature review results were compiled from articles that met the inclusion criteria to address the research objectives regarding trends in genetics research in science learning in junior high schools, using a systematic literature review approach. The analysis focused on the research

method, the focus of the study, and the key findings of each article analyzed. A summary of the literature review results is presented in Table 1. Based on the results of the literature review in Table 1, various findings were obtained related to

trends in genetic research in science learning in junior high schools, which were then analyzed further according to the research focus.

Table 1. Results of Literature Review of Genetics Research Trends in Science Learning in Junior High Schools

No	Author & Year	Title	Journal	Title Rank	Research Results
1	Yeonhee Choi [13]	Uncovering The Secrets Of Genetics: From Dna Structure To Patterns Of Inheritance	Journal Of Genetics And Genomics	Q1	Research results show that genetics is crucial for understanding trait inheritance. The challenge lies in the complexity of the relationships between DNA, genes, and the environment. Efforts include the development of genomics, sequencing, and bioinformatics.
2	Mayana Flávia Ferreira Pimenta, Rafaella Cardoso Ribeiro, Adlane Vilas-Boas [10]	Aprendizagem Das Interações Alélicas Ao Nível Molecular Por Meio De Uma Sequência Didática Com Caráter Investigativo No Ensino Médio	Alexandria: Revista De Educação Em Ciência E Tecnologia	Q2	Research results show that investigative learning enhances engagement and understanding of genetics. Challenges include the abstract nature of genetics and the emergence of misconceptions. Efforts include discussions, problem-solving, experiments, and applications in a biotechnology context.
3	Abdulrahim Basira Jibril [9]	Use Of 5e Learning-Cycle And Concept-Mapping Strategies For Improving Students' Performance In Genetics In Secondary Schools In Kwara State, Nigeria	Journal Of Science And Science Education	SINTA 4	Research findings indicate that the 5E Learning Cycle and Concept Mapping strategies improve learning outcomes in genetics. The challenge is that genetics is difficult to understand, leading students to tend to memorize. Efforts were made through active learning based on the 5Es and Concept Mapping.
4	Emmylou Aspacio Borja Dan Romel Cayao Mutya [14]	Enhancing Student's Conceptual Understanding On The Patterns Of Mendelian Genetics Through Task-Based Learning	JPBI (Jurnal Pendidikan Biologi Indonesia)	SINTA 2	Investigative learning enhances engagement and understanding of genetics. The challenges are abstract concepts and misconceptions, while the learning is facilitated through discussion, problem-solving, experimentation, and biotechnology contexts.
5	Fernando Flores-Camacho, Elena Calderón-Canales, Beatriz García-Rivera, Leticia Gallegos-Cázares, Araceli Báez-Islas [15]	Representational Trajectories In The Understanding Of Mendelian Genetics	Eurasia Journal Of Mathematics, Science And Technology Education	Q2	Understanding of Mendelian genetics develops gradually through various representations. The challenge is abstract concepts and relationships between biological levels, while the approach involves multiple representations such as diagrams, text, symbols, and visual models.
6	Susan Strome, Needhi Bhalla, Rohinton Kamakaka, Upasna Sharma, William Sullivan [16]	Clarifying Mendelian Vs Non-Mendelian Inheritance	Genetics	Q1	Research findings indicate that many students hold misconceptions about Mendelian and non-Mendelian inheritance. Challenges stem from errors in online learning resources and misconceptions about phenotype ratios. Efforts are being made to reinforce basic genetic concepts and improve learning resources based on Mendel's laws..
7	Fadria Anuz, Elya Nusantara, Aryati Abdul, Frida Maryati	Application Of Metacognitive Knowledge-Based	Jurnal Pembelajaran	SINTA 3	Metacognitive-based learning improves learning outcomes in heredity. The challenges include abstract and

	Yusuf, Hartono Mamu, Regina Valentina Aydalina [7]	Learning On Students' Learning Outcomes In Heredity Material At Grade Ixth Junior High School Of Smp Negeri 1 Talaga Jaya	Dan Biologi Nukleus		complex genetic concepts, while the efforts involve organizing thought processes, understanding conceptual relationships, and problem-solving.
8	Marlina Gani, Jovialine Rungkat, Fransiska Harahap, Milan Rogahang [17]	The Influence of the Problem Based Learning Model on Student Learning Outcomes in the Inheritance of Traits Material at SMP Negeri 8 Satap Tondano	Sosied	SINTA 4	Model Problem Based Learning meningkatkan hasil dan aktivitas belajar siswa. Tantangannya meliputi pemahaman persilangan dan hubungan DNA, gen, RNA, serta kromosom. Upaya yang dilakukan melalui PBL untuk melatih pemecahan masalah, berpikir kritis, dan keaktifan siswa.
9	Harun Ibrahim, Frida M. Yusuf, Elya Nusantara [18]	Validity Test of the Development of Learning Devices Using the Reading Questioning and Answering Model on the Inheritance of Traits Material to Improve Students' Self-Regulated Learning and Critical Thinking Skills	Bio-Cons: Jurnal Biologi Dan Konservasi	SINTA 4	The Problem-Based Learning model improves student learning outcomes and activities. Challenges include understanding the cross-fertilization and relationships between DNA, genes, RNA, and chromosomes. PBL fosters problem-solving, critical thinking, and student engagement.
10	Maria Marcelina Dua Nurak, Yohanes Bare, Sukarman Hadi Jaya Putra [19]	Development of LKPD Based on Guided Inquiry on Inheritance of Traits	Journal On Teacher Education (Jote)	SINTA 5	Guided inquiry-based student worksheets (LKPD) are highly valid and suitable for use in learning. The challenges include the complex and abstract subject matter of inheritance, while the effort is to develop LKPDs that help students discover concepts independently and in a structured manner.
11	Lastama Sinaga, Lusdiana Saragih, Lisda Raida Manurung, Lasma Novia Panjaitan, Golarden Purba, Ripe Oloan Hutapea [20]	Utilization of Lesson Study-Based Moodle E-Learning Communities to Improve Student Learning Activities	Jurnal Pendidikan, Sains Sosial, Dan Agama	SINTA 4	The use of LSLC-based Moodle e-learning enhances student learning activities. Challenges include boredom and low online learning engagement, while efforts are being made to utilize Moodle, live worksheets, Quizizz, and lesson study to make learning more interactive and collaborative.
12	Fitria Ningsih, Sarwo Danuji, Hanif Rafika Putri [21]	The Application of Animated Video Learning Media on the Material of Inheritance of Traits on the Learning Outcomes of Grade IX Students at SMP Negeri 4 Glenmore	Saintifik@: Jurnal Pendidikan Mipa	SINTA 4	Animated video media effectively improve student learning outcomes. Challenges include low learning outcomes, limited media, and the abstract nature of inheritance material. Efforts are underway to use animated videos to make learning more engaging and easier to understand.
13	Rahma Hanifa Izzaturrahman, Nurwanti Fatnah, Adiyanti [22]	Implementation of the Teams Games Tournament (TGT) Model Assisted by Baamboozle Media to Increase Student Learning Interest in	Nusra: Jurnal Penelitian Dan Ilmu Pendidikan	SINTA 3	The TGT model, supported by Baamboozle, effectively increased students' interest in learning. Challenges include student passivity, lack of focus, and an abstract perception of the material. The effort was achieved through interactive,

		the Material on Inheritance of Traits in Grade IX of Junior High School			collaborative, game-based cooperative learning.
14	Ariyansyah, Mei Indra Jayanti, Erni Suryani [4]	Implementation of Science Learning Media Using Genetics Buttons for Junior High School Students	Jompa Abdi: Jurnal Pengabdian Masyarakat	SINTA 5	Genetic button media improves student motivation and learning outcomes. Challenges include a lack of practical media and low learning motivation, but efforts are being made to utilize genetic button media, group exercises, and interactive learning.
15	Lalu Ukir [5]	Link and Match Genetic Button Punet Table to Improve Learning Achievement of Inheritance of Grade IX.B Students of SMP Negeri 1 Gunungsari in 2021	Jurnal Visionary: Penelitian dan Pengembangan Di Bidang Administrasi Pendidikan	SINTA 4	Learning strategies that use Punnett squares and genetic buttons improve student engagement and achievement. Challenges include limited understanding of inheritance and science learning outcomes, while efforts are underway to use concrete media to clarify gametes, genotypes, and phenotypes.
16	Moerniningsih [23]	Implementation of the Problem-Based Instruction (PBI) Model in an Effort to Improve Science Learning Achievement in Grade IX Students	Jurnal Parameter	SINTA 4	The Problem-Based Instruction (PBI) model improves students' science achievement. Challenges include low activity, motivation, and understanding of the instructional material. Efforts are made through problem-based learning that encourages inquiry, discussion, and problem-solving.

Mapping Articles Based on Publication Year

Mapping articles by publication year was conducted to identify trends in genetics research within junior high school science education between 2021 and 2026. This analysis provides an overview of the development of research interest and publication intensity in genetics learning. The distribution of articles by publication year is presented in Figure 2.

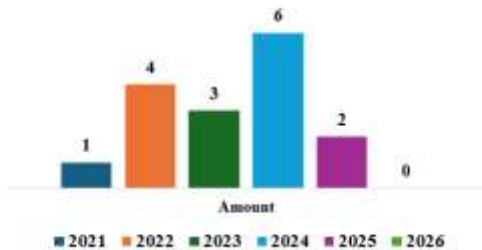


Figure 2. Mapping of Articles by Publication Year

Figure 2 shows that research publications on genetics learning in junior high schools experienced fairly consistent growth during 2021–2024, with the highest number of publications, 6, in 2024. This growth reflects the growing academic concern with genetics as a science topic, known for being complex and abstract, encompassing concepts such as genes, DNA, chromosomes, inheritance, and the interrelationships among biological levels that are often difficult for students to understand. Various research findings reveal that students' mastery of genetic terminology, the mechanisms of crossing over, meiosis, mutation, and the relationship between genotype and phenotype is still inadequate, potentially leading to persistent misconceptions in learning [24], [25].

Efforts to address these issues have led to various studies focused on innovative learning models, strategies, and media. The application of multiple representations in the form of text, symbols, diagrams, visual models, and interactive multimedia is considered capable of facilitating the understanding of abstract genetic concepts while simultaneously improving students' reasoning skills. Similarly, a number of learning media, including instructional videos, crossword puzzles, the Canva platform, and interactive multimedia, have proven effective in catalyzing improvements in student learning outcomes, motivation, and active participation in learning [26].

In addition to media and instructional models, the success of genetics learning is inseparable from study habits, motivation, and the use of technology as complementary supporting components. The implementation of active learning based on problem-solving strategies, the use of concrete media, and learning technology has been shown to positively correlate with strengthening critical thinking skills and improving student learning outcomes [27].

Overall, these findings indicate that the research trend in genetics learning in junior high schools is moving towards the development of innovative learning approaches that integrate active models, visual media, interactive multimedia, and multiple representations to reduce misconceptions and improve students' conceptual understanding.

Mapping Based on Learning Models

Mapping articles based on learning models was conducted to identify trends in instructional approaches used in junior high school genetics education. This analysis provides an overview of the learning models most commonly

used to facilitate students' understanding of abstract genetic concepts. The distribution of learning models identified in the reviewed studies is presented in Figure 3.

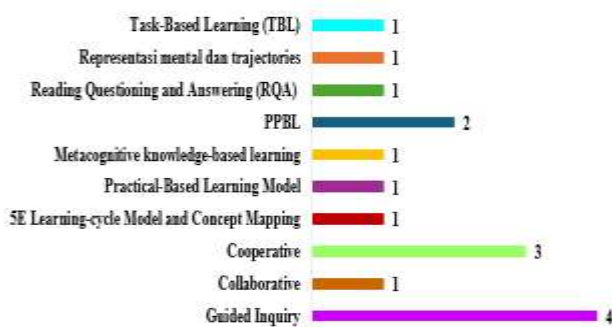


Figure 3. Mapping of Articles based on Learning Models

Guided Inquiry was the most frequently implemented learning model ($n = 4$), followed by Cooperative Learning ($n = 3$) and Problem-Based Learning (PBL) ($n = 2$). The reviewed studies favored student-centered approaches that involve students in constructing scientific knowledge. This preference suits genetics, which asks students to grasp abstract concepts such as inheritance, genes, DNA, and genotype-phenotype relationships through exploration, discussion, and scientific reasoning rather than memorization.

Guided Inquiry contributed to students' conceptual understanding. Students investigated biological phenomena, formulated explanations, and drew conclusions through structured inquiry [28]. Cooperative Learning centered on collaboration: students exchanged ideas, clarified misconceptions, and strengthened scientific argumentation in group discussions [29]. PBL developed students' critical thinking and problem-solving skills by providing authentic genetics problems that connected scientific concepts to real-life situations [30], [31].

The three models differ in instructional focus, but all three promoted active participation and meaningful knowledge construction. No study reported findings that contradicted the effectiveness of student-centered learning. Guided Inquiry mainly targeted conceptual understanding, Cooperative Learning targeted interaction and collaboration, and PBL targeted analytical and problem-solving skills. Each study chose its model to fit its own learning objectives, so the three models do not compete with one another [32], [33].

Student-centered learning dominates junior high school genetics instruction in the reviewed studies. Despite using different models, the studies shared three aims: facilitating conceptual understanding, encouraging active participation, and reducing misconceptions about genetics. They treat active learning as more effective than conventional teacher-centered instruction for handling the conceptual complexity of genetics at this level.

Mapping Based on the Material Studied

Mapping the articles by learning material to identify trends in the genetics topics studied in junior high school science education, and to find which concepts received the most research attention. The mapping shows how much genetic content the reviewed studies cover. Figure 4 presents the distribution of learning materials.

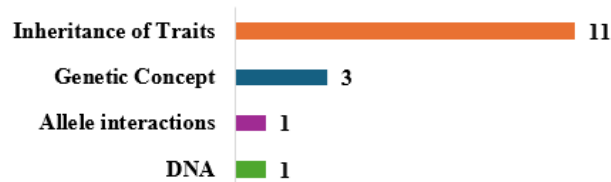


Figure 4. Mapping of Articles Based on the Material Studied

Inheritance was the most common theme in the reviewed studies, appearing in 11 of the 16 articles. General genetics concepts were followed by 3 articles, and DNA and allele interactions appeared in one study each. Junior high genetics research focused on inheritance because it anchors other genetics concepts and fits the science curriculum. It also generates many misconceptions, since students must relate genes, chromosomes, and observable traits, all of which are abstract [34], [35].

Researchers also concentrated on inheritance to address persistent conceptual difficulties. Several reviewed studies found that misconceptions arise when students cannot relate genes, chromosomes, meiosis, and inheritance into a single integrated system. These studies call for instructional approaches that visualize concepts and give students meaningful learning experiences [36], [37]. Few studies investigated DNA and allele interactions, so these topics remain underrepresented. Both matter for a broader understanding of genetics, but the literature suggests that researchers first prioritized mastery of fundamental concepts before moving to more complex topics [38], [39], [40]. This emphasis matches the conceptual demands of the junior high curriculum. The reviewed studies also cover a narrow range of genetics topics. Most focused on classical genetics, particularly inheritance, and only a few explored broader concepts in classroom contexts. Future research could widen the scope by investigating additional concepts suited to junior high students while keeping conceptual understanding and scientific literacy in focus [41], [42], [43].

Inheritance sits at the center of genetics education research because it is the most fundamental and conceptually challenging topic for junior high students. The few studies on DNA and allele interactions highlight a research gap that future work could address while remaining relevant to curriculum objectives. Current research strengthens students' grasp of fundamental concepts as the basis for more advanced topics.

Mapping Based on Type of Research Method

Mapping articles based on research methods was conducted to identify methodological trends in genetics education research at the junior high school level. This analysis provides an overview of the research approaches employed to investigate instructional practices, students' conceptual understanding, and learning outcomes in genetics education. The distribution of research methods is presented in Figure 5.

The mapping results indicate that Classroom Action Research (PTK) was the most frequently employed research method ($n = 5$), followed by quantitative research ($n = 4$), qualitative research ($n = 3$), and mixed-methods and development research, each represented by two studies. The predominance of Classroom Action Research reflects

researchers' strong emphasis on improving classroom learning practices by implementing and evaluating instructional innovations to address students' conceptual difficulties in genetics.

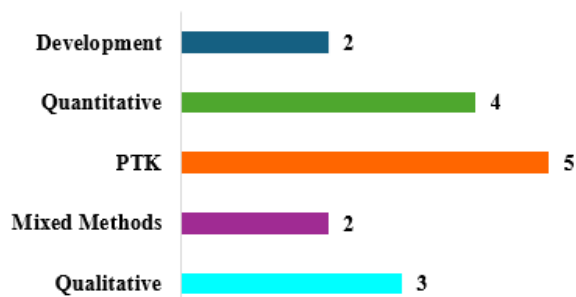


Figure 5. Mapping of Articles Based on the Material Studied

The reviewed quantitative studies primarily evaluated the effectiveness of learning models, instructional media, and teaching strategies in improving students' conceptual understanding and learning outcomes. In contrast, qualitative studies focused on exploring students' misconceptions, learning experiences, and conceptual difficulties, thereby providing a deeper understanding of the factors influencing learning in genetics. Meanwhile, mixed-methods studies combined quantitative and qualitative evidence to provide a more comprehensive evaluation of instructional interventions, whereas development research concentrated on producing innovative learning media and instructional resources to facilitate the learning of abstract genetics concepts [44], [45].

A comparison of the reviewed studies indicates that each research method served distinct yet complementary purposes. Classroom Action Research was predominantly employed to improve classroom practice through iterative instructional interventions, whereas quantitative studies generated empirical evidence regarding instructional effectiveness. Qualitative and mixed-methods approaches provided deeper insights into students' conceptual understanding and learning processes, while development studies contributed practical instructional products that supported genetics learning. These complementary methodological approaches collectively strengthened the evidence base regarding effective genetics instruction in junior high school science education [46], [47], [48], [49].

Despite this methodological diversity, the reviewed literature also reveals an imbalance in research design. The predominance of Classroom Action Research suggests that genetics education research has primarily focused on solving immediate classroom problems, whereas relatively few studies have employed mixed-methods or development research that can generate broader, more comprehensive evidence. This pattern suggests opportunities for future studies to adopt more diverse research designs in order to strengthen the methodological rigor of genetics education research and expand the development of innovative instructional resources [50], [51], [52].

Overall, the reviewed studies demonstrate that genetics education research has employed a variety of methodological approaches to investigate instructional effectiveness and students' conceptual understanding. However, the predominance of Classroom Action Research and the limited number of mixed-methods and development

studies indicate that future research should broaden its methodological approaches to generate more comprehensive evidence and support the development of innovative learning resources for junior high school genetics education

Analysis of Genetics Research Findings in Science Learning in Middle School

A synthesis of the 16 reviewed studies indicates that genetics education research in junior high schools has primarily focused on improving students' conceptual understanding through the implementation of student-centered instructional approaches. Although the studies differed in research design, learning models, instructional media, and learning materials, they consistently addressed similar educational challenges, particularly the abstract nature of genetics concepts and the persistence of students' misconceptions. The increasing number of publications between 2021 and 2024 further demonstrates growing research interest in developing effective instructional strategies for genetics learning. Moreover, the predominance of inheritance-related studies reflects the central role of this topic in junior high school science education, while research addressing DNA, allele interactions, and broader genetics concepts remains relatively limited [13].

Learning outcomes across the reviewed studies

Every reviewed study that used an active learning approach reported positive learning outcomes. Guided Inquiry, the most frequently implemented model, improved students' conceptual understanding by having them investigate biological phenomena through structured inquiry activities [10], [14]. The 5E Learning Cycle and Concept Mapping helped students organize genetics concepts and connect them to one another [9]. Multiple representations and digital learning technologies helped students visualize abstract genetics concepts, which improved both conceptual understanding and classroom engagement [15], [53].

The studies used different instructional approaches but shared an orientation toward active student participation. They differed in emphasis. Guided Inquiry strengthened conceptual understanding through scientific investigation, Cooperative Learning promoted collaborative discussion and peer interaction, and Problem-Based Learning built critical thinking and problem-solving through authentic contexts [28]. No study reported findings that contradicted the benefits of student-centered learning, which gives junior high school genetics education a fairly uniform body of evidence.

Challenges in genetics learning

Despite these positive outcomes, the reviewed studies identified misconceptions as the major challenge in genetics learning. Students struggled to understand inheritance mechanisms, genotype-phenotype relationships, and the relationships among genes, chromosomes, DNA, and observable traits [13], [16]. The studies attributed these misconceptions to the abstract nature of genetics concepts and to students' limited opportunities to build understanding through inquiry-based learning.

Several studies also reported that inadequate learning resources and too few visual representations deepened students' conceptual difficulties. They recommended instructional innovations built on investigation, visualization, and multiple representations to build conceptual understanding and reduce misconceptions [15], [54]. The literature agreed that misconceptions are a major issue in genetics education, and the studies differed only in the instructional strategies they adopted to address them [54].

Educational implications

The reviewed studies show that improving conceptual understanding in genetics requires instruction that engages students in constructing scientific knowledge. They recommend Guided Inquiry, Cooperative Learning, Problem-Based Learning, and other active learning strategies, supported by visual representations and suitable instructional media, over conventional teacher-centered instruction [30], [31]. These approaches improve conceptual understanding, classroom participation, scientific reasoning, and meaningful learning experiences.

The studies also stress strengthening students' grasp of fundamental genetics concepts before introducing broader topics. Because inheritance dominates genetics education research, future instructional innovations should keep prioritizing conceptual understanding and widen students' genetics literacy in stages through curriculum-appropriate learning materials [32], [33].

Research gaps identified from the reviewed studies

The synthesis reveals three research gaps. First, most studies focused on inheritance, and few investigated DNA, allele interactions, or other genetic topics in junior high school science education. Second, Classroom Action Research dominated, so existing work centers on improving classroom practice, while mixed-methods and development research remain scarce. Stronger evidence on how well instructional innovations work across educational contexts requires more comprehensive methods [55], [56]. Furthermore, the studies reported positive impacts of active learning, but few directly compared different instructional models. Future research should compare approaches using shared learning outcomes and research designs to determine which strategies improve genetics learning.

Limitations of the reviewed literature

This review has four limitations. First, only 16 studies met the inclusion criteria, so the available evidence is limited. Second, most studies used Classroom Action Research with small samples, which restricts how far their findings generalize. Third, the studies focused on inheritance, leaving little evidence on other genetic topics in junior high school science education. Fourth, the studies varied in research design, instructional intervention, and assessment instrument, which made direct comparison difficult. Readers should weigh these limitations when interpreting the findings. They also point to directions for future research in genetics education.

The reviewed studies show that student-centered instruction supported by suitable learning media improves

students' conceptual understanding of genetics. The studies used different instructional models and research methods, yet they agree that active learning addresses misconceptions and supports meaningful learning. The narrow range of genetics topics, the dominance of Classroom Action Research, and the small number of reviewed studies call for further research in more diverse instructional contexts and with more varied methods to strengthen the evidence base for junior high school genetics education.

Conclusion

This systematic literature review covered genetics research in junior high school science education published between 2021 and 2026. Inheritance dominated the topics because it anchors students' conceptual understanding of genetics and produces persistent misconceptions. Student-centered approaches, particularly Guided Inquiry, Cooperative Learning, Problem-Based Learning, Task-based Learning, and the 5E Learning Cycle, improved students' conceptual understanding, classroom engagement, and learning outcomes. Multiple representations, visual media, and digital technologies helped students understand abstract genetics concepts and reduce misconceptions. Effective genetics learning requires instruction that engages students in constructing scientific knowledge. Curriculum developers should strengthen inquiry-based learning, multiple representations, and digital learning resources in junior high school science curricula. Professional development programs should teach science teachers strategies to address misconceptions and build conceptual understanding through active learning and appropriate instructional media. The review has limitations. Only 16 studies met the inclusion criteria, and most used Classroom Action Research with small samples, which may limit generalizability. The studies concentrated on inheritance, and research on broader genetics topics remains limited. Readers should interpret the findings with caution.

Author's Contribution

N. A. Dj. Junus, N. Sriastuti, and R. H. Panyo: conducted the literature review, collected and analyzed the data, interpreted the findings, and prepared the manuscript. E. Nusantara, F. M. Yusuf, and M. Latjompoh: conceived and supervised the study, provided academic and methodological guidance, reviewed the research findings, and critically revised the manuscript. All authors read, reviewed, and approved the final version of the manuscript.

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