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# Development Of Punnett Diagram Learning Media On Trait Inheritance Material In Class IX MTs Darul Ulum

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**Abstract:**
Learning of trait inheritance material in grade IX MTs Darul Ulum faces obstacles in the form of abstraction of the concept of genes, alleles, genotypes, phenotypes, and crossover processes, while the use of visual media that helps the understanding of the Punnett Diagram is still limited. This condition causes students to tend to memorize procedures without fully understanding the relationship between genetic concepts. This research aims to develop the Punnett Diagram learning media in the form of learning cards that visualize the stages of crossing in stages and assess the level of validity, practicality, and effectiveness. The research uses the Research and Development method with the ADDIE model which includes the stages of analysis, design, development, implementation, and evaluation. The research subjects consisted of material experts, media experts, science teachers, and 29 students in grade IX MTs Darul Ulum. Data were collected through observation, interviews, documentation, questionnaires, as well as pretest and posttest. The results showed that the media obtained an average validity of 86.00% with the very valid category, the response of teachers 88.40% and the students of 85.80% with the very practical category. The average score of student learning outcomes increased from 58.62 in the pretest to 81.38 in the posttest with an N-Gain value of 0.55 in the medium category. This N-Gain value showed an increase in students' conceptual understanding after the use of media, which supports the conclusion that the Punnett Diagram media is effective as an alternative to science learning. It is concluded that the Punnett Diagram media is valid, practical, and effective in supporting learning inheritance of traits



## Introduction (مقدمة)

Natural Science learning at the Madrasah Tsanawiyah level is directed to build science literacy, reasoning skills, and the ability to apply concepts in everyday situations. However, the effectiveness of learning is not only determined by the breadth of the material, but also by the teacher's ability to translate abstract concepts into representations that can be observed and thought about by students. Learning media has a strategic function in this process because it can channel messages, focus attention, and connect verbal explanations with visual experiences (Wulandari et.al., 2023). The multimedia learning perspective emphasizes that the combination of verbal and visual information in a targeted manner has the potential to facilitate information processing, as long as its presentation does not burden students (Mayer, 2024) Therefore, media development needs to depart from the suitability between the characteristics of the material, learning objectives, and user characteristics. In the context of class IX MTs Darul Ulum, media that is systematically designed becomes relevant to support active, meaningful, and concept-oriented science learning, not just the mastery of terms or procedures in an effective, measurable, and sustainable manner for all students.

Trait inheritance material is an important part of science learning in Grade IX because it introduces the relationship between genes, alleles, genotypes, phenotypes, and the chances of the emergence of hereditary traits. Material complexity arises when learners must relate genetic symbols to the crossover process and interpret the results proportionally. In learning practice, these difficulties can encourage learners to memorize answer patterns without understanding why allele combinations result in variations in certain genotypes and phenotypes (Laouina, 2026)Punnett's diagram provides a matrix representation that allows the possible encounters of gametes to be arranged in an orderly manner, so that the reasoning process can be traced step by step (Butler, 2025) Thus, the diagram does not solely function as a tool to calculate chances, but as a visual vehicle to build a conceptual understanding of the relationship between genetic symbols. Its use needs to be supported by communicative, tiered, and contextual media so that students can move from allele recognition to crossover analysis independently, accurately, and reflexively in classroom learning activities in various situations of basic genetic problem-solving in secondary schools.

Genetic material is often one of the topics that students find difficult to understand because it contains abstract concepts, such as genes, alleles, genotypes, phenotypes, gamete formation, and the opportunity for the emergence of hereditary traits. These difficulties can cause learners to only memorize the completion steps without understanding the relationships between concepts and the reasons for the formation of certain genetic combinations. Recent studies show that the use of visual media and structured representations can help learners connect genetic symbols with the process of inheritance of traits in a more concrete way. Visual representations also play an important role in helping learners interpret the relationships between alleles, gametes, genotypes, and phenotypes during genetic learning (Menendez et al., 2024). In this context, the Punnett diagram serves not only as a tool for calculating crossover chances, but also as a matrix representation that presents possible gamete combinations in a systematic and easily traceable manner (Butler, 2025). The use of Punnett diagrams equipped with illustrations, colors, step-by-step examples, and analytical exercises has the potential to reduce the burden of abstraction and encourage students to understand the crossover process conceptually, rather than just following an answer pattern. Therefore, the development of visual learning media based on Punnett diagrams is relevant to answer the difficulties of learning genetics while supporting science learning that is more active, meaningful, and oriented towards concept understanding.

The study of learning media development shows a tendency to use systematic instructional design to ensure that products are relevant to user needs and learning objectives. The ADDIE model, which includes the analysis, design, development, implementation, and evaluation stages, is widely used because it provides a clear flow from problem identification to product quality assessment (Spatioti et.al., 2022). Several studies in this research document report that such design-based media can be assessed through aspects of validity, practicality, and effectiveness (Sulistyanto et al., 2022)). In genetic materials, media such as electronic modules, interactive multimedia, and visual aids have been developed to increase student engagement and understanding (Errabo & Ongoco, 2024) These findings indicate that the visualization and gradual organization of material is an important element when teaching concepts that contain symbols, opportunities, and relationships between concepts. However, the quality of the media is not enough to be judged by the attractiveness of the display; the accuracy of the concept, the readability of the language, the ease of use, and the measurability of the impact on learning outcomes must be considered in an integrated manner in the context of the target class so that it can be used responsibly and sustainably.

Initial observations at MTs Darul Ulum show that learning trait inheritance still relies on lectures, package books, and explanations on the board. This condition limits students' opportunities to manipulate allele symbols, observe combination patterns, and verify the results of crosses through clear representations. Needs analysis data in the research document showed that 24 out of 29 students had difficulty using the Punnett Diagram, while 25 students stated that it was easier to learn through visual media that contained illustrations, colors, and gradual examples. In addition, 27 students stated the need for more engaging and interactive media. These contextual findings affirm the need for media that not only conveys information, but also guides reasoning procedures from gamete determination to genotype and phenotype interpretation (Menendez et al., 2024) The development of the Punnett Diagram as a learning medium therefore needs to be designed according to the level of development of grade IX students, contain tiered exercises, and allow teachers to facilitate discussions and feedback during science learning effectively.

The research gap of this research lies in the limitations of learning media, which makes the Punnett Diagram the core of visual and procedural representation for trait inheritance material in grade IX students of Madrasah Tsanawiyah. Previous studies tend to emphasize the development of digital media or genetics teaching materials in general, while the need to integrate allele symbols, gamete formation, crossover boxes, genotype ratios, and phenotype ratios in one learning flow that is in accordance with the context of MTs has not been specifically seen in the study document (Isnaeni et.al., 2025). The novelty of this research lies in the development of a Punnett Diagram media in the form of a learning card that visualizes the crossing process in stages, using examples of several characters, and equipped with analytical exercises. The media is designed based on the analysis of the needs of MTs Darul Ulum students, then evaluated comprehensively through expert validation, teacher and student responses, and changes in learning outcomes. Thus, the contribution not only produces visual aids, but also offers a genetic learning design that is simple, contextual, easy to use, and can be empirically tested for feasibility and effectiveness in direct MTs level science learning.

This research aims to develop the Punnett Diagram learning media on trait inheritance material for grade IX MTs Darul Ulum students and assess the quality of its use in science learning. The development is directed to produce card-shaped visual media that presents allele symbols, gamete formation stages, genotype combinations, phenotype interpretation, and systematic crossover exercises. The objectives are described in two problem formulations: (1) what is the level of validity and practicality of the Punnett Diagram learning media on trait inheritance materials for grade IX MTs Darul Ulum students based on expert assessment, teacher responses, and student responses; and (2) how effective is the Punnett Diagram learning media in improving student learning outcomes on trait inheritance materials in grade IX MTs Darul Ulum? The formulation of this problem places the product as an object of development while assessing its usefulness and impact. Operationally, the research uses the ADDIE model and utilizes observation, interviews, documentation, questionnaires, and pre- and post-learning tests to support product evaluation and learning outcomes.

## Method (منهج)

This study uses the research and development method, or *Research and Development* with the ADDIE model, which includes *the analysis*, *design*, *development*, *implementation*, and *evaluation* (Spatioti et al., 2022)The selection of the model is based on its suitability for the research objective, which is to produce Punnett Diagram learning media that is suitable for use in trait inheritance materials in grade IX MTs Darul Ulum. The analysis stage is carried out to identify student characteristics, learning barriers, the availability of learning resources, and teachers' needs for visual media. Information is collected through learning observations, interviews with science teachers, documentation, and questionnaires of student needs. In the design stage, the researcher determines the learning outcomes, compiles the material map, designs the card display, determines illustrations, and prepares examples and crossover exercises. The development stage produces a media prototype that contains allele symbols, gamete formation, cross tables, genotypes, and phenotypes. The prototype is revised based on validator input before being applied in learning. Implementation and evaluation are carried out to assess the applicability of the product and the results of its use in students in a gradual and contextual manner.

The research was carried out at MTs Darul Ulum with subjects including a material expert, a media expert, a science teacher, and 29 grade IX students as media users in the trial stage. The material expert assessed the accuracy and breadth of the content, suitability with the learning objectives, language, presentation, and graphics. The media expert assessed the quality of the display, design, ease of use, and technical aspects of the media. Teachers and students responded to the practicality of the product after the implementation of learning, while the learning outcome test was used to measure the effectiveness of the media. The research instruments consisted of observation sheets, interview guidelines, material expert validation sheets, media expert validation sheets, teacher response questionnaires, student response questionnaires, *and pretest* and *posttest questions* (Kaukaba et.al., 2022). All instruments were compiled based on the indicators of learning objectives of the material, inheriting the properties and characteristics of the Punnett Diagram media. Before implementation, the media was revised according to the validator's recommendations regarding the accuracy of the terms, readability of the text, visual consistency, clarity of illustrations, and the sequence of steps to complete crosses so that they are suitable for use in the classroom.

The research data consisted of qualitative and quantitative data. Qualitative data in the form of observation results, interviews, revision notes, and validator suggestions were analyzed through reduction, grouping, and interpretation extraction to improve the media. Quantitative data from validation sheets and response questionnaires were analyzed descriptively using percentages with a formula comparing the scores obtained to the maximum score, then categorized according to the set eligibility criteria. The validity of the media was determined through the assessment of material experts and media experts, while the practicality was determined through the responses of teachers and students. The effectiveness of the media was analyzed using *pretest* and *posttest scores* from 29 students. The increase in learning outcomes is calculated by *Normalized Gain* or N-Gain, which is the difference between the average *score of the posttest* and *pretest* compared to the difference between the maximum and *pretest scores* (Canes et.al., 2026). The results of the analysis are interpreted into the category of relevant improvement. The integration of qualitative and quantitative findings is used to conclude whether the Punnett Diagram media meets the valid, practical, and effective criteria for supporting the learning of trait inheritance in grade IX MTs Darul Ulum.

The results of the research on the formulation of the first problem showed that the Punnett

## Result (نتائج)

Diagram learning media developed met the criteria of being very valid and very practical for learning to inherit traits in grade IX MTs Darul Ulum. The assessment of the material experts resulted in an average of 85.50 percent, with aspects of content feasibility of 86 percent, linguistics of 84 percent, presentation of 87 percent, and graphography of 85 percent. The assessment of media experts obtained an average of 86.50 percent, which included 88 percent for display, 86 percent for media design, 87 percent for ease of use, and 85 percent for technical quality. The combined average of the two assessments reached 86.00 percent and was included in the category of being very valid. After revision based on expert recommendations, the media was tested on teachers and 29 students. The teachers' response reached 88.40 percent, while the students' response reached 85.80 percent; both are categorized as very practical. These findings indicate that the Punnett Diagram card has the right material, a communicative display, and an easy-to-use procedure, thus supporting the targeted processing of visual and verbal information in genetic learning.

Table 1. Results of Validity and Practicality of Learning Media Punnett Diagram

| Assessment aspects | Assessor/respondent | Percentage | Category |
|---|---|---|---|
| Content eligibility | Material Expert | 86,00% | Very valid |
| Language | Material Expert | 84,00% | Very valid |
| Presentation | Material Expert | 87,00% | Very valid |
| Graphic | Material Expert | 85,00% | Very valid |
| Average validation of subject matter experts | Material Expert | 85,50% | Very valid |
| Display | Media members | 88,00% | Very valid |
| Media design | Media members | 86,00% | Very valid |
| Ease of use | Media members | 87,00% | Very valid |
| Technical quality | Media members | 85,00% | Very valid |
| Average media expert validation | Media members | 86,50% | Very valid |
| Average media validity | Material experts and media members | 86,00% | Very valid |
| Teacher response | IPA Teacher | 88,40% | Very practical |
| Learner response | 29 students | 85,80% | Very practical |

The results of the research in the formulation of the second problem show that the Punnett Diagram learning media is effective in improving students' learning outcomes in property inheritance materials. The effectiveness test involved 29 students in grade IX MTs Darul Ulum who took the *pretest* before learning and *the posttest* after using the media. The average *pretest* score of 58.62 increased to 81.38 in the *posttest*, or an average increase of 22.76 points. The highest score increased from 72 to 94, while the lowest score increased from 42 to 68. Based on the calculation of *Normalized Gain*, an N-Gain score of 0.55 was obtained, which was in the medium category. The improvement showed that the use of cards containing allele symbols, genotype combinations, phenotype illustrations, and crossing stages helped students understand the relationship between systematic concepts. This result is in line with the foundation of CTML, because the combination of Punnett Diagram visualization and verbal explanations facilitates active information processing. Thus, the developed media is not only feasible and easy to use, but also effective as a support for science learning on trait inheritance materials.

Table 2. Results of the Punnett Diagram Learning Media Effectiveness Test

| Learning outcome indicators | Pretest | Posttest | Changes |
|---|---|---|---|
| Number of students | 29 | 29 | – |
| Highest score | 72 | 94 | Increased by 22 points |
| Lowest value | 42 | 68 | Increased by 26 points |
| Average score | 58,62 | 81,38 | Up 22.76 points |
| Skor N-Gain | – | 0,55 | Category sedan |
| Interpretation of effectiveness | – | – | Effective media |

The results of the study prove that the development of Punnett Diagram learning media through the ADDIE model produces products that have met the three main quality indicators of development research, namely validity, practicality, and effectiveness. The validity of the media is shown through the assessment of material experts and media experts with an average of 86.00 percent. The practicality is proven through the positive response of teachers by 88.40 percent and students by 85.80 percent. The effectiveness of the media is shown by an increase in the average learning outcome from 58.62 in the *pretest* to 81.38 in the *posttest*, with an N-Gain score of 0.55 in the medium category. Therefore, the Punnett Diagram media is suitable to be used as an alternative visual media to help students understand the concepts of genes, alleles, genotypes, phenotypes, and the opportunities of crossing results in a more structured manner.

## Discussion (مناقشة)

This research is based on the *Cognitive Theory of Multimedia Learning* (CTML). This theory is relevant because the Punnett Diagram media is designed to help students understand the concept of inheritance through the integration of visual representation and verbal explanations (Mayer, 2024) The theory is based on three assumptions, namely the existence of two visual-pictorial and auditory-verbal information processing channels, limited capacity in each channel, and the need for active processing by learners (Bali et.al., 2026). In media development, the principle is applied through the presentation of allele symbols, genotype cards, cross tables, phenotype illustrations, brief instructions, and examples of completion that are arranged in stages (Lumayaga et.al., 2026). Such a design allows students to select relevant information, organize relationships between symbols, and integrate new knowledge with an initial understanding of trait inheritance. Therefore, cognitive multimedia learning theory is the conceptual foundation in determining the content, display, order of presentation, and learning activities in the Punnett Diagram media. The theoretical suitability was evaluated through expert validation, user response, and measurement of learning outcome improvement using *pretest*, *posttest*, and N-Gain.

The discussion of the first problem formulation focused on the level of validity and practicality of the Punnett Diagram learning media on trait inheritance material in grade IX MTs Darul Ulum. The validation results showed an overall average of 86.00 percent with a very valid category. This achievement indicates that the media has met substantial and technical requirements before being used in learning. In terms of substance, the Punnett Diagram card presents the concepts of alleles, gametes, genotypes, phenotypes, and crossover opportunities in a row (Müller-Wille & Parolini, 2020)From the technical side, the media provides a visual display, color combinations, and instructions for use that support readability. These findings are relevant to the development stage in the ADDIE model, namely, the product needs to obtain expert assessment before being implemented for the target user (Widyastuti & Susiana, 2019) The high validity also indicates the compatibility between the learning objectives, media content, and characteristics of grade IX students. Thus, the media not only functions as a presentation aid but also as a learning tool designed to facilitate the understanding of directional, contextual, and meaningful genetic concepts in learning.

The validation of subject matter experts resulted in an average score of 85.50 percent with a very valid category. The feasibility of the content was obtained at 86 percent, linguistics at 84 percent, presentation at 87 percent, and graphography at 85 percent. These scores show that the content of the media has accommodated the essential elements of trait inheritance, especially the relationship between allele symbols, gamete formation, genotype combinations, and phenotype manifestations. The presentation that obtained the highest score showed that the order of the material, examples of crossovers, and exercises available were seen as logical and easy to follow. However, the relatively lower language score became the basis for revisions to simplify sentences, clarify scientific terms, and adjust the level of readability to MTs students. From the perspective of CTML, concise and directed texts help learners focus on relevant information, so that cognitive processing capacity is not burdened by excessive explanations during cross-breeding and interpreting results independently on various genetic questions (Klepsch & Seufert, 2020)

The media expert's assessment obtained an average of 86.50 percent and was included in the very valid category. The display aspect reached 88 percent, the media design 86 percent, the ease of use 87 percent, and the technical quality 85 percent. These results show that card-shaped media has an adequate visual organization to present the concept of crossing concretely. A clear display helps learners distinguish dominant and recessive alleles, identify gamete positions, and read the results of combinations in the Punnett Diagram box. The use of color and illustration acts as visual markers, not as mere decorative elements. This design suitability supports the assumption of visual-pictorial channels in CTML, as abstract genetic information is presented as a more traceable representation (Cavanagh & Kiersch, 2022) However, expert input related to color contrast, font size, and clarity of illustrations is still used as the basis for product improvement. The revision stage ensures that the media is not only interesting, but also functional, easy to read, and consistently used by students in independent learning activities and classroom discussions.

The practicality of the media was assessed through the responses of science teachers and 29 students after the media was applied to learning inheritance of traits. Teachers gave a response percentage of 88.40 percent, while students gave a percentage of 85.80 percent; both results were categorized as very practical. The teacher's response indicated that the media was easy to prepare, aligned with the material, and helped explain the stages of crossing systematically. For teachers, this function is important because the Punnett Diagram is often taught through whiteboards and book exercises, which can limit students' direct involvement (Syahrul et.al., 2026). Meanwhile, the students' responses showed that the media was easy to use and helped them understand the material. Cards containing allele symbols and combination results allow students to observe and trace the crossover process without just waiting for the teacher's answer (Zamri et.al., 2025). This finding confirms that practicality is not just operational convenience, but the familiarity of the media in real learning situations. Thus, the media design is in accordance with the needs of the users identified at the stage of analyzing the ADDIE model according to the needs of the class.

The high level of practicality can be explained through the suitability of the media with the characteristics of the learners' difficulties in the inherited material. The needs analysis shows that most learners experience obstacles in using the Punnett Diagram and require visual media with examples of gradual completion. The developed media responds to these needs through allele symbol cards, cross variations, phenotype illustrations, and analysis exercises. This structure helps learners connect the stages of determining the parents' traits and the chances of offspring. Within the framework of CTML, the combination of visuals and verbal explanations supports the formation of a more organized mental representation. Students not only see the final result of the cross, but follow the process of forming genotype combinations explicitly (Awiyadi et.al., 2026). This condition explains why the ease of understanding aspects of the material and the benefits of the media receive a positive response. The media provides space for active learning because students can arrange, compare, and discuss various possible crossovers. Therefore, the practicality of media is directly related to its ability to turn abstract genetic concepts into learning activities carried out.

The validity and practicality of the Punnett Diagram media are mutually reinforcing in this study. Validity guarantees that genetic information, language, presentation, and media design meet the feasibility standards based on expert assessment. Practicality shows that the product that has been assessed as feasible can be used effectively by teachers and students in the context of actual learning. The validity of 86.00 percent and the responses of teachers and students of 88.40 percent and 85.80 percent show consistency in design quality and user experience. This is important because the correct media is conceptually not necessarily easy to use, while interesting media does not necessarily have accurate content. In this media, the crosscard integrates the two needs through the right information, a clear sequence of activities, and communicative visualization (Maskara et.al., 2025). Thus, the test results strengthen the decision that the product can be continued in effectiveness testing. The decision is also in line with ADDIE's flow, which places formative evaluation as the basis for product refinement before wider and more tangible implementation.

Pedagogically, the Punnett Diagram media offers a contribution to science learning to facilitate trait inheritance reasoning. When learners use cards to place alleles and fill in crossover boxes, they perform external representations of processes that were previously abstract (Flores-Camacho et.al., 2021). These activities allow teachers to provide feedback on each step, for example, when learners distinguish dominant and recessive alleles or determine phenotype ratios. The quality of the display and ease of use reinforce the potential of the media as a means of discussion, independent exercise, and formative evaluation. These findings suggest that learning innovations do not always have to be based on complex digital technologies. Physical media designed based on user needs, clear visual principles, and conceptual accuracy can still provide meaningful support for learning (Fitriani et.al., 2025). In the context of MTs Darul Ulum, this option is relevant because it allows for flexible use in the classroom and does not rely on digital devices. Therefore, the media of the Punnett Diagram has the potential to be replicated by adjusting the material, student characteristics, and other school learning conditions.

The analysis showed that the success of the Punnett Diagram media in the formulation of the first problem stemmed from the alignment between learning needs, CTML principles, and ADDIE development procedures. The analysis stage identified learners' difficulties in understanding crossovers, while the design stage translated these needs into visual cards, step-by-step examples, and exercises. The expert development and validation stages ensured content accuracy, language clarity, display quality, and ease of use. The final results, which were 86.00 percent validity and very high practicality, showed that the integration of these elements worked consistently. Conceptually, the media reduced genetic abstraction by displaying the relationships of alleles, gametes, genotypes, and phenotypes in a single structured representation. Methodologically, the findings justified the use of formative evaluation before the effectiveness test. However, this assessment still involved one teacher and 29 students, so generalizations needed to be made carefully. Testing in diverse classrooms, schools, and student characteristics is needed to test the stability of the practicality of the media in the context of implementation and the broader learning scale.

The discussion of the second problem formulation was directed to examine the effectiveness of the Punnett Diagram learning media in improving students' learning outcomes on trait inheritance material (Sulikah et.al., 2024). Effectiveness was measured through a comparison of *pretest* and *posttest* scores given to 29 students in grade IX MTs Darul Ulum. The average *pretest* score of 58.62 increased to 81.38 in the *posttest*, resulting in an increase of 22.76 points. In addition, the highest score increased from 72 to 94, and the lowest score increased from

42 to 68. Based on the calculation of *Normalized Gain*, an N-Gain score of 0.55 was obtained in the medium category. These results indicate that the use of media contributes positively to students' mastery of concepts. The increase in scores not only indicates numerical changes, but also illustrates a shift from a limited initial understanding to a better ability to interpret the relationship between alleles, genotypes, phenotypes, and crossover opportunities. Therefore, media are stated to be effective as a support for science learning in the classroom.

The improvement in learning outcomes can be explained through the visual character of the Punnett Diagram media that concretizes the concept of genetics. Before the use of media, learners tended to face difficulties when determining gametes, placing alleles in cross-boxes, and distinguishing genotypes and phenotypes (Ebo & Salic-Hairulla, 2026) Learning cards provide a sequence of activities that explicitly show the relationships between these components. Students can observe allele symbols, pair possible gametes, form genotype combinations, and interpret phenotypes gradually. This process reduces reliance on memorization of formulas or answer patterns. When concepts are presented through steps that can be seen and manipulated, learners have the opportunity to re-examine the reasons for each answer. Thus, media acts as a bridge between symbolic representation of genetics and conceptual understanding. The increase in *posttest* scores shows that the visual bridge helps students apply concepts to crossing questions. This result is also in line with the development goal, which is to provide simple, systematic, and relevant learning facilities to the needs of grade IX students of MTs Darul Ulum.

The findings of media effectiveness are in line with *the Cognitive Theory of Multimedia Learning*, which places the integration of visual and verbal information as the basis for the formation of understanding. Punnett's Diagram media utilizes visual channels through allele cards, cross-boxes, colors, and phenotype illustrations, while verbal channels are realized through clues, terms, and completion examples (Désiron et.al., 2024). The integration allows learners to select important information, construct relationships between information, and relate it to initial knowledge. In trait inheritance, this process is important because learners need to understand not only the meaning of symbols, but also the procedures and reasons for the formation of hereditary trait combinations (Sulikah et al., 2024) Gradual presentation also helps control cognitive load, as students do not receive all information at the same time. The results of the N-Gain category in the medium category show that the multimedia design provides a meaningful improvement, although there is still room for reinforcement. Therefore, the effectiveness of the media is not only understood as a test success, but also as evidence that structured visual-verbal design supports active processing in genetic learning in MTs.

The N-Gain score of 0.55 is in the medium category and needs to be interpreted proportionally. This category shows an increase in comprehension after media use, but does not reflect the maximum change for all students. Variations in abilities, mastery of genetic symbols, opportunity counting skills, and time using media can affect the amount of improvement achieved. An average *pretest* score of 58.62 shows that students start learning with an uneven conceptual foundation. Through media implementation, the average *posttest* score reaches 81.38, which indicates that most of the barriers to understanding can be minimized. However, the achievement of N-Gain signals the need for reinforcement through more diverse cross-training, group discussions, and individual feedback. Teachers can use the media repeatedly on a variety of monohybrid questions so that students do not just follow the example (Yogica et.al., 2020). With this strategy, the process of using the Punnett Diagram card can develop from guided activities to independent problem-solving, so that the opportunity to improve learning outcomes in the next implementation is large and even.

The effectiveness of media is also related to changes in students' learning activities during learning. Punnett's Diagram media encourages learners to be involved in determining parent alleles, arranging gametes, filling in crossover matrices, and interpreting possible heredity (Low

& Ellefson, 2024)These activities make learners actors in the process of knowledge formation, not just recipients of the teacher's explanations. In conventional learning, the crossover step is often displayed once on the board, so students run the risk of copying the procedure without understanding the interconnectedness between the elements (Gloria et.al., 2026). In contrast, the use of cards allows for repetition and direct examination of the allele arrangement. Students can discuss differences in answers, compare crossover results, and correct mistakes with the support of teachers. Cognitive involvement and manipulative activities may explain the increase in *posttest scores*. Thus, the media provides a meaningful learning experience through observation, drafting, and systematic reasoning. These results reinforce the relevance of media for science learning that requires an understanding of the process and the ability to apply genetic concepts. Teachers still need to monitor the process and provide conceptual clarification on a regular basis.

Within the framework of the ADDIE model, the effectiveness results show that the implementation and evaluation stages have provided empirical evidence regarding the function of the media in the context of the target user. The previous analysis stage identified the limitations of the use of visual media in learning the inheritance of traits and the difficulties of learners using the Punnett Diagram. The design stage then produced a learning card with examples and step-by-step exercises, while the development stage refined the product based on expert validation. The increase in scores from *pretest* to *posttest* proved that the series of design decisions was relevant to the learning problems found. The evaluation of learning outcomes through N-Gain complemented the validity and practicality information with evidence on the impact of media use (Putra et al., 2026). Therefore, effectiveness does not stand alone, but is a consequence of the suitability of content, appearance, ease of use, and implementation strategy. A valid and practical product provides initial conditions that support students in learning in a more directed manner. These results show that the application of ADDIE can produce decent media and have an impact on real science learning outcomes.

Although the results show positive effectiveness, the interpretation needs to take into account the limitations of the study. The trial was conducted on 29 grade IX students in one madrasah and used *a pretest-posttest design* without a comparison group. Therefore, the increase in scores cannot be fully claimed as a single result of the use of Punnett Diagram media, as the teacher's explanatory factors, learning motivation, learning time, and previous experience may also contribute. In addition, the medium category N-Gain shows that the media can be improved through the provision of graded questions, variations in the context of inheritance of traits, and remedial guidance for students who are still experiencing difficulties (Syafiqah & Panduwinata, 2025) These limitations do not reduce the feasibility of the results, but place them as preliminary evidence in the context of MTs Darul Ulum. Follow-up research may involve a large number of learners, control groups, and measures of learning retention. Subsequent developments may also test the use of media on cross-hybrids or other genetic concepts. Such a step is needed to strengthen generalizations of effectiveness and identify the learning conditions that best support media use.

The analysis confirmed that the Punnett Diagram media was effective in improving learning outcomes because it answered students' needs for visual representation, step-by-step procedures, and manipulative activities. The increase in the average score from 58.62 to 81.38 and an N-Gain of 0.55 showed a significant change in understanding after media implementation. These results were consistent with CTML, as the crosscards integrated words, symbols, colors, and images to help students organize genetic information. The alignment between the ADDIE stages and the evidence of effectiveness also showed that development was based on the analysis of learning problems, not solely the creation of engaging media. However, the N-Gain category is signaling the need for complementary strategies, especially repetitive exercises, collaborative learning, and differentiated guidance. Media should be positioned as a means of supporting pedagogical interaction between teachers and students, rather than a substitute for learning. With its implementation, the media has the potential to strengthen science literacy, evidence-based reasoning, and problem-solving skills in the inheritance of traits in MTs and schools like Indonesia.

## Conclusion (خاتمة)

This study aims to develop the Punnett Diagram learning media on trait inheritance material for grade IX students of MTs Darul Ulum and assess the level of validity, practicality, and effectiveness of its use in science learning. The results of the study show that the Punnett Diagram media developed meets the criteria of very valid with an average assessment of subject matter experts and media experts of 86.00%, very practical based on the responses of teachers (88.40%) and students (85.80%), and effective in improving student learning outcomes. The effectiveness of the media is shown by the increase in the average learning outcome score from 58.62 in the pretest to 81.38 in the posttest, with a Normalized Gain (N-Gain) value of 0.55 which is in the medium category. This N-Gain value indicates that the media contributes positively to the understanding of students' genetic concepts, although the improvement achieved has not been maximized in all students. Interpretation of the N-Gain score in the medium category shows that the Punnett Diagram media is able to reduce students' initial conceptual barriers, but still needs reinforcement through a variety of crossover questions, group discussions, and differentiation guidance so that understanding can be more optimal. Overall, the Punnett Diagram media makes a significant contribution to learning trait inheritance by presenting structured visual representations, facilitating procedural reasoning from allele determination to phenotype interpretation, and supporting active information processing according to the principles of Cognitive Theory of Multimedia Learning. Thus, this media is suitable as an alternative science learning media that is contextual, systematic, and oriented towards concept understanding at the MTs and similar school levels.

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