Leveraging the Enhanced VARK Model with Kotobee Author Software to Enrich Students' Learning Outcomes in Genetics

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Abstract. The study primarily aimed to address the limitations of the visual, aural, read and write, and kinesthetic model on how integrating Kolb's experiential learning theory can enhance its effectiveness in supporting diverse students' preferences in learning non-mendelian genetics; identified students' preferred learning styles; compared their learning performance using the two models and determined students' perceptions in implementing the enhanced VARK model through Kotobee Author Software. This research employed a quasi-experimental design supported by the qualitative data responses collected through focus group discussion. The participants involved in the study were 98 Junior High School students in a public school. Results showed that the students exhibited strong preferences for kinesthetic, visual, and aural learning styles, with reading and writing methods also playing a significant role, indicating that experiential activities are efficient for these students. The findings revealed the effectiveness of the enhanced model in improving students' learning outcomes. The significant performance improvement demonstrates the potential of this model to address diverse learning preferences more effectively than traditional approaches. Through its technology integration, students have expressed varied perceptions, ranging from increased engagement and motivation to challenges adapting to new learning strategies. While the model has offered more personalized and interactive learning experiences, students have highlighted areas for improvement, such as the need for more explicit guidance and additional support in applying different learning styles. The new model has proven effective in catering to diverse learning needs, yet further refinement is necessary to realize its full potential.

Keywords: experience, learning outcomes, learning styles, perceptions, kotobee author software

1 Introduction

Understanding patterns of non-Mendelian inheritance presents unique challenges for students, as these complex genetic concepts often require more profound levels of analysis and practical application. Traditional learning models like VARK, which cater to

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visual, auditory, reading/writing, and kinesthetic learning preferences, offer a foundation but may fall short of addressing the need for experiential engagement, which is critical in mastering such intricate topics.

As students develop excellent proficiency in evaluating their cognitive processes, they enhance their awareness of their learning mechanisms, improving their ability to apply knowledge across diverse contexts. The interplay between science process skills and experience is paramount, as it empowers them to take ownership of their educational journey, fostering more profound engagement with content and the development of 21st-century skills that are essential in today's rapidly evolving world [1,2].

Science education is no longer solely about memorizing facts and theoretical concepts; it is increasingly seen as a dynamic process that involves critical thinking and problem-solving. A prevalent issue globally in science education: poor science learning, low cognitive skills, and limited comprehension of scientific literacy. It highlights the root cause of these challenges: the lack of adequate teaching methodologies catering to diverse learning styles and individual needs. [3].

The 2022 Program for International Student Assessment (PISA) conducted by the Organization for Economic Co-operation and Development (OECD) showed that the Philippines ranked 77th out of 81 countries globally in Math, Reading, and Science. Science scored 24.00% in the assessment, indicating that students have only achieved basic proficiency in the subject. The average score for the country was 357, which differed significantly from the OECD average of 489. Filipino students ranked second to last in creative thinking, scoring an average of 14 points, which was second to the lowest next to Albania's 13 mean score out of an average of 33 points. These differences point to problems with the standard of science instruction and highlight the need for focused interventions to guarantee that all students receive a high-quality science education.

The official results released of the PISA in 2023 somehow mirror the outcomes in the Caraga Region and Butuan City division, where students performed poorly in scientific-based problem-solving as indicated by the Mean Percentage Scores (MPS) and Least Learned Competencies (LLC) for the school year 2023-2024. Science recorded an MPS of only 62.20% and showed more responses on explaining the different patterns of non-mendelian inheritance as LLC. This positioned science with one of the lowest ranks in MPS and highlights underlying issues within the teaching process, which serve as fundamental problems (DepEd Memorandum No. 54, series of 2023).

An individual's learning style preference can enhance the design of educational programs tailored to their specific needs. However, teachers opted to use their preferences rather than analyzing the diverse needs of the students. Knowing these styles provides a good start for the design of effective instruction. Research shows that students with different learning styles interact with educational materials in varied ways, suggesting that personalized learning can improve engagement and outcomes. While the Visual, Aural Read/Write, and Kinesthetic (VARK) model and questionnaire are reliable tools for assessing these preferences, the relationship between learning styles and learning outcomes is complex and influenced by other factors. It is essential to consider individual differences when developing educational strategies, as this creates a better classroom learning environment and motivates students to pursue and achieve academic goals [4].

To address the diverse learning needs of students and overcome the static limitations of the traditional VARK framework, this study proposes an Enhanced VARK Model that systematically integrates Kolb's Experiential Learning Theory (ELT). Kolb's model outlines four learning stages—Concrete Experience (CE), Reflective Observation (RO), Abstract Conceptualization (AC), and Active Experimentation (AE) which align naturally with VARK's modalities, as shown in Figure 1.

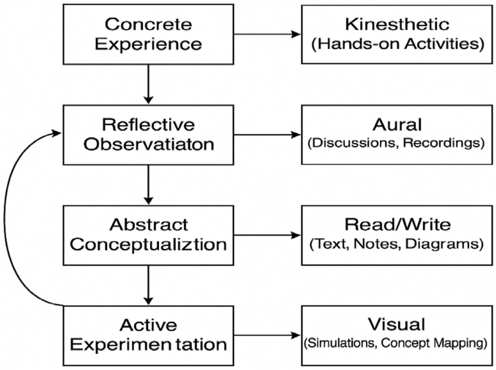

Fig. 1. Theoretical Framework of the Enhanced VARK Model

This integration enables learners to engage in a cyclical process of experience, reflection, abstraction, and application—each corresponding to a dominant learning style: Kinesthetic learners thrive in Concrete Experience, engaging directly with experiments and simulations. Aural learners benefit from Reflective Observation, where listening and group dialogue support meaning-making. Read/Write learners excel during Abstract Conceptualization, processing written materials and articulating theories. Visual learners are engaged through Active Experimentation, where models, mind maps, and visual organizers help test concepts.

This model not only aligns teaching strategies with learners' preferences but also activates all dimensions of learning—sensory, cognitive, and metacognitive. It provides a replicable and theory-backed approach to personalize instruction, especially in abstract subjects like non-Mendelian genetics. The Enhanced VARK model's design ensures that students not only receive information in their preferred mode but are also scaffolded through Kolb's experiential cycle, promoting deeper understanding and higher-order thinking.

2 Methodology

The VARK model framework, proposed by Neil D. Fleming in 1987, is a tool that identifies and categorizes individuals' learning preferences based on four sensory modalities: Visual, Auditory, Reading/Writing, and Kinesthetic. It shows tactics that align with their innate tendencies; students can become more effective learners using the VARK framework to customize instructional methods to meet their learning preferences. Students can boost their capacity to take in, retain, and apply information by developing their metacognitive awareness and self-regulation by recognizing their preferred learning style and becoming flexible learners.

The model is widely used in educational settings to design more inclusive and personalized teaching approaches, ensuring learners engage with content in ways that suit their learning strengths. Learners prefer to process information through images, diagrams, charts, and spatial understanding. Visual learners benefit from visual aids like infographics, concept maps, and illustrations. Aural learners absorb demonstrations. Apparently, for multimodal learners, teachers should provide a variety of instructional methods to cater to their diverse learning preferences. Educators can use a mix of visual, auditory, written, and kinesthetic teaching techniques to ensure these students engage fully with the material and maximize their learning potential.

Learning style is defined as an individual's preferred way of receiving and processing information, and the VARK model categorizes it into Visual, Auditory, Reading/Writing, and Kinesthetic preferences. Understanding a student's learning style can provide insights into tailoring educational interventions that align with their natural preferences, potentially improving engagement and comprehension. Despite its popularity, recent studies have shown that relying solely on learning styles may oversimplify the learning process, as students often benefit from adapting multiple styles. Understanding learning styles is essential for tailoring instruction methods that enhance engagement and retention.

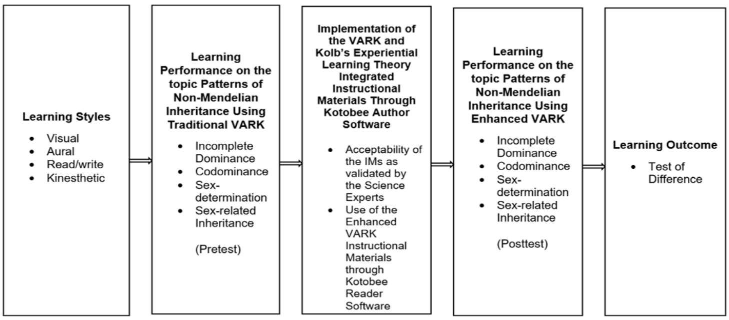

Fig. 2. Research Paradigm of the Study

Learning performance refers to the measurable outcomes that indicate a student's understanding, retention, and application of learned material. Research has shown that aligning instructional methods with learning styles can improve academic performance and retention (Coffield et al., 2024). However, there are debates on the extent to which learning styles impact performance, and this study aims to examine the role they play within the context of VARK. Research suggests that when instructional methods align with students' learning styles, there may be an improvement in academic performance, although the relationship is complex (Clark & Mayer, 2018). Learning performance is a key measure to determine whether educational adjustments, such as enhanced learning models, truly benefit students.

The pre-test using the traditional VARK model serves as a baseline assessment of students' learning performance before implementing any instructional enhancements. In this study, the pre-test provides insight into the traditional VARK model's impact on learning performance. Figure 2 shows the research paradigm of the study. It illustrates how each step in the schematic diagram builds upon previous ones, creating a structured approach to evaluate the effects of an enhanced VARK model on student's learning performance.

The enhanced VARK represents a modified version of the traditional model, incorporating Kolb's Experiential Learning Theory elements to address limitations in the original VARK framework with computer technology used. This enhancement aims to provide a more dynamic, experiential learning approach that moves beyond static preferences and encourages students to reflect, conceptualize, and actively experiment. Integrating experiential learning into VARK has the potential to foster deeper comprehension and more flexible learning skills.

The post-test assesses the impact of the enhanced VARK model on student learning performance, comparing results with the initial pre-test to identify any improvement. This step is essential in experimental and quasi-experimental designs to measure the effectiveness of educational interventions and observe changes in competency. A significant improvement in post-test results would indicate the success of the enhanced VARK model in supporting learning performance.

This quasi-experimental research design involved a control and an experimental group. Both groups were taught the same content on non-Mendelian genetics, within the same time frame (three weeks) and using identical instructional time per session (40 minutes, three times a week). The same teacher facilitated both classes to minimize variability in teaching style and ensure consistent delivery of instructional content. Lesson plans, assessments, and instructional resources were standardized across the groups. The primary difference was the use of the Enhanced VARK model implemented through Kotobee Author Software in the experimental group, while the control group used traditional VARK strategies without digital enhancements.

3 Results and Discussion

3.1 Students' Preferred Learning Styles in Learning Patterns of Non-Mendelian Inheritance

Students' preferred learning styles in studying patterns of non-Mendelian inheritance are crucial for tailoring instructional strategies that effectively address their diverse needs. Non-Mendelian inheritance, encompassing complex genetic principles such as incomplete dominance, codominance, and polygenic traits, often presents challenges for students due to its abstract and intricate nature. Table 1 presents students' preferences toward the visual type of learning styles in learning the topic on different patterns of non-mendelian inheritance.

Table 1. Students' preferred learning styles of the students.

Learning Styles	Mean	Response	Interpretation
Kinesthetic	4.04	Agree	High level of preference
Visual	3.98	Agree	High level of preference
Aural	3.96	Agree	High level of preference
Read/Write	3.58	Agree	High level of preference

Mean: 1.00-1.49– Strongly Disagree, 1.50-2.49 – Disagree, 2.50-3.49 – Neutral, 3.50-4.49 – Agree, 4.50-5.00– Strongly Agree

The findings suggest that students exhibit strong preferences for kinesthetic, visual, and aural learning styles, with read/write methods also playing a significant role. Kinesthetic learning, which emphasizes hands- on engagement, is the most preferred, indicating that experiential activities are efficient for these students. Visual aids such as charts, diagrams, and visualizations are also highly valued, as are auditory methods like discussions and listening to lectures. Although the read/write style is less dominant, it remains an important aspect of the students' learning preferences. Overall, the results emphasize the need for a multimodal approach to instruction.

Research indicates that students exhibit strong preferences for kinesthetic, visual, and aural learning styles, with read/write methods also being significant, which is aligned with the study of medical students, revealed that 71% preferred multimodal learning, with kinesthetic being the most common style at 29.8%, particularly among males [5]. Similarly, research on female undergraduate students highlighted a predominant preference for visual learning, suggesting that diverse instructional strategies should accommodate various modalities [6]. Thus, primary and junior high school studies confirmed that visual, auditory, and kinesthetic styles significantly influence learning outcomes and interest, with kinesthetic styles notably enhancing engagement. These findings underscore the importance of recognizing and integrating multiple learning styles in educational practices to optimize student learning experiences [7].

These findings suggest that instructional practices should integrate various teaching methods to address students' diverse learning preferences. The strong preference for kinesthetic strategies highlights the value of including hands-on activities, simulations, and experiential learning opportunities in the curriculum [4,10] Visual and auditory methods should also be emphasized, with educators incorporating diagrams, videos, discussions, and lectures to enhance understanding. While read/write strategies are less dominant, providing textual resources, structured notes, and opportunities for reflective writing can still support learning. A multimodal approach ensures inclusivity, fosters engagement, and maximizes learning outcomes by catering to students' diverse needs [9].

3.2 Students' Learning Performance Using Traditional VARK and Enhanced VARK Models

Table 2. The significant difference between the pre-test and post-test on the effectiveness of the Traditional and Enhanced VARK models

	Perfor-mance	Mean	SD	Variance	Lowest Score Obtained	Highest Score Obtained
Control	Pretest	9.47	2.97	8.81	4	14
	Posttest	15.27	2.69	7.24	10	20
Experimental	Pretest	10.31	2.54	8.79	5	16
	Posttest	23.48	3.93	13.84	18	25

*Total score = 25

Table 2 shows the control group's mean posttest scores advanced by a lesser degree than that of the experimental group- a rise from 9.47 (SD=2.97) to 15.27 (SD=2.69)- implying some progress by these students. The experimental group made considerable gains, achieving a posttest mean of 23.48 (SD=3.93) that is huge compared to the pre-test mean of 10.31 (SD=2.54). This indicates that the teaching strategy in imparting lessons made a noticeable difference in how the students understood the material.

The difference in standard deviation is information about the degree to which scores diverge from the mean, an indicator of how consistent students were in performance in one or the other experiment. The modest decline in standard deviation from 2.97 in the pretest to 2.69 in the posttest suggests that student performance is becoming more consistent in the control group over time. On the contrary, the experimental pretest standard deviation increased from 2.54 to 3.93 for the post test, showing that all students in the experimental group improved; however, the extent of the improvement differed among students.

Variance, measured as the square of the standard deviation, provides a unique display of student performance dispersion. Through pretest to posttest, variance ranged down from 8.81 to 7.24; this may suggest slight tightening of the spread of scores in the control group. In an opposing position, however, the experimental group evinced an increase in variance, rounded from 8.79 up to 13.84, thus pointing to a much wider spread of scores among the students. A heightened variance, thus arising, would signify that the enhanced VARK functioned with diverse effectiveness noting that some students would take on and make substantial development while other students received only minimal improvement.

Table 3 establishes a detailed statistical summary of students' learning performance. A paired sample t-test was conducted to compare pre-test and post-test scores of the experimental group.

Table 3. The significant difference between the pre-test and post-test on the effectiveness of the Enhanced VARK model

Performance	Mean	SD	SE	t-value	p-value	Remark
Pretest	10.31	2.54	0.56	18.20	0.000	Significant
Posttest	23.48	3.93	0.61			

tested at $\alpha = 0.05$ Level of significance using a Paired sample t-test. SD – Standard deviation, SE – Standard Error

The t-value of 18.20 with a p-value of 0.000 indicates a highly significant improvement in student performance after exposure to the Enhanced VARK model. This strong statistical evidence reinforces the effectiveness of the intervention.

The results reveal a substantial improvement in student performance after introducing the Enhanced VARK model. Compared to their pre-test scores, which were based on the traditional VARK model, students demonstrated significantly better results in the post-test. The statistical analysis confirms the significance of this improvement, suggesting that the Enhanced VARK model had a meaningful and positive impact on students' ability to understand and apply the learning material.

The Enhanced VARK model expands upon the traditional VARK framework by integrating experiential learning strategies, which cater to diverse student preferences and promote deeper engagement. While the traditional VARK model categorizes learners into four distinct styles—visual, auditory, reading/writing, and kinesthetic—research signifies that tri-modal and multimodal approaches significantly enhance learning outcomes, as evidenced by improved performance in post-tests among students utilizing these styles [8]. Also, the Enhanced VARK model emphasizes the importance of flexibility in teaching methods, allowing educators to adapt to varying student needs and preferences, thereby fostering a more inclusive learning environment. This adaptability not only aids academic achievement but also enhances motivation and retention of knowledge, as seen in studies involving medical students and Quran memorization techniques. The Enhanced VARK model's focus on multimodal strategies represents a significant advancement in educational practices, promoting personalized learning experiences that align with individual student profiles [9,10].

Kotobee Author Software was central to the Enhanced VARK model. It allowed the integration of interactive simulations, embedded quizzes, audio narrations, visual infographics, and reflective journaling prompts aligned with Kolb's experiential learning stages. Visual learners accessed interactive diagrams and animations. Auditory learners listened to narrated content and discussion clips. Read/write learners engaged with hyperlinked glossaries and guided note sections. Kinesthetic learners performed drag-and-drop DNA sequence activities and virtual lab simulations.

The software supported differentiated instruction by letting students explore modules based on their learning preferences. Its feedback features also enable real-time interaction and adaptation based on student responses, fostering personalized and active learning.

The findings underline the effectiveness of the Enhanced VARK model in improving students 'learning outcomes. The significant performance improvement demonstrates the potential of this model to address diverse learning preferences more effectively than traditional approaches. These results suggest that integrating experiential and multimodal strategies within the VARK framework can enhance comprehension, retention, and application of knowledge. For educators, adopting such innovative instructional approaches could lead to more inclusive and effective teaching practices, fostering greater academic success across diverse student populations.

3.3 Students' Perceptions of Implementing the Enhanced VARK Model

Table 4 illustrates the results of the focus group interviews followed a semi-structured format and were analyzed using thematic analysis. The process involved: Transcription of audio recordings verbatim. Initial coding of segments using open coding. Theme development through axial coding, identifying core ideas related to perceptions, experiences, and impacts. Triangulation with quantitative data for credibility.

A student stated, "I like how I can actually try the activity in the app—it's not just reading." This quote was coded under "Kinesthetic engagement", which was grouped under the major theme "Increased Engagement." Another stated, "Now I know I learn better when I listen to explanations while reading," which aligned with the theme "Impact on Learning Preferences and Styles."

Table 4. Summary of Students' Perceptions Enhanced VARK model

Major Themes	Core Ideas	VARK Constructs (Total=20 students)
Enhanced understanding and application of non-mendelian inheritance	• Metacognitive awareness	Visual
	• Enhanced application to real-world scenarios	Kinesthetic
	• Improved conceptual understanding	Visual
	• Increased problem-solving skills	Kinesthetic
	• Perceived relevance	Kinesthetic
Impact on learning preferences and styles	• Awareness of learning preferences	Kinesthetic
	• Personalized learning experiences	Kinesthetic
	• Self-efficacy	Read/Write
	• Adaptability of learning strategies	Kinesthetic
	• Acceptance of diverse learning styles	Kinesthetic
Increased Engagement	• Increased engagement with the material	Kinesthetic
	• Improved confidence	Kinesthetic
	• Enjoyment of the learning process	Aural

The findings enhanced understanding and application of non-mendelian inheritance theme highlight the positive impact of the Enhanced VARK model on students' learning experiences, particularly in understanding non-Mendelian inheritance. The model's ability to increase metacognitive awareness, connect learning to real- world applications, and improve conceptual understanding and problem-solving skills suggests that it provides a robust framework for enhancing student learning. Educators can benefit from incorporating such models, as they offer a multifaceted approach that accommodates diverse learning styles and fosters deeper engagement with the material. The perceived relevance of the model's application to future careers indicates that such teaching strategies may also enhance students' motivation and readiness for professional fields requiring advanced problem-solving skills.

By integrating visual, auditory, reading/writing, and kinesthetic strategies, educators can create a more inclusive learning environment that addresses the complexities of genetic concepts, including non-Mendelian patterns such as incomplete dominance and codominance, which are often misunderstood as purely Mendelian traits. Additionally, task-based learning approaches have been shown to enhance conceptual understanding of genetics, suggesting that active participation and varied instructional methods can bridge gaps in knowledge and improve academic performance. Overall, the Enhanced VARK model accommodates individual learning styles and promotes a comprehensive grasp of intricate genetic principles, including non-Mendelian inheritance [11].

The impact on learning preferences and styles theme suggests that the Enhanced VARK model significantly impacts students' awareness of their learning preferences and their ability to adapt learning strategies accordingly. The model's ability to help students discover and embrace different learning styles indicates that personalized and flexible learning approaches are crucial for improving academic outcomes. Educators should consider integrating the Enhanced VARK model in their teaching practices, as it fosters a deeper understanding of student's individual learning needs and provides tools for them to apply various strategies. Moreover, the increased self-efficacy and adaptability observed in students imply that they can better handle academic challenges and develop strategies for lifelong learning [12,13].

Research indicates that aligning learning environments with students' distinct styles—such as visual, auditory, and kinesthetic—can significantly enhance academic performance. Personalized adaptive learning technologies, particularly those utilizing machine learning, have shown promise in dynamically tailoring educational content to individual learning styles, resulting in improved engagement and academic success. Accordingly, recognizing self-efficacy in learners is crucial, as it influences their ability to adapt learning strategies effectively, fostering a more conducive learning environment. These findings underscore the importance of integrating personalized approaches in educational settings to cater to diverse learning preferences [14].

The increased engagement theme underscores the significant role of the Enhanced VARK model in fostering increased engagement among students. The model facilitates a deeper connection with the material by actively involving students in learning and allowing them to experiment with various learning styles. The improved confidence and enjoyment students reported also suggest that the model's interactive and adaptable nature positively impacts students' attitudes toward learning. Hence, promoting collaboration and peer learning indicates that the Enhanced VARK model helps cultivate a supportive learning environment where students can learn from each other and tackle challenges together. The results imply that educators should consider incorporating more interactive and personalized learning approaches, such as the Enhanced VARK model, to enhance student engagement and facilitate more effective learning outcomes [15,16].

4 Conclusion

The study concluded that a multimodal instructional approach is essential for addressing the diverse learning preferences of students, particularly those favoring kinesthetic, visual, and aural styles. Kinesthetic strategies, characterized by experiential and hands-on activities, emerged as the most effective, underscoring the significance of active engagement in learning. Visual aids and auditory methods complement these preferences, enhancing comprehension and retention. Although read/write strategies are less prominent, they remain vital to comprehensive instructional design. These findings advocate for integrating diverse teaching methods to foster inclusivity, optimize engagement, and enhance educational outcomes across varied learning contexts. The Enhanced VARK model significantly improves students' learning outcomes by effectively addressing diverse learning preferences. The substantial post-test performance improvement highlights the model's potential to surpass traditional methods in fostering comprehension, retention, and application of knowledge. These results affirm the value of integrating experiential and multimodal strategies within the VARK framework, supporting its adoption as a transformative approach to inclusive and effective teaching practices. Furthermore, the study concluded that the Enhanced VARK model significantly enhances students' learning experiences, motivation, and engagement, particularly in understanding non-Mendelian inheritance. By fostering metacognitive awareness, adaptability, and real-world application of concepts, the model provides a comprehensive framework for addressing diverse learning preferences. The results emphasize its role in improving conceptual understanding, problem-solving skills, and emotional resilience, highlighting its potential to create a more inclusive and effective learning environment. However, the findings also reveal implementation challenges, including the need for personalized adaptations, adequate teacher support, and additional resources. These insights suggest that while the Enhanced VARK model is a transformative instructional approach, its optimization requires addressing logistical and contextual barriers to fully realize its potential for improving academic outcomes.

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