Enhancing Higher Order Thinking Skills of Low Performing Biology Students Through Combined Teaching Strategies

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Abstract

This mixed-method study critically focused on using combined teaching strategies to enhance the higher-order thinking skills of a low-performing high school Biology class in a Public Secondary School in the Kasur District (Pakistan). Researchers implemented the combined strategies for multimodal learning which included a KWLH chart, minds-on hands-on activities, and multimedia integration (action) to a purposively chosen intact class of low-performing students for a quarter of a year (120 contact hours). Before the intervention, the researchers administered a 50-item pretest which included questions phrased within the higher-order cognitive domains: application, analysis, evaluation, and creation. The same test determined the students' performance after the intervention, which led to improvements in the higher-order thinking skills of the students as evidenced by a statistically significant difference in their pre and post-test scores, classroom observations of invited experts, and student perceptions. Though the intervention is seen to have accomplished its goal i.e. the intervention enhanced the HOTs of low-performing biology students which depicted that customization of the strategies to the learners' needs and learning styles determines the success of the action. It was recommended that for broader implications of this study, it should be conducted across grades with other science subjects like physics, chemistry, and computer sciences.

Keywords: Higher Order Thinking Skills, Combined Teaching Strategies, Low Performers

Introduction

Contemporary learners, often referred to as digital natives or millennials, exhibit a remarkable proficiency in incorporating technology into their daily lives. This trend extends to families with limited financial resources, who also endorse the idea of providing their children with smartphones. These devices serve not only as communication tools but also as platforms for activities such as gaming, web browsing, reading, and various personal, educational, or entertainment pursuits. In addition to computers, televisions, and other technological resources, millennials have access to an abundance of information that was previously predominantly found in extensive encyclopedias, almanacs, and dictionaries housed within libraries.

Given the vast wealth of information readily available to students, it becomes essential for them to acquire enhanced learning skills to effectively manage and leverage this information. This development is crucial for achieving more valuable educational outcomes and fostering their role as contributing citizens in the growth of their country. Consequently, students require

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training to cultivate the essential learning skills necessary in this 21st-century era (NCREL and Metiri Group, 2003).

Higher Order Thinking Skills

The cognitive dimension of a learner's abilities stands as a vital component within the framework of 21st-century skills, as emphasized by Kamisah and Neelavany (2010). Notably, improved cognition is closely associated with students who demonstrate higher-order thinking skills, as highlighted by Heong, Yunos, Hassa, Othman, and Kiong (2011). These skills enable students to enhance their learning capacity, increase their processing speed, and more effectively absorb and integrate information. According to literature, higher-order thinking skills (HOTS), as defined by Lewis and Smith (1993) and Dodge (1997), manifest when individuals take new information and creatively relate, reorganize, and extend it to achieve specific objectives or solutions when faced with complex situations (p. 136). Ramos, Dolipas, and Villamor (2013) have further elaborated on HOTS, encompassing critical, logical, reflective, metacognitive, and creative thinking. They assert that these skills come into play when individuals encounter unfamiliar problems, uncertainties, questions, or dilemmas. The successful application of these skills yields valid explanations, decisions, performances, and products that align with existing knowledge and experience, thereby fostering continued growth in these and other intellectual capacities.

The concept of higher-order thinking Skills (HOTS) is a part of educational reform, drawing inspiration from learning taxonomies like Bloom's taxonomy. Furthermore, HOTS, as defined by Crawford and Brown (2002), can be broken down into three main categories: content thinking, critical thinking, and creative thinking (p. 6). Collins (2014) has further refined and confirmed this description by categorizing HOTS into the following groups This component of HOTS involves students recalling, comprehending, and applying what they've learned (Krathwohl et al., 2001). Within HOTS, critical thinking entails a thoughtful and reflective process aimed at determining what to believe or how to act (Norris & Ennis, 1989). It also encompasses artful thinking, which includes activities such as reasoning, questioning, investigation, observation, description, comparison, connecting ideas, recognizing complexity, and exploring various viewpoints (Barahal, 2008). This dimension covers tasks like recalling information, grasping concepts with understanding, critically assessing ideas, devising creative solutions, and effectively communicating thoughts (Nitko & Brookhart, 2007). Certainly, here is a paraphrased version of the provided text: "HOTS, or higher-order thinking skills, is a concept in educational reform that draws upon learning taxonomies such as Bloom's taxonomy. Furthermore, Crawford and Brown (2002) have defined HOTS as encompassing three main categories: content thinking, critical thinking, and creative thinking (p. 6). Collins (2014) has further refined this definition by categorizing HOTS into the following components: Transfer, which requires students to recall, comprehend, and apply what they've learned (Krathwohl et al., 2001).

Critical thinking is characterized by thoughtful and reflective reasoning aimed at making informed decisions, as described by Norris and Ennis (1989). This also involves artful thinking, which includes skills like reasoning, questioning, investigation, observation, description, comparison, connection, recognizing complexity, and exploring different perspectives (Barahal, 2008).

Problem-solving has been about encompassing tasks such as remembering information, understanding concepts, critically assessing ideas, generating creative solutions, and communicating effectively, as outlined by Nitko and Brookhart (2007).

Several research studies (Mehmood et al., 2019; Brookhart, 2010; Collins, 2014; Polly & Ausband, 2009; Ramos et al., 2013; Thomas & Thorne, 2009) have highlighted a range of teaching methods and educational strategies that have proven to be successful in improving students' higher-order thinking abilities. These approaches involve the use of tools like graphic organizers, establishing links between ideas, employing techniques such as mind movies, fostering problem-solving skills (Cox, 2016), and integrating webquests into the teaching process (Polly & Ausband, 2009).

These studies have observed that these strategies are particularly beneficial for students facing disadvantages, contributing to increased motivation and improved critical thinking abilities among the majority of students. Therefore, the researchers of the latest study aim to investigate which teaching methodologies align best with the learning needs of underperforming science classes.

Teaching Strategies

In part, the researchers' pre-action assessment of student learning reinforces the notion that a combination of strategies could potentially enhance students' higher-order thinking skills. Drawing from existing literature (Mehmood et.al., 2019; Creeemers, 2005; Eison, 2010), it is suggested that incorporating diverse teaching strategies into a classroom setting may yield synergistic effects, fostering a comprehensive approach to improving higher-order thinking skills (HOTS). In their intervention, the researchers experimented with the implementation of three established teaching strategies: the KWLH chart, hands-on minds-on activities, and the integration of multimedia.

KWLH Chart

The KWLH chart is an educational tool crafted to assist teachers in tapping into students' existing knowledge related to a specific subject or topic. Its purpose is to stimulate curiosity, encourage active reading, and promote research. KWL charts are particularly effective when used as a pre-reading strategy, especially in the context of expository texts. They can also function as an assessment tool, helping educators assess the knowledge students have acquired during a particular unit of study. In this chart, 'K' represents what students already know, 'W' stands for what students want to learn, and 'L' indicates what students have learned as they engage in reading or research. KWL charts encourage students to become active thinkers during their reading process (Ogle, 1986), prompting them to seek specific information and reflect on their acquired knowledge upon completing the reading. In the realm of learning, metacognition involves actively monitoring, consciously controlling, and regulating cognitive processes. It encompasses the practice of 'thinking about thinking,' fostering self-awareness and self-regulation (Flavell, 1979). Accordingly, Hershberger, Zembal-Saul, and Starr (2006) argued that KWLH charts may also be used as a strategy to promote better student engagement in science learning. Once they are already engaged and are motivated then better assimilation and accommodation of knowledge may be expected.

Hands-on, Minds-on Activity

A hands-on activity is a hand-oriented/movement-oriented task that helps the students construct their meaning and understanding. It allows the students' minds to grow and learn based on the experiences and the environment they are exposed to. Students acquire knowledge through collaborative discussions, investigations, creative endeavors, and explorations with their peers. As their familiarity with the subject matter grows, they begin to make decisions independently, requiring less guidance from teachers and allowing for more interactive learning experiences (Cooperstein & Kocevar-Weidinger, 2004). For instance, they require access to resources such as computers, videos, books, magazines, manipulatives, and their local library to conduct research. They also need ample time for brainstorming, generating ideas, and refining their concepts. Additionally, it's crucial for learners to feel comfortable making mistakes and starting afresh when necessary. All of these elements are integral to the learning process, enabling students to become self-reliant learners. Unlike laboratory work, hands-on activities don't necessarily demand specialized equipment or materials. According to Jodl and Eckert (1998), hands-on activities are rooted in the use of everyday items, simple setups, or cost-effective materials that are readily available and easy to assemble. Top of Form McGervey (1995) stated that "some hands-on activities can be done for less than a dollar per hand, a few have zero cost. Thus, it will be of no cost if a piece breaks or disappears." Minds-on activity is a mind-oriented task that allows students to develop thinking processes and encourages them to create questions. A very good example of this is when students use the KWLH chart to develop and write down their questions about a certain topic. Moreover, hands-on/mind-on activities entail assignments that require students to utilize both their physical and mental faculties to tackle problems. In these tasks, students formulate a strategy for solving the problem, make predictions about the outcomes, put the strategy into action, reflect on the results, and then compare the outcomes with their initial predictions.

Multimedia

Multimedia can be broadly defined as the amalgamation of two or more forms of media, such as audio, images, text, animations, and video. In the context of educational technology, multimedia pertains to computer-based systems that utilize associative connections to enable users to navigate and access information stored in a blend of text, sounds, visuals, videos, and other media. Multimedia finds versatile applications in instruction, offering creative and engaging approaches. Examples of its use include teacher presentations, student projects, and fostering discovery-based learning. While educators are encouraged to develop their materials, there is also a wealth of high-quality educational multimedia resources available online. One of the pedagogical strengths of multimedia lies in its alignment with our innate human information-processing capabilities. Our eyes and ears, in concert with our brain, form a powerful system for converting raw sensory data into meaningful information. The age-old adage that a picture is worth a thousand words often understates the case, particularly when it comes to moving images, given our keen evolutionary adaptability in detecting and interpreting motion.

Theories Related to Learning and Higher Order Thinking Skills

Following theories are also related to development of higher order thinking skills, in which involves the major role of teachers in their development in the educational setting.

Dewey

According to Dewey (1993) described it higher order thinking skills as sequenced chaining of events which is a productive process moving from reflection to inquiry, critical thinking that leads to conclusion (evaluation) moreover higher order thinking cant evoke spontaneously it has to be evoked by different teaching techniques.

Piaget

Piaget' age stage model explains the cognitive development, which is about operational thinking, logical thinking and systematic manipulation of symbols (higher order thinking skills).

Bruner

According to Bruner, learning process is comprised of active involvement, discovery, inductive reasoning and intrinsic motivation. Stages of Bruner include enactive (hands-on participation), iconic (visual representations), and symbolic (symbols, including math and science symbols).

Gagne
According to Gagne, intellectual skills are developed within hierarchy according to skill complexity so cognitive strategies may be simple or complex to promote thinking skills.

Glaser
Glaser reported that the type of thinking required for problem solving originates in a perceived difficulty, state of doubt, or perplexity.

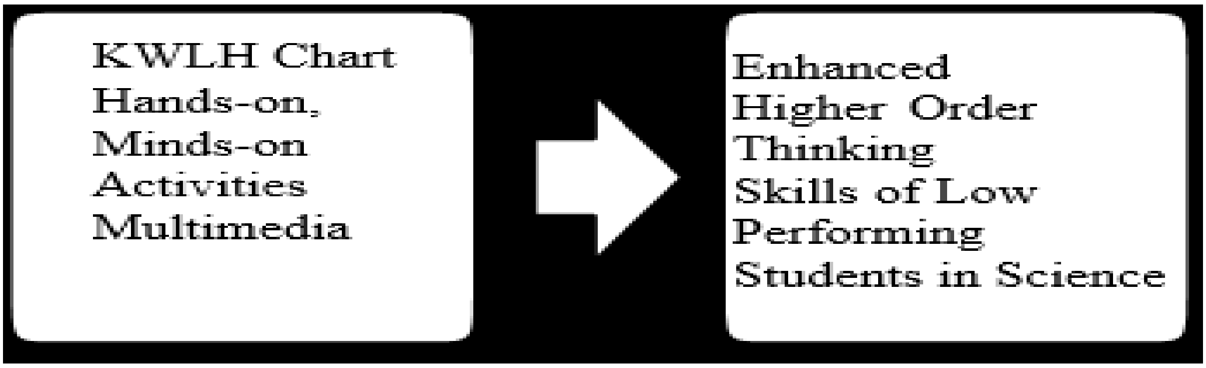
Vygotsky
Vygotsky seems to have consolidated major concepts of cognitive development as giving the concept of zone of proximal development.

Haladyna
Haladyna (1997) expressed the complexity of thinking and learning dimensions by classifying four levels of mental processes (understanding, problem solving, critical thinking, and creativity) that can be applied to four types of content (facts, concepts, principles, and procedures).

Gardner
According to Gardner (1983), multiple intelligences form a major part of an individual's dispositions and abilities. Although Gardner is commonly credited with theories related to multiple intelligences. Some of the abilities associated with the different types of intelligence include forms of thinking, reasoning, and problem solving. Certain components of models or theories of intelligence are similar to factors identified in models and theories of learning.
Researchers have also found that effective teaching strategies not only benefit the high achievers but also improve the low achievers by motivating and developing critical skills and, capabilities of the majoring of the learning. This present study would be about the use of combination of pedagogies which are helpful to improve the biology students.

Statement of the Problem
Based on the aforementioned concepts, Figure 1 below captures the intent of the study to improve the higher order thinking skills of low performing students in science through the use of combined pedagogical techniques.

Figure 1: Framework of Action



The diagram depicted above illustrates the desired impact of employing a combination of teaching methods, including the KWLH Chart, Minds-on, Hands-on activities, and multimedia integration, to elevate the higher-order thinking abilities of deliberately chosen low-performing students.

Objectives of the Research

This mixed method research aimed to determine the effects of combined teaching strategies, (KWLH chart, teacher-prepared hands-on, minds-on activities, and multimedia) on the thinking skills of the students.

Significance of the Study

The present study may contribute to the students in promoting their higher-order thinking skills in biology but also in other branches of science which help them to understand new situations and be creative to solve the forth coming problems in the age of globalization. It may also be beneficial for teachers in helping them to act as facilitators while teaching their students and to reform their teaching strategies. Moreover, it may be beneficial for stakeholders by developing the interest of the major entity the student prohibiting rote learning and promoting conceptual learning. Thus, preparing skilled generation which is the major focus not only needed for 21st-century students' skills but is also useful in achieving the goals of National Education Policy 2009 which emphasized skilled students at the secondary level.

The teacher's training institutions may also be able to design such training that uses combined teaching strategies not only for in-service teachers but also for prospective teachers. This study may be helpful for curriculum developers in devising a curriculum that may be taught according to the needs and interests of learners of the digital age. Ultimately, by developing such interesting teaching strategies there would be affiliation among students and their peers which may help their modalities learning and 100 percent retention and zero drop-out.

In this, the findings of the present study effect of combined teaching strategies on higher-order thinking skills of biology students may be helpful for policymakers, practitioners, curriculum developers, teacher training institutes, experts related to pedagogies, students, parents, teachers, and ultimately the society in this global context.

Methodology

Both quantitative and qualitative methodologies were employed to collect and analyze data concerning the utilization of combined strategies (KWLH chart, teacher-designed hands-on and minds-on activities, along with multimedia) to enhance the higher-order thinking skills of the students. The quantitative approach statistically established the gains and differences in the students’ performance/scores in the administered tests/assessments. The qualitative approach validated the statistically established gains and differences.

Participants

The participants of the study included an intact Grade 9 class classified as low performing group (section 8), consisting of 41 students with an age range of 15-18. These students are considered as low performing because they belong to the bottom 30 percent of the total grade nine population of a High School in Kasur District based on the weighted general averages that they obtained in the final quarter in their previous level (Grade 8).

Material and Instruments

KWLH Chart

The researcher developed a KWLH chart consisting of the K (Know) component, W (want to know) component, L (Learned) component, and H (How will I use) component; the K and W components were filled in at the start of the topic lesson while the L and H components were filled-in at the end of the topic lesson.

Pre-Test and Post-Test

A validated teacher-prepared 50-item multiple choice format test (with four choices) on the respiratory system, circulatory system,
and genetics. These 50 items are questions formulated to assess on the following skills in Bloom's Taxonomy cognitive domain classified under the higher-order thinking level: applying, analyzing, evaluating, and creating.

Hands-on, Minds-on Activities

Researcher-teacher-prepared simple hands-on/ minds-on activities in which the students can devise and plan solution strategy, predict outcomes, activate or perform strategy, reflect on results, and compare results with predictions. Table 1 shows the list of specific hands-on, minds-on activities used as intervention materials.

Table 1: List of Hands-on, Minds-on Activities

Hands-on, Minds-on Activity	Topic
Flame in the glass/ Minute-to-Win It	Respiration
Bottled balloons/ Heimlich maneuver	Respiratory system Mini-Performance Task
Circulatory system Punnett Square Challenge	Genetics – Punnett
It’s a baby in the making- Sex chromosomes	Genetics- Sex chromosomes
Finding the strand	Genetics-DNA

Multimedia

This material includes e-presentations and video clips or simulations for the specific topics: respiration, circulatory system, genetics, incomplete dominance, multiple alleles, and the nature of DNA.

Observation and Survey Form

The open-ended survey and observation form contains questions on student perceptions and teacher-observer’s notes on the conduct of class discussions and lesson implementation.

Data Collection

Pre-Intervention

Before the implementation of the intervention program, the researchers distributed and collected the parent’s consent forms and then administered the pre-test on the respiratory system, circulatory system, and genetics. The researcher distributed the KWLH chart and asked the students to attach it permanently to the last page of their science portfolio.

Intervention and Post-intervention

On the second day and the succeeding meetings that lasted for a quarter (3 months), the students used the KWLH chart at every start and end of the topic lessons. After routine tasks in every lesson or session and after introducing the topic or lesson for the day, the teacher (one of the proponents) asked the students to write what they knew about the subject to extract their prior knowledge or prior concepts. Students also write what they want to know. The teacher (one of the researchers) also used different hands-on, minds-on activities, and different multimedia forms in discussing the topics on the respiratory system, circulatory system, and genetics as shown in Table 1. Formative assessments such as seat works, worksheets, mind or concept maps, and guide questions inclusive in the hands-on minds-on activities detected changes in concepts and formation of logical and concrete knowledge of the concepts or the topics. Invited observers also looked into students' behavioral patterns before, during, and after the session. After all the activities and discussions of the topic, the teacher asked the students to write on the "L" column of the KWLH chart their learned concepts, and in the "H" column their way of applying what they have recently learned. The implementation of the intervention lasted for a quarter of the year, 3 months (120 contact hours). Three science teachers observed and assessed the effectiveness of the KWLH chart, teacher-prepared hands-on, minds-on activities, and multimedia in facilitating a lesson using a classroom observation form.

Data Analysis

The researchers organized all data gathered through the pre and post-tests and the classroom observations. Comparison of pre and post-test results using the t-test analysis determined any significant differences in terms of content or concepts learned by the students. Consolidated comments of observers validated and provided evidence of the quantitatively identified differences in concept formation. The teacher-researcher also considered the number of absences of the students per week from the Last week of August 2023 until the end of the first quarter to determine the effect of the intervention on the student's attendance and engagement.

Results and Discussion

The study yielded the following results on the thinking skills of the students from a low-performing class in a government-supervised high school. Comparing the results of the pre-test and post-test in Table 2 shows that there is an improvement in the students' thinking skills of the students.

Table 2: Results of the Pre-test and Post-test

N=41	Highest Score	Lowest Score	Mean	Standard Deviation	Mean difference	T value	P value
Pre test	18	7	12.12	2.49	9.27	2.00	9.18e-15*
Post Test	34	11	21.39	5.18			

** Significant at 0.05*

The post-test results yielded a higher mean (M = 21.69) and standard deviation (SD = 5.18) than the pre-test (M= 12.12, SD = 2.49). The mean difference of 9.27 is found to be statistically significant. This suggests that the intervention had a significant and beneficial impact on the participants' performance. The progress observed in students' performance can be attributed to the development of their thinking skills. This is evident from the fact that all the items are situated within the cognitive learning domains, specifically in the realms of applying, analyzing, evaluating, and creating, all of which are categorized as higher-order thinking skills.

The students' outputs specifically shown in their KWLH charts provided adequate validation of the aforementioned test results comparisons. Notably, sample verbatim inputs of the students to the KWLH charts presented in Table 3 offered proof of how this intervention helped the students in making meaningful connections of their hindsight (*Know and Want to know*), insight (*Learned*), and foresight (*How would you apply*) about a certain topic.

Table 3: Sample responses of the students in their KWLH chart

Topic	**K (know)**	**W (want to know)**	**L (learned)**	**H (how would you apply)**
Respiratory System	Breath Lungs Diaphragm Oxygen Lungs Asthma Carbon dioxide	Is studying respiratory system important? What organs are involved in the respiratory system? How does smoke affect our body?	learned that. Respiratory system is made up of organs that help us to breath. Alveoli are small balloon like structures which external respiration happens. cigarettes contain harmful chemicals	I could use what I have learned on respiratory system when somebody is chocking in which I can give him Heimlich maneuver by informing people that smoking is dangerous by not smoking
Genetics	Variation Heredity Gene Chromosome DNA	How many chromosomes do we have? Why is studying genetics important? How would my body react if there is a changed in the genes	I have learned that. when X chromosome combined with Y chromosome, the result will be male dominant allele is represented by capital letter while recessive allele is represented by small letter allele is an alternate form of particular gene genotype is the genetic makeup of an organism. DNA molecules looks like a ladder	I could use what I have learned in genetics when I'm about to plan my children In determining if someone who is claiming my relative is really my relative In determining which traits, I have acquired from my father or mother

Table 3 shows that the KWLH chart may have developed the higher order thinking skills of the students. "The 'K' component of the chart served as a platform for students to critically retrieve their existing knowledge and link it to the current classroom discussions. Moreover, the 'W' component contributed to the students' proficiency in formulating questions that required higher-order thinking skills, with a focus on 'how' and 'why' questions, an effective strategy for enhancing such skills as suggested by Cox (2016).

The 'L' and 'H' components of the chart aided students in restructuring their ideas regarding the topics and presented them with choices on how to apply the lessons from the classroom in their everyday lives. These latter two components provided avenues for students to demonstrate their abilities in cognitive learning domains, including analysis, application, and evaluation—categories classified as higher-order thinking skills (Anderson et al., 2001).

In the same vein, the teacher-observers noted several behavioral attributes of students possessing higher order thinking skills as expressed in their verbatim comments in the classroom observation form:

> *"The KWLH chart helped the students to be more motivated in performing the activity and make a recall on their prior knowledge about the topic."*
>
> *"Students maintain and focus their attention and participation to the series of questions given to them."*
>
> *"The students show through their confidence, how feel that they can speak for themselves and express their ideas confidently."*
>
> *"The class showed more student engagement, considering that it is categorized as a low performing class."*

Teacher observations were in alignment with the strategies outlined by Cox (2016), which were found to effectively enhance students' higher-order thinking skills. These strategies included teaching to stimulate inference, promoting elaboration in students' responses, fostering questioning, establishing connections between concepts, encouraging investigation, and employing graphic organizers like tables. Furthermore, students perceived the intervention as enjoyable, engaging, and memorable. They felt challenged and were motivated to collaborate in completing tasks, particularly those involving hands-on and minds-on activities. Notably, these positive emotions generated during the use of these interventions contributed to the creation of a fear-free learning environment. The results of this study were also in alignment with previous researches of Mehmood et al. (2019), Caine et al. (2005), Caulfield et al. (2000), Slavkin (2004), Wagmeister and Shifrin (2000) and Wolfe (2001).

Conclusion and Recommendations

The outcomes of this action research hold the potential to address the increasing demand for enhancing thinking skills, particularly among low-performing 9th-grade biology students. Over the entire first quarter, the teacher-researcher implemented a combination of the aforementioned strategies and collected data through various survey forms and assessments to assess how these strategies impacted the students' thinking skills. As discussed, the consistent use of these combined teaching strategies, including the KWLH Chart, Hands-on, Minds-on Activities, and Multimedia, has effectively nurtured the students' higher-order thinking abilities. Furthermore, these combined strategies aided students in structuring their thoughts and deriving meaning from the classroom lessons they were exposed to. Lastly, the utilization of diverse strategies particularly when implemented simultaneously, injected excitement and challenge into the learning process, thus keeping students engaged and focused on their studies.

The favorable results achieved through this intervention can serve as a valuable benchmark for other educators seeking to enhance thinking skills and increase student engagement. Nevertheless, it is essential to recognize that merely relying on the methods employed in this study may not suffice, as the intervention's success was specific to this particular intact class. Hence, teachers should assess the unique learning styles and characteristics of their students to identify the combined strategies that are most suitable for their classes. Low-performing students may not be easily motivated to learn and even to improve their cognitive skills to gain higher-order thinking skills necessary for scientific literacy and 21st-century learning using previously discovered effective strategies integrated one after the other. It may be that students nowadays need several activated and stimulated senses and attributes for them to completely form and/or improve their thinking skills. Such stance may have largely contributed to the enhanced cognitive skills of the students through the KWLH chart, minds-on hands-on, and multimedia integration. These combined strategies simultaneously triggered aspects of students' learning domains and stimulated their interest to assimilate and accommodate concepts to be learned for the topic. KWLH is a good strategy that is grounded on several reported effective strategies to enhance thinking skills. However, we can still improve and better customize KWLH to focus on investigations and evidence which may further provide venues to improve not only students' thinking skills but also their science process skills. Seemingly, several combinations of strategies may also be discovered with prolonged use by teachers of low-performing students. It may be that in our quest to find which combinations best fit the students; we may be able to come up with a pre-assessment tool to determine which combination is best suited for the current type of students we are handling.

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