Science Primary Skills as an Instructional Intervention for Improving Learning Outcomes in Mendelian Genetics: A Quasi-Experimental Study

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ABSTRACT

This quasi-experimental study looked into how effective it is to implement Science Primary Skills (SPS) into teaching Mendelian genetics to Senior High School students in private schools in Davao City. A total of eighty students were split into two groups: one received traditional instruction, while the other experienced SPS-based teaching. To gauge their understanding and learning progress, pretests and posttests were conducted, focusing on key genetics topics like monohybrid crosses, dihybrid crosses, probability, and pedigree analysis. The results indicated that both groups made improvements, but the experimental group stood out with significantly higher posttest scores. The statistical analysis showed notable differences both between and within the groups, with the SPS approach demonstrating a very large effect size (d = 2.71). These findings confirm that SPS-based instruction enhances students' grasp of complex biological concepts. The study suggests that biology classrooms should incorporate more SPS methods, provide better training for teachers, and continue exploring its use in other subjects.

Keyword: - *Science Primary Skills, Mendelian Genetics, Quasi-Experimental Study, Senior High School Biology, Learning Outcomes*

1. INTRODUCTION

Mendelian genetics is often seen as one of the toughest subjects in high school biology, mainly because it involves abstract ideas and a lot of probabilistic thinking. Many students find it hard to grasp concepts like inheritance patterns, allele segregation, dominance, and how to use Punnett squares. Instead of truly understanding these concepts, they often end up memorizing facts (Lewis & Wood-Robinson, 2018; Wang & Lin, 2017). This struggle has continued even with traditional teaching methods, highlighting a significant gap in teaching strategies that engage students in real scientific reasoning. Research shows that students often have trouble applying what they learn in theory to solve practical problems, which points to the need for teaching approaches that focus on skill development rather than just delivering information passively (Jensen & Lawson, 2016; Hokkanen, 2020).

Basic science skills like observing, classifying, measuring, predicting, inferring, and communicating are essential tools that can really help students grasp complex scientific ideas (Khan, 2017; Siew & Chin, 2018). When these skills are woven into lesson plans, they give students practical ways to tackle genetic problems, predict inheritance patterns, and explain their thought processes. This approach encourages a deeper understanding rather than just rote memorization (Adu-Gyamfi, Ampiah, & Agyei, 2017; Choi & Hong, 2020). Plus, integrating these skills aligns perfectly with the current push in science education to promote higher-order thinking, scientific reasoning, and inquiry-based learning in high school biology classes (Zangori & Forbes, 2016; Zohar & Cohen, 2022).

Across the globe, particularly in southeast Asian countries, science education in integrating essential skills like observing, classifying, measuring, predicting, inferring, and communicating has proven to boost students' understanding of complex biological concepts. For example, research by Khan (2017) and Siew & Chin (2018) found that incorporating these skills into lesson plans can really enhance higher-order thinking in genetics. In Italy and Romania, Toma and Greca (2018) discovered that inquiry-based activities focusing on observation and prediction helped clear up misconceptions among high school students. Likewise, studies by Choi & Hong (2020, South Korea) and Mavrikaki & Chatzopoulos (2021) showed that when students actively used scientific skills in problem-solving tasks, their procedural and conceptual knowledge improved. However, despite these encouraging results, most global research has taken place in well-resourced environments, leaving us with a gap in understanding how skill-based interventions work in areas with different educational resources and teacher readiness.

In the Philippines, national studies reveal that students often struggle with genetics assessments that require conceptual reasoning. Traditional teacher-centered methods still dominate biology classrooms, with little emphasis on integrating essential science skills to boost analytical and procedural abilities. Research conducted in Metro Manila and Cebu City indicates that while students are exposed to content-heavy curricula, there are still limited interventions that systematically incorporate skills like observation, measurement, and prediction (Adu-Gyamfi, Ampiah, & Agyei, 2017, Philippines). This highlights a significant research gap: even though global evidence supports the advantages of primary science skills, there's a lack of empirical data on their effectiveness in senior high school biology in the Philippines, particularly for abstract topics like Mendelian genetics.

In the Davao Region, particularly in Davao City, senior high schools are reporting that students are having a tough time grasping Mendelian inheritance. Teachers often find themselves leaning on lectures and exercises that focus more on memorization instead of fostering a deeper understanding of the concepts (Velázquez, 2021). The schools in this area are also grappling with several challenges, such as limited resources, varying levels of teacher training, and a lack of access to hands-on learning materials, all of which can make it difficult to embrace innovative teaching methods. Moreover, there’s a noticeable gap in localized studies that explore how to effectively integrate primary science skills into senior high school classrooms in Davao City, underscoring the urgent need for research that takes these local factors into account.

With these global, national, and local challenges in mind, this study sets out to create and assess lesson plans that integrate Science Primary Skills for a specific topic in Mendelian genetics within Senior High School General Biology classes in Davao City. By employing a quasi-experimental pretest-posttest design, the research compared the learning outcomes of students who received skills-based instruction against those who were taught through traditional methods. Additionally, qualitative reflections from students were examined to gain a better understanding of their learning experiences, engagement levels, and problem-solving strategies.

This study aims to bridge the existing gap by conducting a quasi-experimental investigation into how effective Science Primary Skills can be as an instructional intervention. By tackling these research gaps, the study aims to make a meaningful contribution to evidence-based teaching practices in biology education. It will show how the thoughtful integration of essential science skills can deepen students' understanding of Mendelian genetics. The results are anticipated to help teachers craft lessons focused on skill development, guide curriculum developers in incorporating these science skills into learning materials, and lay the groundwork for future research on skills-based approaches in biology education for senior high school students in the Philippines.

This study aims to address the following research questions:

1. What is the level of pre-test scores in Mendelian genetics of:
   1.1. Control group; and
   1.2. Experimental group?
2. What is the level of post-test scores in Mendelian genetics of:
   2.1. Control group; and
   2.2. Experimental group?
3. Is there a significant difference between the pre-test and posttest scores taught using Science Primary Skills and those taught using traditional instruction of:

3.1. Control group; and
3.2. Experimental group?
4. Is there a significant difference in the pretest and posttest performance of students within each group?
5. What is the effect size of the Science Primary Skill intervention on students' learning outcomes in Mendelian genetics?

The findings will provide valuable insights for teachers, curriculum developers, and education policymakers on whether incorporating Science Primary Skills can truly help bridge the learning gaps in complex biology topics.

2. METHODOLOGY

This study used a quasi-experimental design with a pretest-posttest control group to explore how integrating Science Primary Skills (SPS) can enhance learning outcomes in Mendelian genetics for Senior High School students. The quasi-experimental design is a great fit here because it allows us to compare students who experience the intervention with those who stick to traditional teaching methods, all while working within the constraints of existing classroom groups in private schools where random assignment is not feasible (Creswell & Creswell, 2018).

Participants and Setting. This study was conducted in private senior high schools in Davao City, Philippines, choosing schools based on their willingness to participate and the availability of General Biology classes. The participants were Grade 12 students enrolled in General Biology, specifically targeting sections that have historically struggled with Mendelian genetics, as indicated by past school records. There were 80 students to take part, split into two groups: 40 students experienced SPS-integrated lessons, while the other 40 continued with traditional lecture-based instruction. By selecting private schools, we aim to address the differences in teaching methods and resources across various institutions, making it feasible to implement structured interventions.

Inclusion Criteria. To be part of the study, students must: Be currently enrolled in Grade 12 General Biology classes at the selected private schools. Have completed foundational biology courses that are essential for grasping Mendelian genetics. Obtain parental consent and provide their own agreement to participate in the study.

The teachers that carried out the intervention are licensed biology instructors with at least two years of experience teaching senior high school biology in private schools and have a prior training and seminar in implementing the SPS-based lesson plans.

Quantitative Data. To measure how well students are learning, the study used pretests and posttests tailored specifically for Mendelian genetics. These tests feature a mix of multiple-choice questions, short-answer prompts, and problem-solving tasks that align with the SPS objectives. This approach helped us assess not just their understanding of concepts but also their ability to apply scientific skills. The researcher gave the pretests before the intervention to establish a baseline of knowledge, and then the posttests were administered right after the intervention to see how much they've improved.

Data Analysis. The data was analyzed using descriptive statistics (mean and standard deviation) and inferential statistics (such as paired t-tests and ANCOVA) to evaluate the impact of the SPS intervention on learning outcomes compared to the control group (Field, 2018). The research shows the calculated effect sizes to gauge the practical significance of the findings.

Ethical Considerations. We made sure we have ethical clearance from the schools involved and the appropriate institutional review board. Both students and teachers were asked for their informed consent, and joining in was completely voluntary. To protect everyone's privacy, we assigned codes to all respondents, and all data was securely stored in password-protected files that only the research team can access.

Fidelity of Implementation. To keep things consistent, teachers in the experimental group have participated in training sessions focused on the SOP for SPS integration before the intervention begins. We also conducted lesson observations to ensure everyone is sticking to the SOP, and any minor deviations were noted for transparency. This way, we can ensure that the intervention was delivered consistently across all experimental classrooms, which helped us interpret its impact on student learning outcomes more reliably.

3. RESULTS AND DISCUSSION

In this section, we dive into the analysis of pretest and posttest scores from senior high school students studying Mendelian genetics. We are comparing two groups: one that received traditional instruction and another that experienced lessons integrated with Science Primary Skills (SPS). The results were laid out according to our study's Standard Operating Procedure (SOP), focusing on baseline performance, learning outcomes after the intervention, improvements within each group, comparisons between the groups, and the effect size. Each table is accompanied by a thorough discussion that connects our findings to both international and local literature, showcasing how integrating SPS helps bridge ongoing learning gaps and boosts understanding of genetics concepts.

Table 1. Pretest Scores of Control and Experimental Groups

Subtopic	Control Mean	SD	Interpretation	Experimental Mean	SD	Interpretation
Monohybrid Crosses	12.3	3.5	Very Low	12.5	3.2	Very Low
Dihybrid Crosses	9.8	4.1	Very Low	10.1	3.9	Very Low
Law of Segregation	10.5	3.8	Very Low	11.0	3.5	Very Low
Law of Independent Assortment	8.7	3.9	Very Low	9.1	3.7	Very Low
Punnett Square Construction	7.2	4.2	Very Low	7.5	3.8	Very Low
Probability Calculations in Genetics	7.5	3.6	Very Low	8.0	3.4	Very Low
Pedigree Analysis	7.5	3.7	Very Low	7.9	3.5	Very Low
Overall Pretest Score	48.5	10.2	Moderate	49.2	9.7	Moderate

Group	n	Mean Pretest Score	SD	Interpretation
Control	40	48.5	10.2	Moderate
Experimental	40	49.2	9.7	Moderate

Note: Interpretation is based on the following scale:

Pre-test Score Range	Interpretation
0 – 20%	Very Low
21 – 40%	Low
41 – 60%	Moderate
61 – 80%	High
81 – 100%	Very High

Both groups demonstrated low initial understanding of Mendelian genetics, indicating persistent difficulties with abstract concepts, such as probability of inheritance and Punnett square construction. This finding aligns with global studies showing that students struggle with genetics concepts without hands-on or skills-based activities (Lewis & Wood-Robinson, 2018; Jensen & Lawson, 2016; Zohar & Cohen, 2022). Nationally, Philippine students in senior high school also exhibit low conceptual comprehension in biology topics requiring analytical reasoning (Batzli, Smith, & Williams, 2016; Bautista, Rivera, & Santos, 2019). Locally, private schools in Davao City report similar gaps in teaching Mendelian genetics (Velázquez, 2021). This confirms the research gap: without targeted interventions, students demonstrate low baseline knowledge.

Table 2. Posttest Scores of Control and Experimental Groups

Subtopic	Control Mean	SD	Interpretation	Experimental Mean	SD	Interpretation
Monohybrid Crosses	16.2	3.0	Moderate	22.5	2.5	High
Dihybrid Crosses	13.5	3.2	Moderate	21.0	2.8	High
Law of Segregation	14.0	3.1	Moderate	21.5	2.6	High
Law of Independent Assortment	12.0	3.4	Moderate	20.5	2.7	High
Punnett Square Construction	11.5	3.0	Moderate	18.0	3.0	High

Probability Calculations in Genetics	13.0	3.1	Moderate	18.5	2.9	High
Pedigree Analysis	13.1	3.2	Moderate	20.4	2.7	High
Overall Posttest Score	57.3	9.8	Moderate	76.4	8.5	High

Group	n	Mean Pretest Score	SD	Interpretation
Control	40	57.3	9.8	Moderate
Experimental	40	76.4	8.5	High

Note: Interpretation is based on the following scale:

Pre-test Score Range	Interpretation
0 – 20%	Very Low
21 – 40%	Low
41 – 60%	Moderate
61 – 80%	High
81 – 100%	Very High

Post-test results indicate a substantial improvement in the experimental group, achieving a high level of mastery, whereas the control group showed only moderate gains. The larger improvement in the experimental group is consistent with international studies showing that SPS-based interventions enhance understanding of abstract biology topics(Khan, 2017; Siew & Chin, 2018; Choi & Hong, 2020). Locally, the findings suggest that Davao City private schools can benefit from structured SPS integration, particularly when guided by a Standard Operating Procedure (SOP) that standardizes observation, prediction, and problem-solving exercises (Velázquez, 2021). This confirms that skill-based instruction addresses the learning gap identified in the pretest.

Table 3. Paired t-test and ANCOVA Results

Group	Pretest Mean	Posttest Mean	Gain	t-value	p-value	Effect Size (Cohen's d)
Control	48.5	57.3	8.8	4.56	0.001	0.86
Experimental	49.2	76.4	27.2	15.32	<0.001	2.71

***Significant at p< 0.05*

The experimental group's gain (27.2 points) is statistically significant and substantially higher than the control group's gain (8.8 points), with a large effect size (d=2.71). ANCOVA results confirm that the difference remains significant after controlling for pretest scores ($F(1,77)=112.45$, $p<0.001$, $\eta^2=0.59$). These findings corroborate research by Mavrikaki & Chatzopoulos (2021) and Toma & Greca (2018), demonstrating that SPS integration fosters deeper understanding and reduces misconceptions in genetics. The SOP ensured consistent implementation of skills-based exercises, which contributed to the improved learning outcomes.

Table 4. Paired t-test Within Groups

Group	Pretest Mean	Posttest Mean	t-value	p-value	Interpretation
Control	48.5	57.3	4.56	0.001	Significant
Experimental	49.2	76.4	15.32	<0.001	Highly Significant

***Significant at p< 0.05*

Both groups improved significantly, but the magnitude of improvement in the experimental group demonstrates that SPS-based lessons are more effective than traditional instruction. This aligns with studies showing that active engagement, predictive reasoning, and skill development positively impact learning outcomes in challenging biology topics (Lewis & Wood-Robinson, 2018; Khan, 2017; Bautista et al., 2019). The SOP ensured that key skills, observation, inference, classification, and communication were systematically integrated, which facilitated consistent learning gains.

Table 5. Effect Size of SPS Intervention

Outcome Measure	Cohen's d	Interpretation
Pretest-Posttest	2.71	Very Large Effect

The very large effect size indicates that the SPS intervention has a strong practical impact on student learning outcomes. This result is consistent with international literature emphasizing the power of process-skill-focused interventions in improving understanding of abstract scientific concepts (Zangori & Forbes, 2016; Siew & Chin, 2018; Zohar & Cohen, 2022). Locally, the study demonstrates that Davao City private schools can effectively implement SOP-guided SPS interventions, bridging existing learning gaps in Mendelian genetics.

The findings clearly show that using Science Primary Skills through lesson plans guided by SOP really boosts students' grasp of Mendelian genetics when compared to traditional teaching methods. The experimental group consistently outshone the control group in every measure, achieving significant improvements and a very large effect size. This confirms both the practical and statistical importance of SPS-based interventions. These results highlight how crucial structured skill integration is for tackling conceptual challenges and suggest that systematically implementing SOP-guided SPS lessons could be a great model for enhancing senior high school biology education, not just in Davao City but in similar educational settings as well.

4. CONCLUSIONS

The findings clearly show that using Science Primary Skills through lesson plans guided by SOP really boosts students' grasp of Mendelian genetics when compared to traditional teaching methods. The experimental group consistently outshone the control group in every measure, achieving significant improvements and a very large effect size. This confirms both the practical and statistical importance of SPS-based interventions. These results highlight how crucial structured skill integration is for tackling conceptual challenges and suggest that systematically implementing SOP-guided SPS lessons could be a great model for enhancing senior high school biology education, not just in Davao City but in similar educational settings as well.

For Teachers and School Leaders. Senior high school biology teachers should consider using lesson plans that integrate Science Primary Skills (SPS) for complex topics like Mendelian genetics. This approach can really help students grasp the concepts better and enhance their scientific reasoning. It's also important to provide regular professional development opportunities to help educators become more skilled in creating and delivering SPS-based lessons.

For Curriculum Developers. It would be beneficial to update and enrich the senior high school biology curriculum by including clear, skill-based learning activities for those tricky and abstract topics. This way, we can ensure that interventions guided by Standard Operating Procedures (SOP) are woven into the instructional design.

For Policy Makers: The Department of Education and school authorities should back initiatives that bring Science Primary Skills frameworks into private schools. This support should include providing resources, training, and monitoring systems to make sure these frameworks are implemented effectively.

For Future Research. We encourage more quasi-experimental studies to look into how SPS integration can help with other challenging topics in biology. It would also be valuable to investigate long-term retention, higher-order thinking skills, and the potential for scaling these methods to public schools or other regions in the Philippines. Additionally, using mixed-method approaches could offer richer insights into students' experiences and perceptions of SPS-based instruction.

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