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International Journal of Science, Technology, Engineering and Mathematics (IJSTEM) is an open-access peer-reviewed quarterly journal focused on recent developments and broad aspects relative to science, information technology, engineering and mathematics. The journal also celebrates the wide spectrum of STEM education accross all educational levels. It is a selective multi-track journal covering all aspects of STEM and STEM education.

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- Curriculum development in STEM program;
- Teaching and learning pedagogies;
- Assessment and performance of STEM students;
- STEM student cognitive development and performance;
- Development and validation of STEM teaching materials;
- Classroom management and discipline in STEM classes;
- Internationalization of STEM education; and
- STEM-focused schools.

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Strategic impact assessment of revitalized science, technology and engineering program

[1]Jerry M. Ortega & [2]Elisa N. Chua

Abstract

The study was conducted to evaluate the revitalized implementation of the Science, Technology and Engineering (STE) program through strategic impact evaluation. Using a descriptive-evaluative design, purposive sampling technique was also employed to identify the 119 former STE students and 17 STE science teachers from selected public Junior High School in the Philippines. A set of adapted tests were used in the gathering of data and questionnaires for the implementation of the STE Program. The results revealed no significant relationship between the learners' profile and the implementation of the STE program as well as no significant relationship between science skills and program implementation except for observing skills. However, there is a positive relationship between students' attitudes towards science subjects to STE program implementation. This study holds true that the STE program in the Philippines has a long way through its development. However, it given high hopes through the positive perception of the students and teachers in the program. While there are other factors to be considered in the evaluation of the program, this study has given fundamental inputs to program development through triangulation with teachers, students and experts.

Keywords: *STE program, science skills, students attitudes in science, students interest in science, crafted guidelines*

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1. Introduction

The global importance of science and technology which dominates every society requires an educational system that provides a venue for the development of scientific knowledge and skills. The rapid development of this field of knowledge through scientific inventions and discoveries poses a challenge to educational institutions to contribute their part in this growing demand for scientific inquiry. In the Philippines, the Department of Education (DepEd) commits itself to the development of the full potential of students in all areas. One of its thrusts is to produce quality learners in the field of science and technology. Through the Special Curricular Program (SCP), the Science, Technology, and Engineering (STE) Program is envisioned that DepEd will produce highly responsible, morally upright, globally competitive, and work-ready learners imbued with desirable values and equipped with 21st-century skills that can contribute to nation building and national transformation while preserving Filipino culture, heritage, and identity (DepEd Memorandum No. 129, s. 2014). The learners of this program are provided with opportunities through an enhanced science-technology-oriented curriculum that will prepare them for higher education in work with a strong focus on science, technology, mathematics, and research (Rafanan et al., 2020; Kennedy & Odell, 2014).

Despite the government's investment in several initiatives aimed at improving education quality, particularly in the fields of science, technology, and engineering, assessment seem too limited (Kayan-Fadlelmula et al., 2022; Aslam et al., 2022; Li et al., 2020; Pierszalowski et al., 2021; Zhan & Niu, 2023). While most studies already pinpointed some alarming challenges of STEM program in the Philippines (Rogayan et al., 2021; Sison, 2022) and various parts of the world (Bardoe et al., 2023; Ejiwale, 2013; Harris & Hodges, 2018; Lee et al., 2019; Al Murshidi, 2019; Hsu & Fang, 2019; Carter, 2020), there are limited studies on the practices and strategies in sustaining the program. There are several studies highlighting the need for student intervention (Kennedy & Odell, 2014; Bertrand & Namukasa, 2020; Stehle & Peters-Burton, 2019; Darling-Hammond et al., 2020; Harackiewicz et al., 2016; Leung, 2023; Kelley & Knowles, 2016; Sáinz et al., 2022; Akcan et al., 2023) however there has been persisting challenges not addressed (Sithole et al., 2017; Ahmed, 2016).

According to Padwick et al. (2023), evaluating the effectiveness of STE program interventions requires process evaluation more than quantitative evaluation. A process evaluation concerns with how a program outcome or impact was achieved, such as a tracer study or impact evaluation. While tracer study is mostly concerned with the graduates' employability (Kula-semos et al., 2020), it also provides essential data to inform program improvements (Chima et al., 2023) while impact evaluation assesses the long-term effect of the program. Hence, in the case of STE program, a strategic impact evaluation is necessary to evaluate both the outcome and its impact. There are several studies that evaluated the STE program in the Philippines (Macaranas & Robles, 2023; Sarmiento et al., 2020; Morados, 2020; Torreǹa, 2020; Andrada & Marasigan, 2020) and tracer studies of STE undergraduate programs (Dotong et al., 2016; Reusia et al., 2020; Ramirez et al., 204) but there is limited tracer study on High School STE program (i.e. Domanais & Quiapon, 2022) due to the late implementation of the K to 12 programs and no studies on strategic impact evaluation of STE program. Hence, this study sees the need to conduct a strategic impact evaluation for the implementation and enhancement of the program itself.

2. Literature Review

2.1. Teaching and learning in STE program

The STE program, one of the Special Curricular Programs offered by the DepEd, provides learners with an enriched, science and technology-oriented curriculum that prepares them for higher education or work in the fields of science, technology, and engineering (DepED Order no. 021, s. 2019). Since the development of science skills has become an important component of science curricula at all levels, the implementation of the scientific technology and engineering program is given special attention. According to Almeyda (2010), precondition knowledge, concepts, and principles can be gained only if the students have certain underlying capabilities. This procedural competence in developing scientific skills is influenced by the scientific basic skills that are needed to practice and understand science. However, learning depends on many factors. For instance, a highly motivated student has a positive attitude toward the subject he is learning (Bureau et al., 2022), hence, teachers should engage students (Hornstra et al., 2015). Similarly, the learning environment inspires not just students who want to go to school but also those who want to study and participate in their studies (Movahedzadeh, 2011 as cited by Maranan, 2017).

In the modern day learning, studies have also shown that the use of technology produces a positive impact on students (Haddock et al., 2022; Ramírez et al., 2021; Francis, 2017; Schindler et al., 2017), in addition to individual factors and forces which play an important role in science teaching. For instance, Joaquin and Andal (2023) suggest flipped program because it has positive effect on students' performance while Leo and Puzio (2016) found that students preferred to watch video lectures away from class and appreciated more active teaching methods. In addition, students become more interested in the learning process when taught science subjects with technology, helping them to complete tasks easier than if they were taught traditional methods (Nawzad et al., 2018).

The role of teachers in learning science has been emphasized in several studies. According to Todd (2020), 50% of the surveyed students said that their teacher affects the level of their interest in science. The interpersonal connection between the teacher and students play a pivotal role in improving the level of students' positive attitudes toward science subjects. For this, dela Rama (2020) asserts the importance of training on teaching and learning such as seminars, and capacity building on subjects related to effective science teaching, conversion of instruction material into an electronic format and familiarity with different functions and features of eLearning platforms. On the other hand, Maffea (2020) cited the lack of appropriate material that not only affects teaching but also gives rise to motivation for teachers to deal with lessons.

2.2. Challenges in the management of STE program

The study of Maranan (2017) disclosed lack of scientific culture and weaknesses in school curricula, instructional materials, learning curriculum, and teaching practice as the major factors leading to low science performance of Filipino students. While the tracer study of Morados (2020) found STE graduates substantially performed better than those who are non-STEs, the Philippines is still lagging in three different global evaluations that scored students' performance in science, technology, engineering and mathematics (Sison, 2022). The increase employability can be attributable to the increased resources at their disposal, as well as adding more science and math subjects into the curricula, alongside a relatively high level of intellectual abilities among STE students. However, several studies had disclosed reasons for poor performance of STEM programs in the country such as teachers' qualifications (Tupas & Matsuura, 2019; Gamboa et al., 2020; Diate & Mordeno, 2021), curriculum (Tupas & Matsuura, 2019; Almazan et al., 2020; Diate & Mordeno, 2021), school facilities (Tupas & Matsuura, 2019; Abas & Marasigan, 2020; Pacala & Cabrales, 2023), teaching and learning (Tupas & Matsuura, 2019; Sadera et al., 2020; Pacala & Cabrales, 2023), learning resources (Tupas & Matsuura, 2019; Gamboa et al., 2020; Sadera et al., 2020) and laboratory facilities for practical learning (Tupas & Matsuura, 2019; Abas & Marasigan, 2020; Pacala & Cabrales, 2023; Diate & Mordeno, 2021). These common problems in the country are similar to the studies in various countries facing the same issue on low STEM performance (Kamba et al., 2019; Abidoye et al., 2022; Assem et al., 2023; Chand et al., 2021; Han et al., 2021; Makgato, 2007; Banerjee, 2016).

3. Methodology

This study is descriptive research with survey as data gathering technique. It used the strategic impact evaluation, which the OECD defines as an assessment of how the intervention being evaluated affects outcomes. According to Rogers (2014), impact evaluation can be undertaken of a program or a policy. The usual evaluation criteria involve relevance, effectiveness, efficiency, impact and sustainability. In this study, these criteria evaluated the school resources, academic program, delivery of instructions, program management and monitoring and evaluation.

The 119 students and the 17 science STE program teachers were chosen through purposive sampling. The student must be enrolled Grade 11 STE program while the teacher must be stationed in any school within third cluster of Laguna Division that offers STE Program and handing science subjects under the STE program. Validators were also chosen based on their educational backgrounds and experience as school administrators and science instructors from different schools inside the Division of Laguna.

Table 1 summarizes the demographic characteristics of the participating students. The research variables include the final grade (μ=92.14; σ=2.3), attitude towards STE program (μ=3.63; σ=0.41), and the various scientific skills such as classifying (μ=4; σ=1.43), inferring (μ=7.4; σ=2.69), observing (μ=4; σ=1.8), making hypothesis (μ=4.5; σ=1.71), interpreting data (μ=5.4; σ=2.34), defining (μ=2.6; σ=1.18) and measuring (μ=3.1; σ=1.45). The final grades of the students range from 85 to 97, the attitude towards STE program ranges from 2.70 to 4.58 weighted means and the scientific skills range from 0 to 12.

Table 1

Demographic characteristics

Characteristic	Highest	Lowest	Mean	Standard Deviation
Final grade	97	85	92.14	2.3
Attitude towards the STE Program	4.58	2.70	3.63	0.41
Classifying skill	7	0	4	1.43
Inferring skill	12	0	7.4	2.69
Observing skill	7	0	4	1.80
Making hypothesis skill	9	1	4.5	1.71
Interpreting data skill	11	1	5.4	2.34
Defining skill	5	0	2.6	1.18
Measuring skill	6	0	3.1	1.45

The study used a test lifted from the Science Learner's manual for Grade 10 recommended by the DepEd and a questionnaire available in the contextualized manual for the implementation of the special curriculum programs in science by DepEd Caraga. In addition, the evaluation of the crafted guidelines used the Basic Education Monitoring and Evaluation Framework according to DepED Order no. 29, s. 2022. For the evaluation of the science, technology, and engineering program in terms of its domain, an evaluation 46 sheet was adapted from the Regional Contextualized Manual for the Implementation of Special Curricular Programs in Science by the DepEd Caraga version 1.0 and was released on October 2021.

The test was administered to the number of respondents present and currently enrolled at the four (4) selected senior high schools within the third cluster district of the Division of Laguna. The testing administration rules were strictly followed and the time allotment was enforced to ensure standard procedures in the test administration. Meanwhile, the survey for the science teachers and coordinators was conducted by the researcher.

The statistical methods used were frequency distribution and Pearson correlation. Kendall's Tau was also used in this study to understand the existing relationship between two variables such as the implementation of the STE program to the development of the scientific skills among the STE students. Pearson r analysis was used for the description of the relationship existing between the scientific skills of the students and the level of implementation of the STE program and the relationship between the revitalized guidelines on the implementation of the STE program with its perceived intermediate outcomes.

4. Findings and Discussion

Table 1

Comparative evaluation of the STE program by students and teachers

Parameters	Students			Teachers		
	Mean	**SD**	**VI**	**Mean**	**SD**	**VI**
1. School resources	3.58	0.33	HO	3.47	0.49	HO
2. Academic program	3.75	0.82	HO	3.62	0.49	HO
3. Delivery of instructions	3.75	0.82	HO	3.58	0.38	HO
4. Program management	3.81	0.72	HO	3.52	0.38	HO
5. Monitoring and evaluation	3.82	0.76	HO	3.34	0.43	HO
Overall	**3.74**	**0.086**	**HO**	**3.51**	**0.11**	**HO**

Legend:	**Range**	**Remarks**	**Verbal Interpretation**
	3.50-4.00	Strongly Agree	Highly Observed (HO)
	2.50-3.49	Agree	Observed (O)
	1.50-2.49	Disagree	Slightly Observed (SO)
	1.00-1.49	Strongly Disagree	Not Observed (NO)

Table 1 shows the comparative evaluation by the students and the teachers. The overall assessment of the students generated a mean of 3.74, which is highly observed. This indicates that the implementation of the different programs among the different schools is properly implemented as perceived by the former STE students. The standard deviation values further show that the respondents have almost the same perception that concretizes the study.

Based on the assessment of the students, the schools are seen as excellent implementors of the STE program. The practices on the implementation of the program coincide with previous studies emphasizing the establishment and provision of relevant instructional materials and teaching methods and techniques (Asabiaka, 2018), resource policies (Hanushek, 2014), appropriate learning environment (Tori & Kallery, 2021), effective teaching and learning process (Yusuf & Dada, 2016), professional development for teachers (Adeyemi, 2016), institutional support (Palines & Dela Cruz, 2021) and program monitoring and evaluation (Vaccaro & Sabella, 2018). Similarly, the science teachers rated the academic program with a mean of 3.62 as the highest while the monitoring of the STE program got only 3.34 that makes it the lowest among the given variables. Based on the result, science teachers agreed that the academic program on the implementation of the STE program supports the development of the students' interest and successful transfer of knowledge to the students based on the verbal interpretation where all of its indicators got a highly implemented level. When it comes to good practice in the curriculum, most of the STE implementers are focused although inclusion of at least two elective science subjects is missing explaining the mismatch between the level of perception of students and teachers in the implementation of STE program. Meanwhile, the monitoring by the regional and division levels and the allocation of the budget for the implementation of the program got the lowest rating because some offices failed to monitor the development of the program and failed to allocate enough budget for proper and effective implementation. The grading system got the highest mean of 3.88 and 0.33 standard deviation because it follows the DepEd Order no. 8, s. 2015 and DepEd Order no. 31, s. 2020. However, the retention of the students in the program becomes a challenge for some teachers as students find it hard to maintain the 88% average rating; hence, they lower the rating to 85%. The results of the assessment highlights the previous recommendations on institutional support for teachers (Manalo & Chua, 2020), effective implementation of teaching strategies (Formalejo & Ramirez, 2017), and sufficient laboratory and learning resources (Palines & Dela Cruz, 2021).

Since the experiences of students are far different than the roles and responsibilities of the STE teachers, the ratings of the two sets of participants are totally different. Several studies identified differences in the perception of teachers and students in the teaching and learning environment of STE program. Fitzgerald et al. (2020), comparing the difference betwee 86 teachers and 2512 grade 9 and 10 students in the United Kingdom, reported teachers' constant overrating of their teaching practices. In Indonesia, while the teachers show the same level of assessment of STEM education, teaching methodologies were not appropriate to the preferences of the students leading to weak achievement in the program (Permanasari et al., 2021). The current findings contrast with the study of Ben-Chaim and Zoller (2001) emphasizing the good correspondence of teaching styles and STEM students' learning preferences in Israel and Saptarani et al. (2018) that students and teachers in Indonesia consider STEM essential for future career development. In terms of geographical location, He et al. (2022) found differences in the perception of Chinese and UK students on STEM program, with Chinese students consistent higher ratings of STEM education than UK students.

This study supports previous findings that students best learned when they are exposed to the learning process and have the opportunity to experience the learning through practical application and work placement. These are the same findings of Fairhurst et al. (2023), Roberts et al. (2018), Su et al. (2022) and Meng et al. (2014). The availability of learning materials greatly aide the learning process. Meanwhile, teachers' program monitoring adds significant ideas for its development. While previous studies pointed out the importance of the STEM learning environment (Margot & Kettler, 2019; Chaya, 2023; Thi To Khuyen et al., 2020; Wang et al., 2011; Pathoni et al., 2022; Sobri et al., 2021; Sellami et al., 2022; Kamizi & Iksan, 2021; Kinkopf & Dack, 2023; Akiri et al., 2021) in the continuous program development, the current study asserts the benefits of program monitoring as a good practice for the better impelementation of the STE Program.

Table 2

Acceptability of the revitalized STE program guidelines

	Students			**Experts**		
Parameters	**Mean**	**SD**	**VI**	**Mean**	**SD**	**VI**
1. Access	2.14	1	A	2.33	0.76	A
2. Equity	2.08	0.74	A	2.22	0.71	A
3. Quality	2.44	0.43	HA	2.78	0.43	HA
4. Resiliency and Well-Being	2.58	0.45	HA	2.81	0.44	HA
Overall	**2.31**	**0.24**	**A**	**2.54**	**0.30**	**HA**

Legend :	*Range*	*Remarks*	*Verbal Interpretation*
	2.34 – 3.00	*Highly Evident*	*Highly Acceptable (HA)*
	1.67 – 2.33	*Evident*	*Acceptable (A)*
	1.00 – 1.66	*Not Evident*	*Not Acceptable (NA)*

Table 2 shows the level of acceptability of the revitalized STE program guidelines. In terms of the acceptability measured by both students and teachers, the equity, or the fairness of the program to be offered to everyone got the lowest mean among the given variables. It has the lowest mean of 2.08 for the students and 2.22 for the evaluation of teachers. On the other hand, resiliency and well-being got the highest mean of 2.58 for the students and 2.81 for the STE science teachers evaluation. The results imply that students have the opportunity to access quality education that could help them in their career and future development. These are similar to the study of Llego (2022) on the inclusivity in the field of education in the Philippines through the ALS providing non-traditional learning opportunities for students. The results are also explained by the study of Choi et al. (2023) on the concept of resilience. Since Filipino students are known to be resilient, they tend to adjust to their school environment. They recognize the flaws of the program implementation but tend to look at the brighter side of the program.

The evaluation of the expert validators shows that the revitalized STE program as to its intermediate outcomes in terms of access and equity is under the acceptable level while the quality and the resiliency and well-being has a highly acceptable level. The results highlight the similar findings of Kart and Kart (2021) on inclusive education and Mamba et al. (2021) on the value of ALS.

Table 3

Test of relationship between students' profile and STE program evaluation

Learner's Profile	*Implementation of the STE Program*			
	Academic Program	Delivery of Instruction	Program Management	Monitoring and Evaluation
Final Grade	-.036	-.079	-.018	-.004
Students' Attitude	.356**	.297**	.231*	.239**
Scientific Skills				
Classifying	-.042	-.043	-.038	-.077
Inferring	-.029	.061	-.023	-.058
Observing	-.182*	-.143	-.219*	-.181*
Making Hypothesis	-.062	-.008	-.046	-.138
Interpreting Data	-.087	-.111	-.079	-.133
Defining	-.156	-.078	-.127	-.157
Measuring	-.035	-.055	-.075	-.056

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

The test of correlation in table 3 shows that the final grades of the STE students are not significantly correlated to the academic program with 0.36 r-value, delivery of instructions r-value of 0.79, program management r-value of 0.18, and monitoring and evaluation with an R-value of 0.004. Meanwhile, students' attitudes towards the program is significantly correlated to the academic program (r-value=.356), delivery of instructions (r-value=.297), program management (r-value=0.231) and monitoring and evaluation (r-value=.239). However, most of the science skills such as classifying, inferring, making a hypothesis, interpreting data, defining, and measuring are not significantly correlated with the implementation of the STE program. Since most of the students obtained a beginner level in the science skills test, it does not provide empirical evidence of relationship with the program implementation parameters. The only skill with positive correlation to the componenets of the program implementation (academic program, program management and monitoring and evaluation) is observing. Since the student-respondents were former STE students from school year 2021-2022, before the implementation of the online and modular modality of learning, they experienced face-to-face learning during their grades 7 and 8. This probably explains the moderately positive attitude towards science. Furthermore, they were acepted into the program with the required outstanding grades in science, math, and English subject.

5. Conclusion

With the assessed revitalized STE program and program guidelines, this study found no significant relationship between the learners' profile and the implementation of the STE program. Similarly, there was no significant relationship between science skills and program implementation except for observing skills. However, there is a positive relationship between the students' attitudes towards science subjects to STE program implementation.

This study holds true that the STE program in the Philippines has a long way through its development. However, it given high hopes through the positive perception of the students and teachers in the program. While there are other factors to be considered in the evaluation of the program, this study has given fundamental inputs to program development through triangulation with teachers, students and experts. The continuous monitoring and evaluation of the program is vital to the performance of the students and the program itself. Hence, this study recommends closer look on the institutional support on the STE program, quality assurance of the program and the tracing of the graduates.

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Effectiveness of project COUNTS in improving students' numeracy skills

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Abstract

Students with learning difficulties benefit from intervention programs. Hence, this experimental research examined the effectiveness of Project COUNTS (Capacitating, Optimizing and Upgrading the Numeracy skills of The Students), a mathematics intervention program, and a continuous improvement venture in a public school in the Philippines during the academic year 2020–2021. It specifically investigated the numeracy skills pretest and posttest performances and its difference, and the difference in the pretest and posttest according to profiles. This experimental study utilized the data from 175 randomly selected grade 8 (91) and grade 9 (84) students under the low-numerate and non-numerate categories through multi-stage sampling. The study utilized the mean, standard deviation, dependent samples z-test, independent samples z-test, and one-way ANOVA. The results showed that the participants' numeracy skills pretest and posttest performance reached low-numerate ($\bar{x}$=15.95, SD=3.30) and numerate ($\bar{x}$=23.27, SD=3.21) levels, respectively. There is a significant difference in the participants' posttest performance when grouped according to their sex (z=2.84, p=0.00); females ($\bar{x}$=24.04, SD=3.22) have better performance than males ($\bar{x}$=22.57, SD=3.04). There was a statistically significant difference in the pretest and posttest performances (z=-11.38, p<0.001), thus confirming the intervention program's effectiveness (large effect size) in improving the numeracy skills of students. Teachers, school heads and superiors, students and parents/guardians, and future researchers can replicate or apply the intervention program to other sets of learners.

Keywords: *numeracy skills, mathematics, project COUNTS, intervention program*

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1. Introduction

Numeracy is one prerequisite fundamental skill learners need to study and develop at an early age to succeed in their higher levels of learning. According to Department of Education (DepEd) order no. 12, s. 2015, one of the predictors of a school's success is the level of a child's progress in the foundational skills, which include numeracy skills. Numeracy, the ability to understand and work with numbers, is broadly explained as the comprehensive understanding, abilities, actions, and attitudes that students must possess to effectively apply mathematical concepts in many contexts (The State Government of Victoria, Australia, 2019). Since the skill is fundamental for students, they must grasp to avoid difficulties in solving higher mathematics problems or problems relating to real-life situations that require calculation. For instance, in the context of Philippine curriculum, junior high school students should have developed their numeracy skills for them to learn easily the mathematical skills needed in senior high school, college, and even in the workplace.

In most challenged students, intervention programs, strategies to improve students' performance, are widely implemented in mathematics. For example, Mononen et al. (2014) applied early numeracy intermediations for children, Perez (2023) used numeracy station items, Clarke et al. (2018) investigated initial competence in moderating the intervention effects of ROOTS, Singh et al. (2021) explored the use of Math Zap, a card game and an academic tool for developing numeracy abilities in the setting of intellectual calculation, Frazier (2019) investigated the effectiveness of a peer tutoring intervention administered by students with autism spectrum disorder to improve the early numeracy, Layug et al. (2021) examined the interventions used by teachers to improve the numeracy skills of grade 7 students, and Wallit (2016) conducted action research on enhancing the mathematics performance of grade 6 pupils using Arts in Math (AIM).

There has been multitude of studies conducted testing specific intervention imposed on a specific scenario. While some of these studies are similar in context, the students involved were entirely different. Most researchers agree that the students' intervention program must be contextualized (Reddy et al., 2021; Johnson, 2008; Bonganciso, 2016; Nanyinza & Munsaka, 2023). For example, the division-level pretest on junior high school students at Gulod National High School (GNHS) in 2020-2021 revealed that out of 2,735 students who were tested, 584 (21.4% of the students tested) scored low in numeracy (11–20 out of 40), while 37 (1.4%) scored non-numerate (1–10 out of 40). It signifies that these students still have no strong foundations in the skills, particularly in whole numbers, fractions, decimals, and integers. Thus, with the alignment of the education or program supervisor's I-numerate project in mathematics, the GNHS mathematics teachers made plans and actions to solve this school-level problem. To contextualize the situation, the Project Capacitating, Optimizing, and Upgrading the Numeracy Skills of The Students (COUNTS), an intervention program and a continuous improvement project, aimed to develop the numeracy skills and performances of the low and non-numerate students from Grade 7 to 10. The program employs school-based intervention materials focusing on four areas, namely whole numbers, integers, decimals, and fractions, aligned to the learning competencies. The program proponents incorporated varied active teaching strategies during the application of COUNTS including the utilization of manipulative materials, Quizzizz application, reviewer with step-by-step explanation, brochures on verbal phrases to symbols, and scheduled skip counting activity via phone call/video conference in mathematics. While the participants from the previous studies include children, elementary pupils, 7th graders, and students with autism spectrum disorder, the current experimental study aimed to determine effects of COUNTS on the improvement of numeracy skills of public high school students, particularly the grade 8 and 9 who belong to low-numerate and non-numerate categories.

This study desires to determine the performance in the numeracy skills pretest and posttest, compare the means in the numeracy skills pretest and posttest, bridge the gap by testing the difference in the numeracy skills pretest and posttest performances when grouped according to the participants’ sex and age, and determine the effectiveness of the intervention program by comparing the participants' pretest and posttest numeracy performances and calculating the effect size. The study is limited to 84 students in grade 9 and 91 students in grade 8, who were enrolled during 2020–2021 academic year. Since the DepEd established the MATATAG program in the Philippines, where numeracy improvement is one of the aims, the findings of this study could be fundamental inputs to the program and the department. Thus, these findings and intervention strategies can be used by elementary and high schools and can be applied even by mathematics teachers and future researchers in different divisions and regions to improve learners’ numeracy skills.

2. Literature Review

2.1. Theoretical Framework

The cognitive learning theory explains how internal and external factors influence an individual's mental processes to supplement learning (Vilamis, n. d.). Learning delays and difficulties arise when cognitive processes are affected, leading to poor numeracy skills and mathematics performance. As learning involves a substantial restructuring of existing cognitive structures, cognitive learning theory views motivation as essentially intrinsic, implying that good learning requires a significant personal commitment on the learner's part. When students are demotivated, they are unable to contribute effectively to the topic. Supportive, intrinsic, and remedial approaches are effective because they rely on students' strengths to build intrinsic motivation, and remediation is conducted in a secure atmosphere so that students can make their own interpretation of knowledge and make connections with related topics.

Further, Piaget's theory of constructivism argues that people produce knowledge and form meaning based upon their experiences (Teachnology, n. d.). This experience causes the individual to develop new outlooks, rethink what were once misunderstandings, and evaluate what is significant, ultimately altering their perceptions. This theory emphasizes that learning occurs as learners are actively involved in the process of meaning and knowledge construction rather than passively receiving information, offering students opportunities to learn important mathematical concepts and procedures with understanding. Sa'dijah et al. (2023) suggest teachers to use task-oriented learning experiences, particularly constructivist teaching methods, to improve numeracy skills of students.

In this study, cognitive learning and constructivism theories were connected since active teaching strategies were incorporated during the application of COUNTS such as utilization of manipulative materials, Quizzizz application, reviewer with step-by-step explanation, brochures on verbal phrases to symbols, and scheduled skip counting activity via phone call/video conference in teaching mathematics. These external factors would motivate and engage students in the learning process and influence an individual's mental processes resulting in an enhanced understanding of the numeracy skills.

2.2. Mathematics and Numeracy

Society's progress relies on the crucial role of mathematics, which should not be ignored. Many factors, including teaching methods, strategies, environmental factors, student motivation, and assessments, affect effective math learning. Increasing their emphasis will help students' math literacy. Recent innovations in teaching methods have not improved math achievement, which is concerning (Tan & Pagtulon-an, 2018).

Numeracy refers to the awareness, abilities, habits, and attitudes that students need to be able to use mathematics in a variety of contexts. It requires understanding mathematics' role in the world and being able to use math abilities. Most people use numbers, computation, geometry, statistics, and probability in their daily lives, research, and work. Problem solving, logic, mathematics, mathematical structure, and functions and relations help people understand the natural and human worlds and their interactions (The Department of Education and Training Melbourne, 2017). According to Tout et al. (2020), numeracy includes the knowledge, skills, attitudes, and actions pupils need in many situations. Grunau (2020), Hong et al. (2020) and Lopes (2020) found comparable results. Their research shows that adults with poor reading and math skills struggle at work, in the community, and at home. These problems include obtaining and keeping a job and helping their children with school. Hence, the significance of numeracy skills in real life in undeniable.

Layug et al. (2021) describe mathematics literacy which encompasses a comprehensive understanding and appreciation of mathematics' capabilities, rather than just complex formulas. It involves applying basic mathematical knowledge in everyday life, understanding, and combining mathematical concepts, terminologies, facts, and skills to meet real-world situations. Pitogo and Oco (2023) add that numeracy abilities are an integral part of mathematics and mastering them is essential to improving one's performance in the subject. Additionally, Guhl (2018) emphasizes the importance of early mathematics instruction for future studies, as pupils are most receptive to learning during this developmental period, especially at-risk ones, and young learners' naturally open brains are ideal for this. The researcher even emphasized that the cornerstone of all subsequent mathematics study is numeracy abilities. These skills are a more significant predictor of future success in elementary school. In addition, early math and numeracy pupils comprehend basic math ideas and numbers (Harris & Petersen, 2019). Early numeracy and math abilities are crucial for school and life math proficiency and problem-solving. Research shows that early arithmetic and numeracy training predicts future math ability (Gashaj et al., 2023; Aunio & Niemivirta, 2010; Davis-Kean et al., 2022; Braak et al., 2022) making it the best reason. Math and numeracy help should begin early because schools struggle with it.

Prior studies like Blume et al. (2021) have demonstrated that, even when domain-general abilities like working memory and IQ are considered, basic numerical abilities predict young student's progress in math. Fundamental numerical skills such as the ability to comprehend number magnitude, mathematical fact knowledge, and conceptual and procedural knowledge are important indicators of student's mathematical achievement, even after adjusting for domain-general cognitive skills.

Furthermore, numeracy is not uniform. Hirsch et al. (2018) examined the relevance of basic numerical abilities for students' mathematics grades using three operationalization; fundamental numerical skills, preparatory arithmetic skills, and informal mathematical understanding applied to numbers and counting. Brumwell and MacFarlane (2020) supported these findings, which criticize teaching numeracy as mathematics, calling it an antiquated notion. Postsecondary students may be out of practice since numeracy requires persistent practice, not simply applicable abilities. Meanwhile, Bacordo (2019) states that teaching mathematics is critical for teaching pupils' life skills. Thinking at the highest level of mental activity involves both mathematical reasoning and mental computation (Gurbz & Erdem, 2018), where a positive correlation exists between mental computation and mathematical reasoning. Mathematical reasoning is crucial in determining which mental computing method to employ. Hence, students with high mental computation levels have better mathematical reasoning.

The study of Piper et al. (2018) highlighted the value of teaching resources such as textbooks, structured guides, and professional development for teachers to improve students' reading and numeracy skills. These elements support effective lesson delivery, accommodate a variety of learning styles, and keep educators abreast of the most recent teaching approaches. Meanwhile, Indefenso and Yazon (2020) found a positive correlation between students' numeracy and financial literacy, with financial literacy rates varying directly with improved numeracy. In addition, there was a significant relationship between mathematics problem-solving and financial literacy components among junior high school students implying that numerate and good problem-solver student is also financially literate. Similarly, Wardono and Mariani (2018) found that students with high-capacity skills demonstrate better problem-solving abilities, while those with low-ability skills show significant improvement, as manifested by the low proficient students in PISA (Programme for International Student Assessment).

2.3. Numeracy Interventions

Several studies employed several numeracy interventions. According to Mononen et al. (2014), there are a variety of instructional design features, including explicit instruction, computer-assisted instruction, gameplay, and the use of concrete-representational-abstract levels in mathematical concept representations for children aged four to seven, which improved mathematics performance. Similarly, Perez (2023) found the manipulative, relevant, and interactive materials helped students' ability to work independently and accurately. For example, Clarke et al. (2018) used ROOTS, a 50-lesson mathematics intervention program aimed at strengthening whole-number ideas and skills in at-risk kindergarten pupils and found that starting skills had a moderating effect on student outcomes, but the relationship did not alter based on group size. Meanwhile, Singh et al. (2021) used Math Zap, a card game for developing numeracy skills in the context of mental computation. The study noted that while students enjoyed playing a Math Zap card game, they also improved their numeracy skills. Moreover, Frazier (2019) found peer tutoring intervention effective for students with autism spectrum disorder (ASD) to improve the early numeracy skills. The study also showed that students with ASD improved their academic skills due to participating in an educational peer tutoring intervention led by peer tutors with ASD.

According to Sa'dijah et al. (2023), teachers may use task-oriented learning experiences, such as constructivist teaching methods, to improve students' numeracy skills in Indonesia. However, teachers in the Philippines suggest different interventions. For example, Layug et al. (2021) employed conferences with parents and students, one-on-one tutorials, redoing low-score activities, home visits, supplementary materials, fewer activities, and remedial classes for Grade 7 students struggling in mathematics. The effectiveness of these strategies ranges from moderately to highly effective, aiming to close the gap between math-failing students. Lynch (2019) asserts the value of peer assessment and self-assessment although children's performance in mathematics continued to decline despite the teachers' best attempts to adopt interventions. For this, Wallit (2016) suggests the use of Arts in Math (AIM) for grade 6 students incorporating students' innate artistry with learning mathematics. While some classroom interventions are effective, several studies also emphasize that gender differences have an effect in terms of numeracy and mathematical skills development. For instance, Heyder et al. (2019) emphasized that in higher education, success in mathematics requires a certain, innate aptitude or math brilliance but detrimental to student diversity.

3. Methodology

This experimental study, which used a pretest and posttest design and only had one group (experimental only), aimed to determine the effectiveness of the intervention program, the Project COUNTS. The study used the Raosoft online calculator to determine the sample size through an experimental design. Out of the 319 population of low-numerate and non-numerate grade 8 and 9 students, there were 175 participants selected randomly through multi-stage sampling. Low-numerate students are those with scores between 11 and 20, while non-numerate students are those who obtained scores between 0 and 10 in the 40-item numeracy skills pre-assessment. By stratified random sampling technique, the participants of the study were 84 or 48% students from grade 9 and 91 or 52% students from grade 8. These students were enrolled at GNHS, Division of Cabuyao City, Laguna, in 2020–2021.

Table 1

Demographic profile of the participants

Sex	Frequency	Percentage
Male	92	52.6
Female	83	47.4
Total	**175**	**100.0**
Age	**Frequency**	**Percentage**
12 years old	3	1.7
13 years old	44	25.1
14 years old	78	44.6
15 years old	36	20.6
16 years old	12	6.9
17 years old and above	2	1.1
Total	**175**	**100.0**

Table 1 demonstrates the profile of the students in terms of sex and age with male participants (92, or 52.6%) more prevalent than females (83, or 47.4%). It also shows that the participants aged 14 are dominant in this study (78, or 44.6%). On the other hand, the least of the age groups belong to 17 years old and older (2, or 1.2%).

The study utilized the data from the results of the 40-item numeracy skills pretest and posttest administered in November 2020 and June 2021, respectively. The 40-item test was constructed and validated by the DepEd Cabuyao City Education Program Supervisor and select mathematics master teachers. The multiple-choice test includes 10 items for each numeracy skill (whole numbers, decimals, fractions, and integers). The reference scale for pretest and posttest is shown in table 2.

Table 2

The reference scale for numeracy skills pretest and posttest

Mean Range	Verbal Interpretation
31.00 – 40.00	Highly Numerate
21.00 – 30.99	Numerate
11.00 – 20.99	Low-numerate
1.00 – 10.99	Non-numerate

Source: DepEd Cabuyao City, 2021

The researchers collected the participants' demographic profile and their results on the pretest and posttest of numeracy skills conducted in 2020–2021. The pretest and posttest (Numeracy Skills pretest and posttest from the Department of Education) contain four categories, namely whole numbers, fractions, decimals, and integers, with ten questions each category aligned to the learning competencies. The researchers asked permission from the Schools Division Superintendent (SDS) and school head to utilize the pretest and posttest results on the numeracy skills of the students in 2020–2021 at GNHS. They also sought permission from the parents concerning the inclusion of their children in the program and data gathering. After approval, the researchers coded and analyzed the data for interpretation. The researchers strictly applied the data privacy act and DepEd's time-on-task policy during the program implementation and data gathering.

The implementation of Project COUNTS run from January 2021 to June 2021. The proponents performed a root-cause analysis to determine the cause and effect of the problem; thereafter, proceeded with proposing specific solutions in the intervention. Four selected teachers in mathematics created the review or intervention materials. The teachers developed that materials, which included pretests, posttests, and step-by-step explanations of how to solve problems with whole numbers, fractions, decimals, and integers. The review materials were validated by the math department's head teacher and master teachers. Each learner was categorized as low-numerate or non-numerate and was given a copy of the printed material. The students submitted their pretest and posttest outputs after a week.

Table 3 shows the intervention program matrix for the low- and non-numerates in 2020-2021.

Table 3

Project COUNTS intervention program matrix for the low- and non-numerates in AY 2020-2021

Objectives	Solutions	Activities	Persons Involved	Time Frame	Expected Outcome
1. To improve students' numeracy skills – whole numbers, fractions, decimals, and integers	Create intervention materials in a sort of reviewer	Teachers provide a step-by-step explanation in the reviewer on Whole Numbers, Fractions, Decimals, and Integers.	Head Teacher, Continuous Improvement Team, Math Teachers, Parents and Students	January to June 2021	Improved numeracy skills
2. To improve students' interest in Mathematics	Use of manipulatives in the intervention / teaching	Teachers provide manipulatives on whole numbers, fractions, decimals, and integers. Manual	Head Teacher, Continuous Improvement Team, Math Teachers, Parents, and Students	January to June 2021	Improved students' interest in Mathematics
3. To resolve students' difficulty in simplifying the order of operations	Strengthen the teaching strategy in Grouping symbols and mathematical Operations (GEMDAS)	Students will undergo a schedule for Skip Counting Activity through phone call/video conference. Quizziz will be employed for online learners. Parents will be oriented about it.	Head Teacher, Continuous Improvement Team, Math Teachers, Parents, and Students	January to June 2021	Students could simplify problems on order of operations
4. To improve students' familiarization on some Math vocabulary	Familiarize math vocabulary on translating statements into mathematical sentences	Math teachers would provide brochures (teacher-made materials) on verbal phrases to symbols.	Head Teacher, Continuous Improvement Team, Math Teachers, Parents, and Students	January to June 2021	Students got familiar with Math vocabulary

Researchers allotted a week for each competency in whole numbers, fractions, decimals, and integers to ensure a thorough understanding of each. Afterwards, they aligned the manipulative materials with whole numbers, fractions, decimals, and integers. They created fraction bars, base chips, and others so that solving problems would be simple. They also provided instructions on how to solve problems including Filipino instructions so that students would comprehend the directions in their native tongue. The learners had the manipulative materials for one week and returned them to school after use.

The mathematics teachers virtually met the learners for a skip counting activity and recitation on the multiplication tables. They also provided activities available in the Quizzes application. Afterwards, the mathematics teachers provided pamphlets on the verbal phrase translated into symbols. These were teacher-made materials created for the improvement of learners' math vocabulary. The materials have been laminated so that they will not be torn or destroyed quickly.

Mean and standard deviation were used to determine the level of numeracy skills performance in the pretest and posttest. Dependent samples z-test was used to determine the significant difference between the pretest and posttest performances of the students, and independent samples z-test to determine the significant difference in the pretest and posttest performances of the students when grouped according to their sex. One-way ANOVA was also used to determine the significant difference in the numeracy skills pretest and posttest performances of the students when grouped according to their age. Lastly, Cohen's D was used to determine the effect size of the difference between the numeracy skills pretest and posttest performances of the students.

4. Findings and Discussion

Table 4 presents the numeracy skills performance of the student participants in the pretest and posttest.

Table 4

The numeracy skills performance of the students in the pretest and posttest

Test	Mean	Standard Deviation	Interpretation
Numeracy Skills Pretest Performance	15.95	3.30	Low-numerate
Numeracy Skills Posttest Performance	23.27	3.21	Numerate

Legend: 31.00 – 40.00 highly numerate, 21.00 – 30.99 numerate, 11.00 – 20.99 low-numerate, 1.00 – 10.99 non-numerate

Based on the results, the 40-item numeracy skills pretest performance of the participants reached the "low-numerate" level ($\bar{x}=15.95$, $SD=3.30$), while the participants' numeracy skills posttest performance reached the "numerate" level ($\bar{x}=23.27$, $SD=3.21$). As seen in the table, the participants' level of numeracy skills posttest performance is greater than their pretest performance. There was an increase in the participants' posttest performance of 7.32. The result of this study is consistent with Wallit (2016) that participants’ posttest performances in the first and second quarters are higher than the pretests. Hence, integrating a structured intervention program helps improve participants’ posttest scores.

Table 5 shows the significant difference in the participants’ pretest and posttest performances in the numeracy skills assessment grouped according to their sex. The results of the numeracy skills pretest performance show that females *($\bar{x}$=16.43, SD=3.03)*, with an interpretation level of “low-numerate”, had better performance than males *($\bar{x}$=15.51, SD=3.48)*, with “low-numerate” level performance. Concerning the posttest performance, females *($\bar{x}$=24.06, SD=3.22)*, with the “numerate” level, still have better performance than males *($\bar{x}$=22.57, SD=3.04)*, with the “low-numerate” level. Similar findings were found in the study of Heyder et al. (2019) that in terms of natural math brilliance, females have stronger mathematical ideas than males.

Table 5

Test of difference in the participants’ pretest and posttest performances in the numeracy skills assessment when grouped according to their sex

Sex	Mean, SD	Interpretation	z	P-value	Decision	Interpretation
Pretest						
Male	15.51±3.48	Low-numerate	-1.75	0.08	Failed to reject the null hypothesis	Not significant
Female	16.43±3.03	Low-numerate				
Posttest						
Male	22.57±3.04	Numerate	-2.84	0.00	Reject the null hypothesis	Significant at 0.01
Female	24.06±3.22	Numerate				

Legend: 31.00 – 40.00 highly numerate, 21.00 – 30.99 numerate, 11.00 – 20.99 low-numerate, 1.00 – 10.99 non-numerate

The results of the independent z-test show that there is no significant difference between the male and female numeracy skills pretest performances *(z=-1.75, p=0.08)*. It signifies that the numeracy skills performance of both male and female participants in the pretest does not vary. It means that pretest numeracy skills performance level of the participants was the same. In addition, there is a significant difference between the male and female numeracy skills posttest performances *(z=-2.84, p<0.001)*. It signifies that the numeracy skills posttest performance of the two sexes was statistically significantly different at the 1% level of significance.

Table 6 shows the significant difference in the participants' pretest and posttest performances in the numeracy skills assessment grouped according to their age. The results on the participants' numeracy skills pretest performance show that 16-year-old participants obtained the highest mean *($\bar{x}$=17.08, SD=3.55)*, with interpretation "low-numerate" level, while 13-year-old participants got the least mean *($\bar{x}$=15.52, SD=3.43)*, with interpretation "Low-numerate" level performance. On the other hand, the participants' numeracy skills posttest performance showed that 13-year-old participants obtained the highest mean *($\bar{x}$=24.16, SD=3.42)*, with interpretation "numerate" level, while 17-year-old and above participants got the least mean *($\bar{x}$=22.00, SD=0)*, with interpretation "numerate" level.

Table 6

Test of difference in the participants' pretest and posttest performances in the numeracy skills assessment when grouped according to their age

Age	Mean, SD	Interpretation	F	P-value	Decision	Interpretation
Pretest						
12 years old	16.00±0	Low-numerate	5.49	0.36	Failed to reject the null hypothesis	Not significant
13 years old	15.52±3.43	Low-numerate				
14 years old	15.56±3.43	Low-numerate				
15 years old	16.86±2.78	Low-numerate				
16 years old	17.08±3.55	Low-numerate				
17 years old and above	17.00±2.83	Low-numerate				
Posttest						
12 years old	23.00±4.36	Numerate	8.71	0.12	Failed to reject the null hypothesis	Not significant
13 years old	24.16±3.42	Numerate				
14 years old	22.87±3.04	Numerate				
15 years old	23.39±3.48	Numerate				
16 years old	22.58±2.19	Numerate				
17 years old and above	22.00±0	Numerate				

Legend: 31.00 – 40.00 Highly Numerate, 21.00 – 30.99 Numerate, 11.00 – 20.99 Low-numerate, 1.00 – 10.99 Non-numerate; Significant if $p < 0.05$

The results of the one-way ANOVA show that there is no statistically significant difference in the participants' pretest and posttest performances in the numeracy skills assessment grouped according to their age. It signifies that participants' pretest and posttest performances in numeracy skills in terms of their age do not vary *($p>0.05$)*. The study's result was supported by Kadosh et al. (2013), who found that mathematical age *(p>0.05)* and chronological age *(p>0.05)* did not differ across the groups. Kadosh et al. integrated the "Catch Up" intervention to increase the numerical abilities of their participants.

Table 7 presents the test of difference between the participants' pretest and posttest performances in the numeracy skills assessment. The results of the dependent z test show that there was a significant difference between the numeracy skills pretest and posttest performances of the participants *(z=-11.38, p<0.001).* Therefore, the null hypothesis was rejected. The results indicate that the intervention program—Project COUNTS—implemented by the researchers and select school mathematics teachers was effective. It was further confirmed by the effect size using Cohen's D *(2.47)* that the program's usefulness reached a large effect.

Table 7

Test of difference between the participants' pretest and posttest performances in the numeracy skills assessment

Test	Mean Difference	Effect Size (D)	z	P-value	Decision	Interpretation
Numeracy Skills Pretest and Posttest Performances	7.32	2.47 (Large)	-11.38	< 0.001	Reject the null hypothesis	Significant at 0.01

Legend: Significant if p < 0.01; 0.2=Small Effect, 0.5=Medium effect, 0.8=Large effect

The result is consistent with the findings of Mononen et al. (2014), Clarke et al. (2018), Frazier's (2019), Layug et al. (2021), Perez (2023), and Hunter et al. (2016) confirming that application of intervention program to improve numeracy skills is effective.

5. Conclusions and Recommendations

The findings revealed that the numeracy skills pretest performance showed that females had better performance than males, although they belong to the common category, which is Low-numerate level. Concerning posttest performance, females still have better performance than males. This study concluded that there was no significant difference between the male and female numeracy skills pretest performances. Hence, the null hypothesis was retained. Meaning, the numeracy skills performance of both male and female participants in the pretest was not different. Meanwhile, there was a significant difference between the male and female numeracy skills posttest performances. Thus, the null hypothesis was rejected. It signifies that the numeracy skills posttest performance of the two sexes was statistically significantly different with the application of COUNTS. Additionally, the results on the participants' numeracy skills pretest performance showed that 16-year-old participants obtained the highest mean, while 13-year-old participants got the least mean. On the other hand, the participants' numeracy skills posttest performance showed that 13-year-old participants obtained the highest mean, while 17-year-old and above participants got the least mean. The results show that there was no statistically significant difference both in the participants' pretest and posttest performances in the numeracy skills assessment grouped according to their age. So, the null hypothesis was retained. Hence, the numeracy skills of the participants remain the same regardless of age with or without the application of COUNTS. Lastly, the findings revealed that there was a significant difference between the numeracy skills pretest and posttest performances of the participants. Therefore, the study rejected the null hypothesis, indicating the effectiveness of the intervention program—Project COUNTS—implemented by the researchers and select school mathematics teachers. The researchers' implementation of the intervention program—Project COUNTS—alongside select school mathematics teachers proved to be effective. The effect of Project COUNTS was further confirmed by the result of Cohen's D for effect size, which shows that the applied program reached a large effect.

The statistically significant difference in the numeracy skills pretest and posttest performances of the learners indicates the true effectiveness of the intervention program applied by the select teachers and researchers. Thus, school heads, supervisors, and higher officers in the DepEd may consider adopting or applying Project COUNTS as an intervention program in schools to improve students' numeracy skills. Teachers may extend efforts in distributing and collecting the learners' intervention materials and outputs. They, especially the mathematics teachers, may adopt or adapt the Project COUNTS intervention program for their students with very low performances in the numeracy skills assessment. They may collaborate with or seek assistance from their co-teachers in mathematics on how to apply the intervention program to their participants.

This study is limited to the demographic profile of the respondents in terms of sex and age, and the numeracy skills pretest and posttest performance. The respondents were limited to 175 low- and non-numerate grade 8 and 9 students who were enrolled at GNHS in

2020–2021. Hence, future researchers may apply the same intervention program to different respondents and grade levels at different locales. They may expand the number of participants to validate the effectiveness of the program and include other demographic characteristics as research variables. A quasi-experimental study is also suggested if they find it hard to randomly select their respondents.

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Multisensory supplementary instructional material in earth and space science

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Abstract

This study determined the effect of the developed multisensory supplementary instructional material in enhancing scientific knowledge of grade 9 learners. Moreover, the study assessed significant difference between the pre-and post-assessment scores of the learners who used the instructional material and the significant relationship between the perceived acceptability of the multisensory supplementary instructional material and the students' level of scientific knowledge. Using descriptive-developmental research, it involved 30 grade 9 students during the school year 2022-2023. A cognitive diagnostic test in terms of remembering, understanding, applying, analyzing, evaluating, and creating was used to identify the least-mastered competency among the topics. Pre- and post-assessment, which measured the scientific knowledge of the students, went through internal and external validation of the panel of examiners and group of teachers. Results revealed a significant difference between the pre-and post-assessment scores of the students as to content and epistemic knowledge whereas there is no significant difference found in the procedural knowledge. It can be inferred that the students enhanced their scientific knowledge after the utilization of the multisensory supplementary instructional material. However, there is no significant relationship obtained between the students' perception on the acceptability of the material to their level of scientific knowledge.

Keywords: *multisensory supplementary instructional material, least-mastered competency, scientific knowledge, learning preferences*

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1. Introduction

The Philippine Department of Education (DepEd) established a new standard at the aftermath of the pandemic dubbed as *"new normal in education*" which utilize both modular and face-to-face classes to further address the issues and concerns on health and safety and educational concerns of every student. This ensure learning would be available, pertinent, and maintain its quality regardless of the circumstance. Hence, pupils were taught via modular distance learning, particularly in remote locations with little to no internet access. However, several studies argued the effect of modular distance learning, emphasizing its effectiveness (Roque, 2022; Serrano & Farin, 2022; Boholano et al., 2022; Fernandez, 2021; de Ocampo, 2023; Lachica & Pineda, 2023; Tanucan et al., 2023; Aksan, 2021; Capinding, 2022; Villanueva & Campos, 2022) and ineffectiveness (Dangle & Sumaoang, 2020; Dargo & Dimas, 2021; Bustillo & Aguilos, 2022; Talimodao & Madrigal, 2021; Cajurao et al., 2023) in achieving the subject learning outcomes. Despite the varying degree of agreement and disagreement on the modular system, many studies still recommend development of contextualized learning materials (Aviles et al., 2021; Kaminski & Sloutsky, 2020) to help students learn better (Jou et al., 2022; Humana & Rahmat, 2022; Suryawati & Osman, 2018; Manjares & Pasia, 2023) and facilitate systematic teaching and learning process (Garcia et al., 2022; Astrero et al., 2020; Ambrose et al., 2013; Johar et al., 2018; Manlunas, 2022). Hence, in the Philippines, development of contextualized learning module is still highly encouraged.

One of the common subjects in school that is highly contextualized based on the needs of students in the module distance learning is science. Researchers and educators alike believe that students will be able to comprehend things more thoroughly through the use of appropriate and readily available materials (Dunlosky et al., 2013; Frimpong, 2021). The availability of textbooks, proper chalkboards, mathematics kits, science kits, teaching guides, science guides, audio-visual aids, overhead projectors, and other materials is one of the most important components of the instruction-learning process (Bukoye, 2018). It is imperative that teachers provide their students with resources outside of textbooks when teaching science; these resources might include a range of educational tools that would surely improve the students' understanding of the material. According to Munna and Kalam (2021), while traditional teaching techniques like lectures, textbook discussions, and the like are valuable and ought to be employed in the classroom, educators also need to modify their methods to fit the requirements of each individual student. Hence, teachers should also incorporate a variety of strategies into every part of their education to accommodate the different learning styles of their pupils.

Since innovative flexible learning practices have been shown to improve students' learning results (Müller et al., 2023; Kariippanon et al., 2019; Müller & Mildenberger, 2021), several schools throughout the world have already replaced conventional classroom arrangements with them (Kim, 2020). In the flexible learning, students should be provided with additional support in the form of relevant study materials in order to fill any gaps in the learning process. Similarly, teachers are highly encouraged to create supplemental instructional materials to help students fill in the gaps between modular learning to in-person sessions specifically with students' limited and insufficient resources. This will help students stay on track and recover from their previous learning.

Given the effectiveness of contextualized learning materials and the necessity of flexible learning practices, this study aimed to create and validate supplemental multimodal educational material to help students grasp science more deeply and to advance their scientific knowledge. Through a variety of exercises aligned with the least-mastered competencies, this study identifies potential improvements in the learners' performance.

2. Literature Review

2.1 Multisensory Supplementary Instructional Material

It is imperative for every teacher to develop instructional materials that will boost students' understanding and will encourage them to do more in science. According to Hofstein and Naaman (2018), pupils cannot understand science unless they have worthwhile practical experiences in the school laboratory. Without significant hands-on experiences in the classroom laboratory, science cannot be engaging to pupils. Hence, the K–12 basic education courses must utilize the pupils' 21st-century skills including information, media, technology, life, and professional skills, as well as learning and innovation skills. For this, Suarez (2018) suggests that usage of particular learning materials coupled with appropriate teaching styles were capable of developing learning capabilities of students. These abilities could differ from discipline to discipline and could be cultivated through particular techniques based on the subject and the technique.

It has been demonstrated that using multimodal instructional materials is a successful teaching method across a variety of subject areas. According to Shams and Seitz (2013), multisensory learning strategies can more closely replicate real-world situations and are therefore superior for learning. Mayer (2014) suggests that incorporating multiple sensory modalities into instructional materials can enhance student learning. Therefore, while it may not be necessary to tailor instructional materials to individual learning preferences, it is beneficial to include a variety of sensory modalities to engage students and promote learning.

Researchers from several fields have noted various advantages of using a multisensory approach. According to Manches (2011), using manipulatives—both real-world and virtual—such as multisensory technologies—allows students to effectively articulate what they have learned. Through role playing, materials that are commonly used, and other practical ways, students get familiar with fundamental abilities. They can thus better understand real-world problems through multisensory approach exercises, preparing them for a variety of careers, vocations, and other platforms for skill exhibition. The students satisfy their desire to learn through a variety of senses, including constructing models, learning through manipulatives, adding depth to scenes, collaborative learning techniques, discussion, and demonstrations. Thus, the use multisensory materials are cushion to learners with learning needs.

According to Obaid (2013), when teachers use multisensory instruction in their classroom, they are teaching the students to link letters with the written symbol. Multisensory activities are based in learning by whole brain that means, the best way to teach concepts is through the involvement of multiple areas in the brain. This is done through adding auditory or visual components to reading assignments, like pictures, illustrations or even online activities. In this manner, you can help students develop stronger and increased literacy skills. This has been manifested in the study of Davidson and Wesimer (2014), when children had improved performance after receiving instruction using a multisensory approach that relied on visual, auditory, kinesthetic, and tactile activities. Similarly, Li and Li (2020) found that the students who received multisensory instruction demonstrated significantly greater gains in content knowledge and higher levels of engagement.

2.2 Least Mastered Competencies

In the Philippines, teachers need to look attentively at the least-mastered competencies (LMC) in the Basic Education Curriculum for Grades K–12. The LMC is one of the pillars on the revision of the current curriculum. In 2018, just before the health crisis broke out, as part of the Quality Basic Education reform plan and a step toward internationalizing Philippine basic education, the Philippines participated in PISA for the first time on behalf of the Organization for Economic Co-operation and Development (OECD). The country's fifteen-year-old children scored lower in reading, math, and science than students in most of the countries and economies that took part in PISA 2018. In the Philippines, 22% of pupils achieved Level 2 or higher in science. These pupils are able to recognize the proper explanation for common scientific events and can apply this knowledge to determine whether a conclusion is valid based on the evidence presented in simple scenarios. In science, hardly no student was a top performer, indicating they were proficient at Levels 5 and 6. These kids may apply their knowledge of and about science in a variety of ways, independently and imaginatively (OECD, 2018).

Learning difficulties are frequently caused by students' poor understanding of the material, particularly biology. According to Chinyere et al. (2020), helping students increase their understanding of subjects like biology is the most difficult task for teachers. Pupils' prior knowledge, intelligence, and motivation have an impact on these challenges. However, the teaching-learning process is at the control of the teachers. Cabual (2021) reiterates that learners have different learning pace, they learn through various activities and their unique differences and qualities became a factor that makes a teacher think of their strategies. Their different learning strategy challenges the teacher to think of techniques and approaches that promotes an increased academic performance in science and a decreased number of least-mastered competencies.

2.3 Scientific Knowledge

School closures and learning loss during the health crisis can have a long-term negative impact on the current cohort of school children (Engzell et al., 2021; Brackx et al., 2023; Hairol et al., 2023). Global evidence from past health and disaster-related emergencies show that the impact extends well beyond the period of the disaster or pandemic. It is also likely to affect the children's economic potential and productivity in adulthood, thus undermining the country’s competitiveness (Cho et al., 2021). To be able to adapt to the demands of a rapidly changing world, scientific knowledge is a must. This focus aligns scientific literacy with the growth and development of life skills. It distinguishes the need for intellectual ability in a social context, and it further specifies that everyone should be literate in science. This suggests being concerned with social demands, learning how to handle societal conflicts, and arriving at wise decisions (Yates & de Oliveira, 2016). According to Bang (2015), learning about people and the natural world is the major goal of studying science. Hence, it combines previous knowledge with new knowledge while also learning more about the fundamentals of life. Additionally, it is to make recommendations for how to integrate it into the formal education system (Sotero et al., 2020).

Scientific knowledge is very significant for an individual (Radder, 2017) although frequently used but rarely defined (Miller, 1983). The phrase "scientific knowledge" refers to both a state of mind and a body of knowledge of science and technology (PISA Assessment and Analytical Framework, 2018) that involves comprehension of scientific concepts and procedures necessary for independent judgment, involvement in civic and cultural activities, and economic output (Palines & Ortega-Dela Cruz, 2021). Understanding of scientific principles, events, and procedures, as well as the capacity to use this knowledge in novel and, occasionally, non-scientific contexts (PISA, 2018). The three types of knowledge assessed in PISA include content, procedural and epistemic knowledge.

Science literacy is vital because it provides a context for solving societal issues, and because a science-literate population can better cope with many of these issues and make educated and informed decisions that will affect their lives and the lives of their children. This includes the development of skills that can be employed in all learning areas, such as problem-solving skills, using technical terms, or applying scientific concepts and processes. Therefore, the ability to use scientific evidence is considerably more crucial than having a thorough comprehension of it. Because science touches all part of our lives, it is essential to be scientifically educated (Ajayl, 2018).

1.4 Learning Preferences

Science education has long been seen as the ultimate goal of all institutions of learning, from primary to higher education. In order to create a culture that is more advanced and evolved, educators and students have realized how important it is to teach and study about science. In order to effectively teach science courses and ensure that students obtain the skills they need to be lifelong learners, a variety of strategies, methods, and approaches have been developed over time.

Every adolescent is unique and should be taught according to his/her style of learning. Briggs and Myers (1975) put focus on the consideration of student's individual learning style in an effective teaching-learning process. Previous studies support the use of various teaching methods in order to satisfy variability of students' learning styles within educational programs (Brown et al., 2001; Alhourani, 2021; Kharb et al., 2013; Ridwan et al., 2019; Romanelli et al., 2009; Singh et al., 2016; Renzulli & Sullivan, 2009). However, researchers disagree that teachers need to alter any teaching methodology that best fit learning style of each student as learner can easily adapt to any teaching style (Prajapati et al., 2011). There would be no enhancement in academic performance by matching teaching style and student's learning style preferences (İlçin et al., 2018).

Learning style refers to the variations that people have in their approaches to learning (Rayner, 2001). The capacity to modify lessons to account for the unique characteristics of each student is crucial to educational success. In addition to understanding the value of teaching utilizing a variety of learning styles, a teacher should be providing an atmosphere that meets the needs of the students' diverse learning preferences. Understanding a student's learning style provides information about their unique preferences. It can be easier to build, modify, and develop curriculum and educational programs that are more effective when learning styles are understood. In order to enhance learning outcomes, it is crucial to assess students' preferred methods of learning (Brown et al., 2001).

According to Basit (2017), a student's learning style focuses more on how they learn during the learning process than on the subject matter being covered. Each student has a unique set of skills and preferences about how to gather and process data. Some students learn better while using visual media, such as reading. Some students may learn more effectively verbally by listening to lectures given in person, while others may learn more effectively by participating in class activities and applying what they have learned. In the study of Umali and Chua (2020), active learning approaches may help teachers gain educationally sound ideas and strategies to improve learning, teaching and assessing in a modularized context. Students, on the other hand, who will be exposed to the learning approaches may experience varied learning activities that will enhance their thinking skills.

Hence, teachers can identify and distinguish learner’s preferences (Nilson, 2015; Mustafa, 2021).

The VARK model of students' learning styles developed by Neil Fleming and Baume (2006) is extensively used by researchers. The abbreviation VARK stands for Visual, Auditory, Reading/Writing Preference, and Kinesthetic. According to the paradigm, students' various methods of information interpretation are referred to as "preferred learning modes." For accessing and comprehending new knowledge, the visual learning style favors images, maps, and graphic organizers. Auditory learners benefit from speaking and listening during lectures and group discussions because it helps them comprehend new content. Mnemonics are helpful for students, and repetition is a useful study technique. The read-and-write learning style benefits most from verbal learning. These pupils may exhibit extensive note-taking or reading habits and transform abstract ideas into written works. Information is better understood by kinesthetic learners when it is presented tactilely. These pupils are active learners who learn best by doing things themselves (Ameer & Parveen, 2023).

According to Cardino and Ortega-Dela Cruz (2020), learning styles play a crucial role in how teachers demonstrate their students' understanding of the material. Rezaeinejad et al. (2015) assert that identifying the students' learning styles will enable the teacher present the lesson that students can cope with easily, make varied teaching tactics, and lead to their academic accomplishment. However, additional elements including sex, gender, and personality as well as heritage, breed, and environmental influence may also have an impact on learning styles. Peers, schools, communities, and cultures can all have an impact on this.

3. Methodology

This study used descriptive-developmental research design to determine the effect of multisensory supplementary instructional material in enhancing scientific knowledge of Grade 9 students in science. Developmental research, as opposed to simple instructional development is described by Richey and Nelson (2001) as the systematic study of designing, developing, and evaluating instructional programs, processes and products that must meet the criteria of internal consistency and effectiveness.

The respondents of the study were the 30 Grade 9 students of an integrated school in the Philippines for the School Year 2022-2023. On the other hand, the experts who corroborated the multisensory supplementary learning materials were composed of one master teacher, one head teacher from secondary public schools, two JHS science teachers from secondary public schools and one Grade 10 science subject teacher, one science coordinator, one teacher for English, and one ICT coordinator. There were eight expert respondents who validated the developed multisensory supplementary learning material.

The study used different instruments to gather data and information, which include survey questionnaire, cognitive diagnostic test, lesson exemplar and pre-and post-assessment tests. The survey questionnaire was adapted from the University of California (2006) to assess the students' learning preferences and learning challenges at home that would help in the development of the instructional material. The lesson exemplar focused on the topic "demonstrate the identification of constellations throughout the year using models," extracted from the K to 12 Grade 9 Module during the third grading period. The 50-item cognitive diagnostic test was adapted from Zamboanga Del Norte National Highschool. From the least-mastered competencies identified from the cognitive diagnostic test, the multisensory instructional material was developed. Lastly, the 30-item multiple-choice pre-assessment and post-assessment were developed based on a table of specification reflecting the learning competencies. Questions were aligned with the PISA framework, covering content, procedural, and epistemic knowledge. Clear directions were provided to prevent confusion among respondents. The pre-assessment was given before the utilization of the developed instructional material whereas the post-assessment was given after the exposure to the material.

To ensure the validity and reliability of the instruments, both internal and external validation processes were conducted. The instruments were scrutinized by a panel of experts, including the researcher's adviser, subject specialist, statistician, and technical editor, during the internal validation. All corrections and recommendations from the panelists were incorporated into the final version of the instruments.

4. Results and Discussion

Table 1 shows students' science performance before the intervention. This shows that a total of 30 students were assessed using a grading scale with four categories; 10% of the students are in the outstanding level on the first quarter then percentage decreased to 3.33% on the second quarter period. It also shows that most of the students are in the fairly satisfactory level. It means that the student has demonstrated a level of understanding and competency in the subject matter that is deemed satisfactory by the teacher based on the criteria set by the curriculum.

Table 1

Students' performance in science

Grade	First Quarter			Second Quarter		
	f	**%**	**Level**	**f**	**%**	**Level**
90-100	3	10	O	1	3.33	O
85-89	7	23.33	VS	7	23.33	VS
80-84	9	30	S	8	26.67	S
75-79	11	36.67	FS	14	46.67	FS

Legend: 74 and below [Did Not Meet Expectations]; 75-79 [Fairly Satisfactory(FS)]; 80-84 [Satisfactory(S)]; 85-89 [Very Satisfactory(VS)]; 90 and above [Outstanding(O)]

This grade range indicates that the student has achieved a level of proficiency that meets the minimum standard for the subject, but there is still room for improvement. On the other hand, it was evident that the majority of students were performing at a lower level during the second quarter, indicating that there is a learning gap being displayed by the pupils.

Table 2

Learning preferences of the students

Learning Preference	Mean Score	SD
Visual	24.00	5.61
Auditory	24.53	3.76
Kinesthetic	25.33	3.06
Read/Write	25.57	2.74

Legend: 32-24 (Highly Preferred); 23-16 (Moderately Preferred); 15-8 (Slightly Preferred); 8-0 (Not Preferred)

Table 2 shows the learning preferences of the students. According to the mean scores, the students like read/write learning methods slightly more than auditory, kinesthetic, and other learning methods. Additionally, their preference for visual learning is a little bit lower.

This implies that in order to properly deliver their lectures, teachers should consider the various learning preferences of their pupils. They can adapt their teaching methods to fit a variety of learners' learning preferences by including written materials, interactive exercises, and visual aids. This can improve students' comprehension and retention of the lesson and foster motivation and interest in learning to consider a variety of instructional strategies to meet their needs. The results led to the design and development of a multisensory instructional that would cater the various learning preferences of the students.

Table 3

Diagnostic test mean scores of the students as to cognitive domain

Domain	Mean	SD	Remarks
Remembering	76.00	1.770	Unsatisfactory
Understanding	78.83	9.370	Unsatisfactory
Applying	72.89	7.083	Poor
Analyzing	76.33	7.630	Unsatisfactory
Evaluating	74.52	6.485	Poor
Creating	71.73	8.193	Poor

Legend: 74 and below (Poor); 75-79 (Unsatisfactory); 80-84 (Satisfactory); 85-89 (Very Satisfactory); 90 and above (Outstanding)

Table 3 shows the mean scores of the students in the diagnostic test as to cognitive domain. It reveals that students have unsatisfactory result from the domains remembering, understanding and analyzing. The data showed that students were not able to remember concepts, definitions, names and series of events. Moreover, they may have difficulty identifying patterns or relationships between the stars in the constellation, or breaking down the topic into its constituent parts. Additionally, they are in the unsatisfactory level on the understanding domain because they cannot explain the concepts and theories about constellation using their own words. The result also showed that they are poor in the cognitive domains applying, evaluating and creating. This means that the students are poor in applying a particular context or situation to solve problems or complete tasks, they also have difficulty in combining and reorganizing the information of constellation in a novel way to form a new whole. They failed to make judgments about the topics discussed. Through this, the multisensory supplementary instructional material was designed and developed.

Table 4

Pre and post-assessment performance of the students as to scientific knowledge

Scientific Knowledge	Pre-Assessment			Post-Assessment		
	Mean	SD	Level	Mean	SD	Level
Content Knowledge	79.89	8.498	*D*	85.56	3.784	*P*
Procedural Knowledge	78.79	5.178	*D*	80.24	4.472	*AP*
Epistemic Knowledge	79.47	4.972	*D*	82.00	2.896	*AP*

Legend: 74 and below [Beginning (B)]; 75-79 [Developing (D)]; 80-84 [Approaching Proficiency (AP)]; 85-89 [Proficient (P)]; 90 and above [Advanced (A)]

Table 4 summarizes the students' pre-assessment and post-assessment performance. This shows that on the pre-assessment performance of the students, all of them are in the developing level in terms of content, procedural and epistemic knowledge. During the conduct of the pre-assessment test, majority of the respondents have least information about the topic. This suggests that based on the legend, the students struggle with understanding the topics being introduced, prerequisite and fundamental knowledge and/or skills have not been acquired or developed adequately to aid understanding. On the other hand, after the utilization of the designed and developed material, the students improved and increased their scientific knowledge scores from developing to proficient and approaching proficient level. Both in the procedural and epistemic knowledge, the students developed fundamental knowledge and skills as well as core understandings of the topics, however, they still need the guidance and assistance from the teachers and peers, yet they can transfer what they learned through authentic performance tasks. In the content knowledge, the students developed knowledge and skills and can transfer their understandings through different performance task with no guidance from the teachers and peers.

Table 5 summarizes the test of difference in the level of scientific knowledge of the students before and after the use of the multisensory supplementary instructional material. Paired t-test was employed to determine if there is a significant difference between the pre-assessment and post-assessment scores of the students as exposed to the multisensory supplementary instructional material. It reveals that upon the exposure of the students in multisensory instructional materials, significant improvements occurred in their content and epistemic knowledge.

Table 5

Test of difference in the level of scientific knowledge before and after the use of the multisensory supplementary instructional materials

Scientific Knowledge	Pre		Post		Mean Difference	t	df	Sig. (2-tailed)
	Mean	SD	Mean	SD				
Content Knowledge	79.89	8.50	85.56	3.78	5.67	3.42	29	.002
Procedural Knowledge	78.79	5.18	80.24	4.47	1.45	1.12	29	.272
Epistemic Knowledge	79.47	4.97	82.00	2.90	2.53	2.66	29	.013

*Difference is significant at the 0.05 level

During the execution of the lesson, the students participated well in the discussion. It has been observed that the students gain deeper facts, concepts, ideas, and hypotheses about the topic. The multisensory instructional materials helped students to make connections between the information they were learning to use multiple senses to process and remember the information. These also allowed them create assertions and meaning of key words like theory, hypothesis, and data. During the conduct of the study, they were able to work independently, they listened to the instruction by scanning the generated QR code. Moreover, they may listen and revisit the lesson multiple times by accessing the link of the uploaded video lesson on YouTube. Manches (2011) confirms that the use of manipulatives, both materials and virtual type such as multisensory technologies offered a suitable enabler to students to express their learning. Students are acquainted with basic skills using the role plays, materials of common use and other practical methods.

However, table shows that there is no significant difference in the pre-assessment and post-assessment scores in the procedural knowledge after the use of the multisensory instructional materials. During the conduct of the study, it was observed that the students are exposed to the material once and covered only one competency thus resulting to insufficient practice which may hinder motivation and engagement with the procedures. Additionally, limited transferability of procedural knowledge to different contexts may also be a cause to limit improvement. Finally, a lack of timely feedback and opportunities for reflection may also hindered learners' ability to identify areas for improvement. This supports the findings of

Suarez (2018) that the usage of particular learning materials and teaching styles were capable of developing learning capabilities.

Table 6

Test of correlation between the level of acceptability of the multisensory supplementary instructional material to the students' level of scientific knowledge

Scientific Knowledge	**Multisensory Supplementary Instructional Material**		
	Intellectual	**Life Skills**	**Affective Dev't**
Content Knowledge	-.099	.210	.137
Procedural Knowledge	-.174	-.089	.301
Epistemic Knowledge	-.045	.121	.281

**Correlation is significant at the 0.01 level (2-tailed).

Table 6 summarizes the test of relationship between the perceived level of acceptability of the multisensory supplementary instructional material to the level of students' scientific knowledge. It utilized Pearson Moment Product Correlation to find the significant relationship among variables and was tested at 5% level of confidence.

It can be observed that after the exposure to the multisensory supplementary instructional materials, students' science performance was improved, students were able to develop critical thinking skills by working independently. They were able to answer the guide questions through watching the uploaded video lesson on YouTube using the tablets assigned to them. This confirms the findings of Umali and Chua (2020) that remembering and understanding sub-skills in lower order thinking skills is greatly enhanced using collaborative approach. Through the use of multisensory kit, they were able to remember the different patterns of each constellation, they also identified some on a night sky and were able to film it as well. It is understood that their science performance increased, however their perception on the acceptability of the material has no bearing to their scientific knowledge.

Findings from this study reveal that while multisensory supplementary instructional materials exhibit the potential to enhance learning experiences, their correlation with the level of scientific knowledge is nuanced. The impact of these materials varies based on factors such as design, quality, and integration into the learning process, underscoring the significance of well-planned implementation. The research emphasizes the diversity in learning styles, indicating that the effectiveness of multisensory approaches is contingent on individual preferences. Some learners derive substantial benefits, while others may not find them as effective, highlighting the inadequacy of a one-size-fits-all approach. This underscores the need for personalized and flexible educational strategies. Furthermore, the correlation between the use of multisensory materials and scientific knowledge acquisition is influenced by the specific content being taught. The study identifies that certain scientific concepts lend themselves well to multisensory approaches, whereas others may not necessitate or significantly benefit from such materials.

In the context of effective teaching methods, the study underscores that instructional materials alone, even when multisensory, cannot guarantee improved learning outcomes. Teacher expertise, instructional strategies, and the classroom environment emerge as pivotal factors in shaping scientific knowledge, emphasizing the holistic nature of effective pedagogy. In conclusion, this study contributes insights that advocate for a nuanced and context-specific approach to the integration of multisensory materials in education, recognizing their potential benefits while highlighting the importance of considering various factors for optimal learning outcomes.

The execution of the material once may also be a reason. However, for optimal results and a deeper understanding, it is essential to encourage further exploration and engagement with the material. This can be achieved through repeated exposure, hands-on experiences, and varied learning opportunities. By providing opportunities for students to revisit the material, apply their learning in different contexts, and engage in collaborative activities, a more comprehensive understanding and mastery of the subject matter can be achieved. Therefore, while the initial execution of the material is crucial, the subsequent exploration and continued engagement with the content lead to the best results.

5. Conclusion

This study found that students highly preferred the use of visual, auditory, kinesthetic, and read/write learning modalities. Thus, learning preference variation is observed. The extent of acceptability of the developed multisensory supplementary instructional materials in terms of design elements and material content are highly acceptable. The students' perception on the acceptability of the developed multisensory supplementary instructional materials as to intellectual skills, life skills, and affective development were highly acceptable. The result of the post-assessment scores of the students in terms of content, procedural and epistemic knowledge were statistically higher than their pre-assessment scores. The study also indicates that there is a significant difference between the pre-assessment and post-assessment scores of students in their level of scientific knowledge as to content and epistemic knowledge, whereas there's no significant difference between pre-assessment and post-assessment scores of the students in terms of procedural knowledge. Thus, the null hypothesis is partially sustained. However, there is no significant relationship found between the perceived acceptability of the multisensory supplementary instructional material and the students' level of scientific knowledge. Thus, the null hypothesis is sustained.

Since the study revealed that the use of multisensory supplementary instructional materials strengthens and increases students' scientific knowledge, and has a positive impact on students' learning outcomes, it is recommended that school administrators, teachers, and students initiate the use of the material. With the utilization of the multisensory supplementary instructional material once, future researchers may conduct a study investigating why there is no significant difference obtained based on the pre- and post-assessment scores of the students in terms of procedural knowledge after the utilization of the multisensory supplementary instructional material. They may modify the multisensory supplementary instructional material to better fit with the lesson in other quarters or grade levels. They may also modify by adding more challenging activities that will promote feedback and communication with other people.

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