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Long Paper

Chemistry Inquiry-Based Lessons to Enhance Learning of Students with Multiple Intelligences

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Abstract

This study aimed to develop inquiry-based lessons intended for junior high school classes undertaking chemistry subjects anchored on multiple intelligences. The study employed the descriptive-developmental method of research for three homogenous classes of Grade 10 enrolled in the school year 2016 – 2017 using the teaching materials innovated by the researchers. The effects of the developed inquiry lessons for multiple intelligences groups were tested using the standardized achievement test, Science Process Skills Inventory, and the Science Motivation Questionnaire for the attitude of students toward science in terms of motivation. Based on the analysis of the gathered data in the study, it was found that the students' dominant intelligence varied across multiple intelligences groups: Interactive, Analytical, and Introspective. The developed lessons where the science-inquiry approach was applied were focused on the seven chemistry topics: Kinetic Molecular Theory, Boyle's Law, Charles' Law, Gay-Lussac's Law, Combined Gas Laws, Avogadro's Law and Biomolecules in 7E's format. More basic process skills than integrated process skills were manifested. The developed inquiry lessons for multiple intelligences made a difference in the level of conceptual understanding but did not satisfy the 75% performance level in general. The attitudes developed by students in the conduct of the developed lessons of the respective groups were intrinsic motivation, career motivation, self-determination, self-efficacy, and grade motivation. With these, it is a must for a teacher to consider the occurrence of multiple intelligences among students in planning and delivering the lessons. Opportunities in developing science process skills must be given to the students in any possible part of the lesson. Constant usage of varied science hands-on activities must be provided to students to develop their conceptual understanding, science process skills, and attitude toward science.

Keywords – multiple intelligence, inquiry approach, academic performance, science process skills, motivation

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INTRODUCTION

Every individual is an asset to the nation as the main source of improvement of the society and helps in the sustainability of culture and norms. Education, by far, is the key to eradicating poverty which has become the long - time running dilemma of society. Yet, sociologists uphold the belief that it can bridge humans and life which implicates progress and changes in the society they live in. Based on much research literature, for learning to be meaningful a student should be engaged actively and personally in the educational process. One common problem for teachers is how to make students self-motivated toward learning new things. One way of doing this is to anchor science lessons into students' individualism, teachers should know something about the students. One of these is the presence of multiple intelligences among students which has been a trending study in the field of education. It considers every learner unique and follows specific intelligence defined by Howard Gardner (1983). The distinct characteristics contribute to the totality of a person that determines how he thinks, feels, and behaves toward other people or a situation.

The researchers emphasized that aside from attitude, content and process skills goes hand-and-hand in science education. It is therefore rational to also pattern the class activities on the multiple intelligences of the learners since not all are capable of performing well in all types of process skills. It is not only how students think that it is important in a learning situation but also how well they do their tasks, especially in a procedural learning situation. Hence, this study aimed to develop inquiry-based lessons for multiple intelligences. Considering the nature of learners through multiple intelligences brings about the effectiveness of content learning which is reflected in academic performance. MI-based instruction is already used in e-learning, reading, biology, physical education, and others but there is no report that is used in teaching Chemistry topics, particularly about Gas Laws and Biomolecules. Moreover, there is no study conducted yet treating the multiple intelligences in their three categories (Interactive, Analytic, and Introspective).

The researchers would like to emphasize that knowledge, science process skills, and attitude are equally essential in science education. Backed up with the results of the study from the literature review, it is therefore rational to also pattern the class activities on the multiple intelligences of the learners since not all are capable of performing well in all the types of science process skills. Hence, this study aimed to develop inquiry-based lessons for the three categories of multiple intelligences (Introspective, Analytical, and Interactive) to enhance students' science conceptual understanding, science process skills, and science motivation in the selected Chemistry lessons.

The study is focused on the attainment of the following objectives:

1. To determine the multiple intelligences of students in terms of Introspective, Analytic, and Interactive intelligence;
2. To develop Multiple Intelligence-based Inquiry Lessons in Chemistry;
3. Determine the science process skills manifested by the students in the science inquiry lessons; and
4. Determine the effect of the developed science inquiry lessons on students' conceptual understanding, science process skills, and science attitude.

LITERATURE REVIEW

Inquiry-based Approach

Since 1960, the major concern among curriculum innovators around the globe in science teaching. The inquiry-based approach has been used across the discipline to engage learners actively in the learning process. Inquiry stimulates and reinforces students' imagination and curiosity. It plays an important aspect in the science curriculum across grade levels and in every component. With the use of the experimental results, students gain knowledge and/ or compare their previous knowledge with the new knowledge. Through the inquiry-based approach to learning, this can be easily attained where concepts and skills are developed and applied. Using this approach means integrating formulating hypotheses, group experimentation, collection and analysis of information, and product creation (Mello et al., 2019; Xenofontos et al., 2020). Aside from applications of the learned concepts, it is also the drive among teachers to let the students know that the subject matters they are learning are interconnected and interrelated and that the concepts and skills they have gained can be used in enhancing their learning in other related subject matters such as mathematics, social science, and technology and livelihood education.

Multiple Intelligences

The perspective and understanding of things around us are highly affected by intelligence which varies from person to person contributing to individual differences. This leads to our varying strengths and weaknesses in many aspects of life (Prasetyo, 2016). Another prominent psychologist, Howard Gardner, believes that every individual is unique in terms of the innate intelligence he possesses and this distinct intelligence is what makes a person different from others. It is believed that an individual does not possess only one intelligence. The Multiple Intelligences are claimed to affect the capability to think (in its cognitive domain) and how a person acts and feels towards others and in his environment. The study of Ahvan, et al. (2015) suggests that multiple intelligences highly contribute to students' academic performance. This is similar to the results of the study by Lei et al (2021) which emphasized that teaching with multiple intelligences would affect learning achievement and motivation and that learning motivation positively impacts learning achievement.

Science Conceptual Understanding

The term conceptual understanding is viewed both as a process and an ability to acquire and organize newly learned knowledge and use it for practical application. To optimize the student's ability for conceptual understanding, there have to be lots of factors to consider including both intrinsic and extrinsic factors. Intrinsic factors include but are not limited to interest in science learning, preference for learning science, and abilities. The study by Kim and Song (2009) suggests that an intrinsic attitude toward science exclusively triggers students' interest as well as conceptual understanding in physics subject. Hence, once the students have positive attitudes toward learning science, they learn science concepts better. Extrinsic factors, on the other hand, involve various science teacher interventions in delivering the lesson effectively to effect conceptual understanding such as in the study of Mahawan and Celedonio (2023) shows that computer-aided instruction enhanced students' conceptual understanding and mastery of learning competencies in life science as reflected in their test scores. An almost similar study to this current study by Blessing et al. (2021) revealed that using learning styles-based differentiated instruction has a significant effect on students' conceptual understanding compared to the conventional approach in instruction.

Science Process Skills

Science process skills are grouped into basic and integrated skills. Categorized under basic process skills are observing, inferring, measuring, communicating, classifying, and predicting while integrated process skills include controlling variables, defining operationally, formulating hypotheses, interpreting data, experimenting, and formulating models. In the case of Indonesia, Rini and Aldila's (2023) study found that there has been an assessment of science process skills in the learning institution but it is rarely done leaving less opportunity for the students to develop these skills specifically critical thinking skills. This proves that the science process skills are not given enough focus as the development of conceptual understanding and that it affects the ability of the learners to apply learned concepts. In the Philippines, the study of Tirol (2022) in science suggested that alignment of science process skills on the spiral progression of the topics must be given attention in the curriculum development after arriving at the conclusion that it is not spirally sequenced as the curriculum. On the other hand, teachers can modify learning resources to develop science process skills among students in science subjects. This is similar to the study conducted by Barquilla and Cabili (2021) wherein the enhanced developed module in GAS Laws not only developed and improved the students' 21st-century skills but also improved their conceptual understanding and academic performance level.

Attitude towards Science

For over the years of science education, among the knowledge, skills, and attitude that educators have to develop among students, attitude is the least explored aspect as to why and how attitude contribute to effective science learning thus, no direct evidence discuss the strong relationship between science attitude and achievement. To the findings of several studies, it is found that the use of simple tools in learning science creates positive attitudes among learners (Kirilmazkaya & Dal, 2022); science lessons being held in a science laboratory learning environment and learning motivation can predict how the students engage in science learning (Haw et al., 2022) and there is a positive and moderate relationship between students' attitude toward science and science learning achievement (Mao et al., 2021). These findings are significant because they may predict the findings of the current study on the use of various learning resources, the use of a science laboratory environment, and the effect of strengthening attitudes to students' science achievement.

METHODOLOGY

The study focused on how the developed Science Inquiry Lessons for Multiple Intelligences affected learners' achievement level, process skills, and motivation towards science from the three homogenous sections of 10th-grade students consisting of one hundred thirty-one (131) students in Donsol National Comprehensive High School-Sta. Cruz Extension. This study made use of a mixed-method approach which answered the problems of the study. The researchers developed lessons that catered to the multiple intelligences of the students and were implemented all throughout the classes, in which classes included in the study received and underwent the same treatment with the absence of control groups. A descriptive-developmental research design is employed in conducting the study. A descriptive research design was done in describing the distribution of the multiple intelligences of students in every class as well as the quality of the developed inquiry-based lessons which catered to the multiple intelligences of the students. The developmental research design was in line with the development and validation of the MI-based inquiry lessons in Chemistry. This was then followed by quantification of the rating obtained from the jurors who assessed and validated the developed lessons. For the quantitative research method, the researchers used the three survey questionnaires which are the Multiple Intelligences (MI) Inventory developed by McKenzie (1999), Science Process Skills Test adopted from Arnold et al. (2013), and the Science Motivation Questionnaire. Hence, the data were gathered through in-person surveys using these questionnaires.

To determine the effects of the developed lessons on the students on the conceptual understanding and science process skills, the two-tailed T-test was used to compare the pre-and post-test mean scores in the tools used; the formula is shown in Equation 1. The same statistical treatment was used to determine the difference in the test scores in the pre-test and post-test in the developed 60-item standardized achievement test covering all topics in the developed inquiry-based lessons. The validation of the standardized test was done through pilot testing of the material in an almost identical secondary school with the same student population and class settings and obtained a result of a normal distribution of raw scores in the conducted pilot test. Furthermore, the identified easy and difficult items underwent revision based on the results of the item analysis. In the analysis of the t-test result, a p-value of less than 0.05 is said to be statistically significant while a p-value of greater than 0.05 is considered insignificant. For nonparametric data analysis on the results of the Science Motivation Questionnaire, the researchers used Wilcoxon to determine the significance level of the change in six types of students' motivation. This formula is shown in Equation 2 below.

$$t = \frac{\sum d}{\sqrt{\frac{n(\sum d^2)-(\sum d)^2}{n-1}}}$$

Equation 1

$$W = \sum_{i=1}^{N_r}[\mathrm{sgn}(x_{2,i} - x_{1,i}) \cdot R_i]$$

Equation 2

RESULTS

Multiple Intelligences of Students

This study did not treat students in their specific intelligence and focused on the three general categories of multiple intelligences (MIs): introspective, analytical, and interactive. According to Gardner, an individual can certainly possess two or more intelligence depending on his nature, interest, or strengths. For instance, as shown in the data of the Introspective group, Student A, has four (4) intelligence thus MI namely, Logical/mathematical, Intrapersonal, Existential, and Bodily-kinesthetic; it only shows that this learner basically shows an inclination for analyzing data through patterns of numeric values (Logical/mathematical), in familiarization and own potential, skills and strengths and weaknesses (Intrapersonal), in getting the essence or purpose of doing a task or a thing itself (existential), and in working with the involvement of the body parts (bodily-kinesthetic).

Students were grouped as Introspective because the dominant intelligence of learners falls under the category of this group are Existential, Intrapersonal, and Spatial. The intelligence of the learners in this group with the highest percentage was Existential (18%) then followed by Bodily-Kinesthetic (17%) and Intrapersonal (14%) as shown in Table 1. Since these were the identified top intelligence of the students, therefore the learning tasks must involve reflective activity regarding the importance of the concepts in day-to-day living as a student and as a part of the community; inclusion of laboratory or hands-on activities in the lesson that would involve mobility of the body; and individual tasks such as seat work allowing the students to work individually to challenge and evaluate own learning.

Table 1. Dominant Multiple Intelligences of Introspective Group

Intelligence	**Frequency**	**Percentage**
Existential	37	18%
Bodily-Kinesthetic	35	17%
Intrapersonal	28	14%
Visual/Spatial	25	12%
Musical/Rhythmic	24	12%
Naturalist	18	9%
Interpersonal	17	7%
Logical/Mathematical	14	7%
Verbal/Linguistic	9	4%
TOTAL	**207**	**100%**

Likewise, in the presented result of the students' multiple intelligences of the Analytical group, the same concept was shown in the Introspective group wherein learners did possess varied intelligence. These students were grouped in the Analytical group because their dominant intelligence falls under the category of the Analytical Group which was described as individuals possessing intelligence of Musical/Rhythmic (16%), Logical/Mathematical (13%), and Naturalistic intelligence (13%) which is shown in Table 2 below. This group implies that the learning of the students should encourage interaction between each learner to attain an understanding of concepts, skills, and attitudes. This group was highly noted for their abstract and rational thinking and processing of information as the learners were engaged in the learning process.

Table 2. Dominant Multiple Intelligences of Analytic Group

Intelligence	**Frequency**	**Percentage**
Musical/Rhythmic	29	16%
Logical/Mathematical	24	13%
Naturalist	24	13%
Existential	23	13%
Bodily-Kinesthetic	19	11%
Intrapersonal	18	10
Interpersonal	16	9%
Visual/Spatial	13	7%
Verbal/Linguistic	12	7%
TOTAL	**178**	**100%**

The last group was named Interactive because this suggests that students learn best through the involvement of social interaction. The MI's categorized under this group are Kinesthetic, Interpersonal, and Verbal intelligence. Tasks were easily carried out when done by the group. Through this type of intelligence, the students were able to absorb, construct understanding and apply concepts with the help of others. Social process among students opens the way for brainstorming, and sharing of ideas, skills, and attitudes.

Table 3. Dominant Multiple Intelligences of Interactive Group

Intelligence	Frequency	Percentage
Bodily-Kinesthetic	31	21%
Interpersonal	20	14%
Existential	20	14%
Intrapersonal	18	12%
Verbal/Linguistic	15	10%
Naturalist	14	10%
Musical/Rhythmic	12	8%
Visual/Spatial	11	8%
Logical/Mathematical	4	3 %
TOTAL	**145**	**100%**

This finding in the research study did not just identify the specific intelligence of the students to cater to their needs and interests in the learning process but it also implied that individuality among students was very vast and that there was a high possibility that most, if not all, of Gardner's intelligence, can be present in an individual. This is shown in the table below.

Table 4. Percentage of Combined Multiple Intelligences Group

Intelligence	Percentage
Introspective-Analytical	15%
Analytical-Interactive	8%
Introspective-Interactive	17%
Introspective-Analytical-Interactive	61%
TOTAL	**100%**

When all the intelligence of the students involved in the study was combined, it results in combinations of intelligence. It is shown in the percentage column in Table 4 that the combinations of intelligence were possible not just within the scope of the categories of the three groups but the combinations of these intelligence groups. This is in consonance with the study of Yavich and Rotnitsky (2020) whose findings revealed that there are students with more than one dominant intelligence.

Developed Science Inquiry Lessons

The seven developed lessons were Kinetic Molecular Theory, Boyle's Law, Charles' Law, Gay-Lussac's Law, Combined Gas Laws, Avogadro's Law, and Biomolecules following the 7Es format. These topics were among the least learned competencies in Chemistry in Grade 10 which the researchers attributed to the fact that these integrate scientific and mathematical processes together to understand the concepts. An inquiry lesson based on the 7Es format basically consisted of seven parts: Elicit, Engage, Explore, Explain, Elaborate, Evaluate and Extend. The use of a new teaching model is found similar to the study conducted by Karsli et al. (2020) on the "Effects of a 5Es Learning Model on the Conceptual Understanding and Science Process Skills of Pre-Service Science Teachers: The Case of Gases and Gas Laws" which results confirms that the using 5Es learning model is more effective in teaching concepts and science process skills in Gas Laws topics than the traditional instruction.

The result of the validation of developed lessons showed that the topics were very appropriate to the science inquiry approach, well-formatted to the 7E's inquiry lessons and it connects the concepts involved in every topic to the environment they live in. Since this study developed lessons to cater to multiple intelligences, there were parts of the lessons which were preferably assigned to specific MI groups because they were in accordance with their intelligence. Other groups still participated in every task they wished to take part in. In summary, Table 5 presents the inquiry-based activities included in the seven developed lessons that catered to the three classifications of MI.

For instance, in the lesson on Boyle's Law, all the groups were able to conduct tasks that were aligned with their intelligence at the elicit part of the lesson. The Interactive group was assigned to enumerate the properties of gases that they observed in the classroom and acted out the meaning of such properties through body language The Analytical group, on the other hand, accomplished tasks wherein they differentiated the common terminologies being used such as mass, weight, temperature, and kinetic energy, and had drawn out examples from objects around them. While the Introspective group was assigned to give importance to knowing these properties as they live on a day-to-day basis, this group is inclined to the affective aspect of learning in which they achieve conceptual understanding better with the involvement of emotive connection.

This study focused on the general characteristics of the three categories of multiple intelligences and not on the specific tasks for each intelligence. However, when an individual multiple intelligence was to be specified, the study also accommodated activities for them to perform in science lessons. To name a few, Verbal intelligence was considered by allowing them to make a *hugot* line related to the topic (CL); State the concepts of gas laws from the conducted activity, Experimentation in Explore part in all the developed lessons for the Bodily-Kinesthetic, Solving practical situations which most of them includes computation practical problems involving all Gas Laws for the Logical intelligent students, and Creating open verse lyrics on the PPAP song telling what happens to a balloon when exposed to the flam for Musical intelligence, and many others.

Table 5. Science Inquiry Skills

Lesson	Learning Competency	Inquiry-based Activities
Kinetic Molecular Theory (KMT)	Explain the relationship between volume, pressure, and temperature using kinetic molecular theory	• Describe the behavior of gas molecules from their daily observation around them. • Design activity on how the relationship of three variables (V, P & T) can be explained. • Explain the behavior of gases usually observed using Kinetic Molecular Theory.
Boyle's Law (BL)	Investigate the relationship between volume and pressure at the constant temperature of a gas	• Define and describe the properties of gases: mass, volume, and temperature. • Design an activity to explain the relationship between volume and pressure if the temperature is constant. • Solve situational problems using Boyle's Law equation. • Explain natural phenomena using concepts of Boyle's law.
Charles' Law (CL)	Investigate the relationship between volume and temperature at a constant pressure of a gas	• Determine two variables involved in exploding can when heated. • Explain the relationship between volume and temperature, if the pressure is held constant, through an experiment. • Solve situational problems using the Charles' Law equation. • Explain natural phenomena using Charles' Law.
Gay-Lussac's Law (GLL)	Investigate the relationship between pressure and temperature at a constant volume of a gas	• Explain the importance of reading and following the safety precautions on perfume/cologne cans. • Explain the relationship between pressure and temperature at constant volume by designing an activity. • Solve situational problems using the Gay-Lussac's Law equation. • Explain natural phenomena using Gay-Lussac's Law.

Table 5. Science Inquiry Skills (cont.)

<table>
<tr><th>Lesson</th><th>Learning Competency</th><th>Inquiry-based Activities</th></tr>
<tr><td>Combined Gas Laws (CGL)</td><td>Investigate the relationship between volume and pressure at a constant temperature of gases at a constant number of moles</td><td>• Express volume-pressure and volume-temperature relationships through graphs.
• Explain natural phenomena involving gases using these relationships.
• Combine Boyle's Law and Charles' Law equations.
• Solve problems mathematically using Combined Gas Laws equation.
• Explain natural phenomena commonly observed in the environment using the law.</td></tr>
<tr><td>Avogadro's Law (AL)</td><td>Investigate the relationship between volume and mole at constant temperature and pressure</td><td>• Explain why the balloons inflate when blown.
• Conduct an activity to explain the relationship between number of moles to volume.
• Explain how situational and mathematical problems be explained by Avogadro's Law.
• Explain natural phenomena using concepts of Avogadro's Law.</td></tr>
<tr><td>Biomolecules (BioM)</td><td>Recognize the major categories such as carbohydrates, lipids, proteins and nucleic acids</td><td>• Determine what the body compositions are through a video presentation.
• Investigate to identify biomolecules through structures and functions, identify building blocks and determine the present biomolecules in food samples.
• Explain how to distinguish biomolecules in terms of structure, functions, and building blocks.</td></tr>
</table>

In general, all the groups were able to do the same activities in Elicit, Explore and Extend parts. Elicit part is where the teacher determined what the students already learned from the previous lessons discussed in science. To attain this purpose, the teacher needed to let all the students be involved in the elicit phase of the lessons. The Explore phase was where the students conducted experiments that answered the given questions for each lesson. Since the research study was all about the utilization of the inquiry approach which involved hands-on experimentation, it was a must for the researchers to include student-centered activities in which the students must take in. Therefore, whatever intelligence a student has, performing the given tasks in Explore tasks was a must. It was also a way to explore things beyond what the students were inclined to; for instance, visual-intelligent students can do tasks involving mathematical computation not just merely presenting or analyzing graphs and/or tabular data. This allowed the students to work on their own strengths while exploring what they can do more to address their weaknesses. The Extend phase of the lesson allowed students to apply the learned concepts or to bridge the current lesson to the next, it was also a must for the teacher to give it to the whole class in knowing whether they were ready to apply the learned concepts or not or perhaps to make the connection of the recently learned lessons to the next.

Developed Science Process Skills

In general, the seven (7) Basic Science Process Skills included and assessed in this study were: using scientific knowledge to form a question (formulating question), formulating question answerable by collecting data (formulating question), communicating scientific procedure to others (communicating), recording data, using science terms to share results (communicating), using models to explain results (communicating) and Using results of the investigation to answer the question asked (communicating). On the other hand, the four (4) Integrated Science Process Skills included were: designing investigations, using data to create graphs for presentation (formulating models), creating a display to communicate data and observations (formulating models), and analyzing investigations and other data.

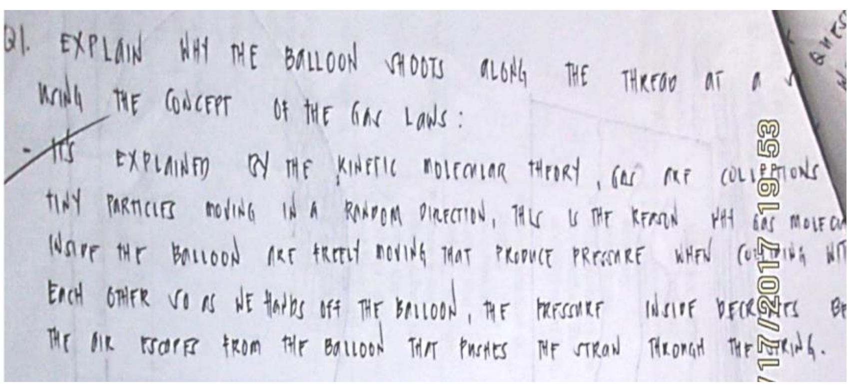
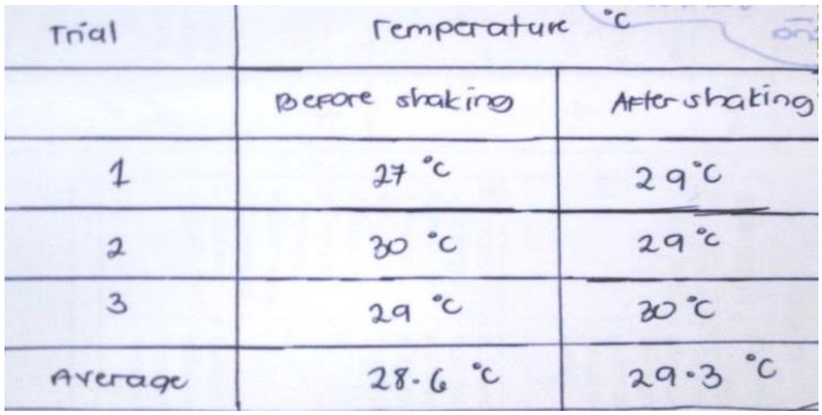


Figure 1. Output of Students in Explaining Natural Phenomenon

Figure 1 shows part of the output submitted by the Analytical group and was checked by the teacher. It was the task given by the teacher to the student wherein they were asked why an inflated balloon with an untied mouth shot forward after it was released. As shown in the output, the students were able to explain it well and correctly and used scientific terms in explaining this phenomenon. The developed skills were analyzing investigations and data as well as Using scientific terms to share results. On the other hand, Figure 2 shows the output presented by the Introspective group in Gay-Lussac's Law. During the conduct of the activity, the students were tasked to determine the relationship between pressure and temperature. In the activity proper (Elaborate), the students shook the Erlenmeyer flask with denatured alcohol inside and temperature was measured before and after the shaking of the flasks. The gathered data through the readings of the temperature in the alcohol thermometer were presented by the group through the table presented.



Trial	Temperature °C	
	Before shaking	After shaking
1	27 °C	29 °C
2	30 °C	29 °C
3	29 °C	30 °C
Average	28.6 °C	29.3 °C

Figure 2. Tabular Presentation for Communicating Data and Results

Given that the science process skills were developed after delivering an inquiry-based approach in teaching, this result is supported by the findings in the study of Aulia et al (2023) on "Increasing Science Process Skills Using Inquiry Learning Model" which showed that application of inquiry learning model improves students' science process skills.

Effects of Developed Chemistry Inquiry Lessons on Students' Conceptual Understanding

The performance level on conceptual understanding was determined using the following indicators: Superior (90- 100), Meeting Standard (75-89), Below Standard (35-74), and Poor (0-35). Based on a comparison of the results of computed mean scores in the pre-test and post-test across the MI group using paired t-tests, among the three MI groups in Table 7, the Interactive group consistently showed the highest improvement of conceptual understanding in all the lessons obtaining the highest mean score difference, followed by the Introspective and lastly by Analytic group.

The result of the study of Ahvan, et al. (2015) was taken into consideration by the researchers in explaining this occurrence. The study revealed that verbal, spatial, and logical intelligence are the best predictors of academic performance achievement which means to say that due to the complexity of this intelligence, the students having these have the tendency to be academically competitive. Going back to the presented data in Table 3 which shows the dominant intelligence the students had, the Bodily-Kinesthetic (Spatial) intelligence ranked first as the top intelligence among students.

Table 7. Comparison of Mean Score in Achievement Test of MI Groups

Lesson/MI	Pre-	Performance	Post-	Performance	Mean

Group	Test	Level	Test	Level	Difference
KMT					
Introspective	31.02	Poor	57.18	Below Standard	26.16
Analytic	22.79	Poor	40.93	Below Standard	18.14
Interactive	27.08	Poor	57.99	Below Standard	30.90
Boyle's Law					
Introspective	34.16	Poor	55.56	Below Standard	21.40
Analytic	24.84	Poor	51.85	Below Standard	27.02
Interactive	34.88	Below Standard	66.67	Below Standard	31.79
Charles' Law					
Introspective	34.36	Poor	53.09	Below Standard	18.72
Analytic	23.09	Poor	40.52	Below Standard	17.43
Interactive	30.86	Poor	55.25	Below Standard	24.38
Gay-Lussac's Law					
Introspective	34.77	Below Standard	44.24	Below Standard	9.47
Analytic	25.49	Poor	37.25	Below Standard	11.76
Interactive	32.10	Poor	48.15	Below Standard	16.05
Combined Gas Laws					
Introspective	33.60	Poor	56.88	Below Standard	23.28
Analytic	31.65	Poor	45.94	Below Standard	14.29
Interactive	38.89	Below Standard	60.32	Below Standard	21.43
Avogadro's Law					
Introspective	33.54	Poor	52.88	Below Standard	19.34
Analytic	28.98	Poor	44.88	Below Standard	15.90
Interactive	38.58	Below Standard	58.02	Below Standard	19.44
Biomolecules					
Introspective	34.54	Below Standard	53.70	Below Standard	19.14
Analytic	32.98	Poor	44.66	Below Standard	11.98
Interactive	41.36	Below Standard	58.95	Below Standard	17.59

Therefore, it was one of the factors that affected the highest mean gain of scores in the Achievement Test taken aside from the given explanation by the researchers a while ago. Furthermore, the researchers found the findings related to the meta-analysis study of Ferrero et al (2021) on the use of MI-based materials and activities of teachers as shown in the thirty-nine (39) analyzed studies worldwide to enhance learning outcomes. This revealed that although the majority of the studies analyzed claimed that it caused significant learning improvement for the students, some studies claimed otherwise which might be due to methodological flaws by including a small sample size or failure to use control groups; or when trying to replicate previous studies on the MI-based interventions which basically reported insufficient information on the tools/devices and activities used as well as how the outcome has been measured which caused inefficacy on the application of MI in the classroom. With the identified gap between the theory and the classroom practice, the researchers suggested the use of MI-based intervention after high-quality research on its effectiveness has been performed. As Willingham (2014) stressed, the best way of learning is not anchored on the abilities or intelligence of the students but on the content itself.

Effects of Developed Chemistry Inquiry Lessons on Students' Science Process Skills

There is a significant difference in the scores in Table 8 when the *p*-values are lower than the alpha value of 0.05. This can be seen in the data gathered in the Introspective group wherein all the measured skills both basic and integrated science process skills were developed. While the Analytical group developed almost all skills except the two subskills of communicating skill, it is notable that there were few skills developed with the use of the developed lessons in the Interactive group.

As viewed by the researchers, it was due to the contributing factors of multiple intelligences and the learning opportunities given in the developed lessons. When the students have been observed and studied in the original three categories: Introspective, Analytical, and Interactive groups, the bigger perspective of the capabilities and development of students was given attention because this was basically what they are innately born with. Hence, even though the students can noticeably do better in certain tasks, teachers must still provide opportunities that would challenge them as well as develop the skills that need further development and practice as what was done in this research study.

Effects of Developed Chemistry Inquiry Lessons on Students' Science Attitude

It has been found in the study by Suciani et al (2022) that the student's learning styles and motivation significantly impact learning outcomes and that integrating the Multiple Intelligences Theory in the curriculum strengthens students' motivation to learn English. A Wilcoxon signed rank test was used on the comparison of the rating from the Science Motivation Questionnaire (SMQ) to test if there is a significant difference in the six types of motivation. The presented data in the Table 9 were computed quantitatively using the *p*-value, and the Wilcoxon test statistics (W). The indicators corresponding to the five-point Likert scale used in the study in interpreting all types of motivation were Very Low, Low, Moderate, High, and Very High.

Table 8. Comparison of Weighted Mean Values of Science Process Skills

Science Process Skills	Introspective	*p*-	Analytical	*p*-	Interactive	*p*-

	Pre-test	Post-Test	value	Pre-test	Post-test	value	Pre-test	Post-test	value
Basic Science Process Skills									
Using Scientific knowledge to form a question (Formulating Question)	2.17	2.50	1.33×10^{-3}	1.88	2.41	9.99×10^{-6}	2.17	2.67	8.13×10^{-14}
Formulating questions answerable by collecting data (Formulating Question)	2.15	2.85	6.46×10^{-6}	2.20	2.76	2.79×10^{-3}	2.28	2.33	0.37
Communicating scientific procedure to others (Communicating)	2.37	2.72	2.05×10^{-3}	2.29	2.73	0.21	2.53	2.83	3.78×10^{-3}
Recording data	2.24	2.76	1.2×10^{-7}	2.32	2.46	1.93×10^{-3}	2.25	2.86	6.97×10^{-3}
Using science terms to share results (Communicating)	1.94	2.87	2.32×10^{-4}	2.12	2.54	4.29×10^{-2}	2.08	2.58	1.29×10^{-2}
Using models to explain results (Communicating)	2.35	3.19	0.41	2.41	3.12	0.19	2.44	2.92	0.29
Using results of the investigation to answer the question asked (Communicating)	2.28	2.96	6.66×10^{-4}	2.37	2.71	1.38×10^{-2}	2.56	2.86	2.76×10^{-4}
Integrated Science Process Skills									
Designing investigations	2.15	2.83	1.78×10^{-2}	2.20	2.68	5.36×10^{-3}	2.33	2.44	6.25×10^{-2}
Using data to create graphs for presentation (Formulating Models)	2.09	2.74	1.26×10^{-6}	2.17	2.44	4.77×10^{-4}	2.28	2.64	1.23×10^{-2}
Creating a display to communicate data and observations (Formulating Models)	1.89	1.93	1.05×10^{-5}	2.07	1.93	1.65×10^{-2}	2	1.89	7.74×10^{-2}
Analyzing investigations and other data	2.50	2.96	3.27×10^{-6}	2.44	2.85	1.26×10^{-2}	2.25	2.86	0.30

Table 9. Level of Motivation of Introspective Group

Types of Motivation	Wilcoxon Test Statistics (*W*)	*p*-value	Pre-Test	Post-Test
Intrinsic Motivation	181.5	0.000	Moderate	Moderate
Career Motivation	146.0	0.000	Low	Moderate
Self-Determination	142.0	0.000	Low	Moderate
Self-Efficacy	269.5	0.002	Moderate	Moderate
Grade Motivation	164.0	0.000	Moderate	Moderate

Based on the computation of the Wilcoxon signed rank test, it was determined that this group showed a statistical significance median increase in the level of all types of motivation after the delivery of the developed lesson given that the p-values are less than the assigned alpha value, 0.05, that is, $p<0.05$. The researchers attributed this to the Introspective group being highly notable for its personal connection with the tasks involved in order to establish an understanding of the concepts by seeking their relevance in real life. This improvement is related to the result of the study by Fawcett-Adams (2011) regarding Science Career Motivation and Influences in which repetitive exposure of children to experiences involving science, mostly done through maternal influence, motivates science career selection. This means that since inquiry lessons were task-oriented, the planned tasks and activities for the students would not just focus on the outcome of the lessons but also on the student's interests and needs for them to be happily engaged in the learning process. Establishing an interest in learning science, developed an interest in pursuing a science-related career. Figure 3 is evidence of their interest in learning science as shown in their attentiveness to what was taught.

Figure 3. The Introspective Group while watching a Video clip

It was also found that there was an improvement in the student's perspective on their level of determination. According to the indicator of the computed mean score, the students' view was changed from "lowly motivated" to "moderately motivated". This means that as they were engaged in the learning process from the first developed lessons until the last one, they were able to develop an attitude of perseverance in learning science, might it be in terms of accomplishing the tasks or learning the science concepts well. When students were expected to accomplish the tasks, it builds the student's determination to finish them in accordance with the expected outcome. In the developed and executed lessons, the students were given successive tasks which entailed that students cannot proceed to the next tasks unless the expected objectives were attained. It required them to be motivated in accomplishing the tasks; in the same way, they were motivated to learn the concepts not just for the current situation they were involved in but also for future purposes. Moreover, the lessons and their included activities were able to show their self-efficacy in the process. Since this group was highly extrinsically motivated by grades, it means that this group was capable of good performance.

Table 10. Level of Motivation of Analytic Group

Types of Motivation	Wilcoxon Test Statistics (*W*)	*p*-value	Pre-Test	Post-Test
Intrinsic Motivation	168.0	0.002	Moderate	Moderate
Career Motivation	170.5	0.006	Moderate	Moderate
Self-Determination	57.0	0.000	Low	Moderate
Self-Efficacy	38.0	0.000	Low	Moderate
Grade Motivation	145.0	0.003	Moderate	Moderate

As revealed in the data in Table 10, the mean rating score showed that all these types of motivation were 'moderately' developed upon using the developed Chemistry MI-based Inquiry lessons. The Analytic group's intelligence is in line with the high-order thinking skills. And since this group is where the logical-mathematical intelligent students were categorized, it was in their favor to express their ideas, especially the relationship among variables through equations or anything involving numbers to easily understand the concept being learned. The researchers considered the reason that the students, due to their innate personality and intelligence, were already competitive enough that they have already motivated even before undergoing the treatment of the study. The students were determined to get high scores on the test given by the teacher as shown in Figure 4. The scores that they got motivated them to do better in science learning.

Figure 4. Students' engagement in the conduct of the test

This internalization of the science learning obtained by the students resulted in the improvement of the self-determination attitude of the students. Competitive students are more likely to reflect and realize the importance of learning such science concepts especially if they will help enhance their performance as students and real-life capabilities. The activities given before and after the activity proper in the developed lesson plans were in line with their intelligence therefore it suits their interests that awaken their attention.

Figure 5. Collaboration of the Analytical Group in Biomolecules Lesson

The Analytical group was good at analyzing data or any information presented to them, since they did activities that involve such they were able to enjoy it with themselves, and their group mates. Figure 5 illustrates Analytic students who were seriously engaged in the presentation of their ideas on how they would classify and arrange the templates regarding the composition, structure, and function of biomolecules. They shared ideas first on how the templates were related to one another and then thought of the way they can present their ideas in a creative manner. Afterward, they attached the given template to the manila paper one by one with the help of all members. This was done in part 1 of the Activities in Explore phase of the Biomolecules lesson. It was also found that the students in the Analytical group were able to "see" the essence and connection of science in their future careers. The researchers believe that this was developed because of interrelated factors: the competitive nature of the group, high-order thinking skills, and science lessons and activities enjoyed by the students in the developed lessons.

Table 11. Level of Motivation of Interactive Group

Types of Motivation	**Wilcoxon Test Statistics (*W*)**	***p*-value**	**Pre-Test**	**Post-Test**
Intrinsic Motivation	157.5	0.078	Moderate	Moderate
Career Motivation	185.0	0.034	Low	Moderate
Self-Determination	127.0	0.018	Low	Moderate
Self-Efficacy	94.0	0.003	Low	Moderate
Grade Motivation	118.5	0.033	Moderate	Moderate

On the other hand, the students of the Interactive group were able to develop all the attitudes measured in the Science Motivation Questionnaire based on Table 11. The *p*-values in all types of motivation were lower than the alpha value of 0.05 except in the intrinsic motivation which tells that there was a significant difference in these attitudes after the developed lessons were used for the groups while the moderate level of intrinsic motivation in the pretest and posttest were statistically insignificant. This group was characterized by being inclined to affective and analytical processes. Providing an opportunity for this group to collaboratively engage in a series of activities increased their self-confidence, especially when the expectations of a teacher or of the lesson objectives were achieved. It is in the self-awareness of the students that somehow, they find relationships and connections through the trend of their academic performance and the grade they expected to receive. This group was very competitive during the implementation of the lessons in terms of realizing the importance of learning the science concepts in explaining natural phenomena as well as processing the concepts in order to answer the questions and basically to draw out analysis from the gathered data to make sense of the tasks done.

Since all the developed lessons allowed the students to perform activities that enabled them to use critical thinking and make use of the scientific method in answering the questions in the Elaborate phase as well in the Elaborate phase, the students were able to establish a good rapport with science as reflected in their responses that they considered taking science-related career later on. It was natural for them that they accomplished and finished the task with a willingness to learn and receive high grades because of their good performances. The developed lessons sustained the confidence of students in accepting and performing challenging tasks.

DISCUSSION

The intelligence of the learners in the Introspective group with the highest percentage was existential (18%) then followed by bodily-kinesthetic (17%) and intrapersonal (14%). The Analytical group was dominated by musical/rhythmic intelligence (16%), followed by logical/ mathematical, naturalist, and existential intelligence with 13%. Bodily-kinesthetic (21%), existential (14%), and interpersonal (14%) intelligence dominated the Interactive group. The study also considered the occurrence of overlapping intelligence groupings which were: Introspective-Analytical (15%), Analytical-Interactive (8%), Introspective-Interactive (17%), and Introspective-Analytical-Interactive groups (61%).

The seven selected science lessons were Kinetic Molecular Theory, Boyle's Law, Charles' Law, Gay-Lussac's Law, Combined Gas Laws, Avogadro's Law, and Biomolecules. This study determined the impact of the science inquiry-based approach on students' conceptual understanding, science process skills, and attitudes. The 7Es format was then followed to provide the students a with series of activities in the lessons. It included the Elicit, Engage, Explore, Explain, Elaborate, Evaluation, and Extend phases. Each part consisted of tasks allotted for a particular MI Group. Students within the MI groups were given specific parts of the lesson to take part in to achieve the objectives. The developed lessons were aligned with the Multiple Intelligences (MI); thus, appropriate activities and tasks were designed and given at a specific part of the lessons. The planned tasks were in accordance with their strengths and intelligence which were determined at the start of the study.

More basic process skills were manifested than integrated process skills in the use of the developed inquiry-based science lessons. The developed inquiry lessons for multiple intelligences made a difference in the level of conceptual understanding but did not satisfy the 75% performance level of DepEd in general. The Introspective group developed all the Basic Science Process Skills (BSPS) measured in the utilized SPS inventory while the developed Integrated Science Process Skills (ISPS) were designing investigations, using data to create a graph for presentation (formulating models), creating a display to communicate data and observations (formulating models) and analyzing investigations and other data. The Analytical group developed all the Integrated Science Process Skills but was not able to develop the skill, communicating scientific procedures to others (communicating) as Basic Science Process Skills. Lastly, the Interactive group did not develop the skill of formulating question answerable by collecting data (formulating question) and using models to explain results (communicating) skills, and among the four (4) skills, only one was developed which was using data to create a graph for presentation (formulating models). All of the groups developed all the attitudes included in the Science Motivation Questionnaire which were categorized as intrinsic, career and grade motivation, self-determination, and self-efficacy.

In general, the seven developed lessons: Kinetic Molecular Theory, Boyle's Law, Charles' Law, Gay-Lussac's Law, Combined Gas Laws, Avogadro's Law, and Biomolecules significantly made great impacts on the development of Science Process Skills and Science Attitude but less on the instruction especially on Conceptual Understanding. The factors that highly contributed to these developments were facts that the lessons were made in the application of an inquiry-based approach wherein students were given successive and relevant tasks and activities that allowed the progression of skills. These activities were given in accordance with the student's needs, interests, and strengths. However, much emphasis must be given to the outcome of science learning, the conceptual understanding, not just on the process of attaining an understanding of concepts.

CONCLUSIONS AND RECOMMENDATIONS

Based on the findings of the study, the following conclusions were: (1) The Introspective group was dominated by existential intelligence, musical/rhythmic intelligence in the Analytical group and Bodily-kinesthetic intelligence dominated the Interactive group. (2) The utilization of the inquiry approach in the developed lessons provided better learning opportunities for the MI groups that catered to the student's needs, interests, and learning styles. (3) The students manifested the majority of the expected science process skills in the implementation of the developed lessons. (4) There is no significant effect to students' conceptual understanding in using the developed Chemistry inquiry-based lessons but rather developed the students' basic process skills than integrated process skills and improved all types of attitudes in terms of intrinsic motivation, career motivation, self-determination, self-efficacy, and grade motivation among students.

With these, it is therefore recommended that: (1) Revisions must be done prior to the execution of lessons considering the type of MI dominant in the class, the type of science skills and attitudes aimed to be developed in the lessons, class size, and well-established method, tools, and activities to be used in applying the theory in learning Chemistry lessons. (2) Opportunities in the development of Integrated Process Skills must also be given emphasis in designing the lesson. (3) Constant usage of varied science hands-on activities must be provided to students to develop their conceptual understanding, science process skills, and attitude toward science.

IMPLICATIONS

Inquiry Lessons for Multiple Intelligences lead to the acquisition of Science Process Skills in selected topics in chemistry as well as the development of a positive attitude. It is therefore a must for a teacher to consider this in planning and delivering the lessons. The lessons must be responsive to the student's needs, interests, and strengths and must be inquiry-based. Learning activities should also be focused on the development of integrated science process skills, not just the basics. It was then of significance in making the lessons anchored on the inquiry-based approach because the students were given continual tasks. Careful planning and implementation of the MI-based lesson are important in achieving the desired learning outcomes.

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DECLARATIONS

Conflict of Interest

The Authors declare that there is no conflict of interest.

Informed Consent

Informed consent on the use of personal information and images was obtained from all individual participants included in the study.

Ethics Approval

All protocols of research ethics were followed in compliance with the data confidentiality and citation of all resources as reviewed by the Institutional Research Ethics Committee.

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