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MULTIMODAL REPRESENTATIONS ACROSS SCIENTIFIC GENRES: PERSPECTIVES FROM SCIENCE TEACHERS' PRACTICES

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A B S T R A C T

Multimodal representations have caught science education researchers' attention due to its immense role in meaning making. While much have been written about this area of research, the interplay between multimodal representations and scientific genres in classrooms is yet to be fully explored. The purpose of this study is to examine multimodal representations across scientific genres from the viewpoints of science teachers. With Filipino science teachers as respondents, we employed a sequential explanatory mixed methods research design to determine the frequency of occurrence of scientific genres in classrooms as well as the frequency of use of multimodal representations across each scientific genre. First, we administered the questionnaire, analyzed the result then conducted a follow-up interview to determine how and why scientific genres and multimodal representations are utilized. Results revealed that information report and explanation are the genres most utilized by science teachers primarily because they conform to curriculum standards and that these support students' learning and skills. On the other hand, experimental account and argument genres are used less often largely due to lack of available materials and teacher competence. Across these genres, linguistic-verbal, visual-graphical and gestural-kinesthetic representations are "always" used while material-operational and mathematical-symbolic are used to a lesser extent. More importantly, this study confirms again that science teaching is multimodal mainly to address each student learning needs and make meaning making thus, science learning, easier. Important implications to practice and research are discussed.

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1. INTRODUCTION

In today's technology-dominated era, it is hard to imagine learning and teaching through a single mode, that is, language alone. Even before the 'computer' era, meaning making in classrooms employs at least two modes of representations; a teacher explaining a lesson, for example, would use verbal and written language and at least a hand or bodily gesture. Thus, teaching and learning is multimodal (as explained by Jewitt in the book entitled Technology, literacy, learning: A multimodal approach in 2008).

Multimodality is when two or more modes are used in conjunction to create meaning (as explained by Lemke in the book chapter entitled Multiplying meaning: Visual and verbal semiotics in scientific text in 1998). Diagrams, graphs, equations, and tables are examples of representations that are crucial to the way meaning is made and transduced in science (Nielsen & Yeo, 2022). Hence, teaching and learning the subject is essentially multimodal (as explained by Kress in the book entitled Multimodal teaching and learning: The rhetorics of the science classroom in 2001). In addition to models used in representations such as atomic models, model of solar system and the like, the advancement and rise of digital technologies have brought changes in the way meaning making is done. In science, understanding these complications requires analysis of both multimodal representations and scientific genre. As a staged, purpose-driven social activity, genre is described as how texts are organized in accordance with that activity's goals (Martin, 2007). Multimodality, on the other hand, has been used to analyze the learning processes of students using a variety of multimodal tools, such as diagrams, symbols, and gestures (Tang, 2016; Van Rooy & Chan, 2017).

When students construct a representation using more than one mode, it becomes a multimodal representation. Multimodal representations range from the use of different representations including language, text, diagrams, tables, models, drawings, portfolios, artefacts, and embodied forms such as gestures, role play and exhibitions of performance. Van Rooy and Chan (2017) identify five of the most common modes used in science education. These modes are as follows: verbal linguistic (spoken and written language), visual-graphical (image, diagram, graph), mathematical-symbolic (number system, equation), gestural-kinesthetic (hand gesture, gaze), and material-operational (physical object, tactile manipulative).

Genres in science classrooms are generally grouped into: information report, experimental account, explanation, and argument (Tang & Rappa, 2021). Scientific genres in science education were originally classified and identified based on written texts. It has been assumed that these written texts reflect what is actuated in classrooms by learners and teachers (as explained by Fairclough in the book entitled Discourse and social change in 1992). However, the assumption on written texts failed to consider non-verbal representations such as bodily gestures. This leads to an additional consideration, a multimodal representation, which can be classified into five general categories: linguistic-verbal, mathematical-symbolic, visual-graphical, gestural-kinesthetic, and material-operational (Tang et al., 2022; Van Rooy & Chan, 2017).

To concretize the gap of the study, literatures suggest that multimodality and genre are two intertwined constructs that considerations for both in an inquiry, rather than two isolated phenomena, results to more meaningful insights. This has been termed multimodal genre. Analyses of multimodal genre had been widely used in the fields of media and language studies (as explained by Hiippala in the book chapter entitled Multimodal genre analysis in 2014) but has also gained, although still relatively few, following in science education (Tang, 2023; Tang et al., 2022). Some of these studies made use of scientific genres in the analysis of meaning-making in science classrooms while some have scrutinized how books represent meaning across each genre – all showing patterns. While they have unquestionably advanced the field of study, they failed to explain how and why teachers used such representations in a specific genre - they would have uncovered more insights on the teaching and learning of science. By doing so, for example, Nielsen et al. (2020) understood pre-service teachers' decision-making on the choice of modalities for digital explanation, an important benchmark for professors to understand and help their students in teacher education. Thus, there is a need to venture into the occurrence and use of scientific genres and multimodal representations and the reason how and why these occurred in science classrooms.

1.1 Scientific Genres

There are four major genres in science namely, information report, experimental account, explanation, and argument (Tang & Rappa, 2021). Each of these genres has a number of functional stages. The purpose of an information report is to organize information about things or events through identification and classification to name entities and to describe the attributes and properties of entities. The purpose of an experimental account is to present the procedures and results of an experiment based on the objective, hypothesis, procedures used, apparatus used, and observation or conclusion of the experimenter. Explanation seeks to account for a phenomenon's underlying causes or processes by explaining the phenomenon and the implications of a series of causes and consequences. The goal of an argument is to present a claim and supporting evidence in favor of the claim by stating, justifying, and discussing the position of two claims.

Relative to experimental account, laboratory work is not always a useful strategy for teaching science knowledge (Hart et al., 2000). However, the investigation has shown that it can be successfully used for other purposes. Experiments were used in this case to help students think about one aspect of science (developing, communicating, and verifying procedures and results from experiments). It's interesting to consider whether this objective would have been met if there had been an expectation that students would engage with or try to explain the results of their experiments, as is usually the case. Rollnick in the book chapter entitled Identifying potential for equitable access to tertiary level science in 2010 emphasizes the complexity of experimentation and the teaching of it requires not only localized competencies but also the ability to change cognitive frames throughout the process and link each stage to both the previous and subsequent stages. They focused on specific aspects of experimentation to date, namely, student understanding of measurement and uncertainty in the scientific context,

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it is clear that broader issues must also be addressed. It is especially important to consider how students perceive science as a whole. Thus, students' perspectives on the nature of science, as well as how they frame science-related activities, are critical components toward the goal of successful meaningful participation.

The role of explanation in relation to potential consequences arise from the lexical ambiguity of the word explanation (Rocksén, 2016). The study provides empirical examples of how disciplinary norms of valid explanations manifest in science classroom communication. A dialogical analysis reveals three conversational structures provided by the teacher: asking for acts of explanation, providing opportunities to talk about what explanations are in this context, and providing opportunities to talk about explanations constructed by students. These three structures make it easier to learn how to evaluate and justify explanations. There are three potential meanings of the word "explanation": an everyday meaning, a pedagogical-professional meaning, and scientific meaning. The coexistence of these three potential meanings is suggested to have communicative consequences in science education.

Faize et al. (2017) performed a critical review of scientific argumentation in science education. The authors argued that, while scientific argumentation is useful and interesting in science classrooms, it is not without challenges. Conducting argumentation with students who lack prior knowledge or hold contradictory beliefs may present issues of accepting other people's arguments or creating confrontational situations in class. Furthermore, the benefit associated with improving conceptual understanding, discovering new knowledge, and developing critical skills necessitates additional research into the processes by which these benefits can be realized. However, argumentation may be useful in science education as a dialogic and interactive process. The issue of prior knowledge for constructing arguments can be addressed by assigning some reading material to the class as homework. This would assist students in developing a basic knowledge base for the next class's argumentation activity. It is also recommended that the argumentation activity be carried out in small groups of students. This will improve the argumentation process by allowing students to interact with one another.

1.2 Commonly Used Modes in Science Education

There are four commonly used modes in science education namely, verbal-linguistic (spoken and written language), visual-graphical (image, diagram, graph), mathematical-symbolic (number system, equation), gestural-kinesthetic (hand gesture, gaze), and material-operational (physical object, tactile manipulative) (Van Rooy & Chan, 2017).

Nygård Larsson and Jakobsson (2020) indicate that students' word and term negotiations are critical in the process of identifying, specifying, elaborating, and explaining how scientific phenomena are related. Several students use scientific terms, as well as more general or everyday words and expressions, to productively elaborate their reasoning. However, Kamberelis and Wehunt (2012) demonstrate that language usage in science education typically occurs at an implicit level, with teachers and students adopting a hybrid language without clarifying the contexts in which words and expressions belong. Furthermore, Serder and Jakobsson (2016) argue that using an unconsidered hybrid language in science classrooms may increase complexity and increase the risk of misunderstandings.

Gates in the book chapter entitled The importance of diagrams, graphics and other visual representations in STEM teaching in 2018 come to the conclusion that illustrations or diagrams are effective when both the text and the illustrations are "appropriate" for the task. The text in that case was explanatory (rather than descriptive or narrative), and the diagrams represented both the structure and the dynamic of the instruction. According to Carney and Levin (2002), carefully constructed text illustrations improve learners' performance in general. van Garderen et al. (2014) found that weaker students engaged differently with diagrammatical forms because they didn't know what a diagram was, what it was for, how it was created, or how it was used. This could be an example of a larger issue in the learning representation process. Any representation will be meaningless if a student cannot see the structural relationships between the representation and the concept being targeted.

In utilizing physical manipulatives in the classroom, students create and use representations to organize record and communicate ideas; select, apply and translate these ideas to solve real-life problems (Cope, 2015). These are also concrete artifacts that encourage hands-on engagement with the topic under consideration and which are purposely intended to promote learning in a teaching and learning environment (Chiphambo, 2012).

Physical manipulatives have also been verified to have a constructive effect on the improvement of students' problem-solving skills and conceptual understanding. Physical manipulatives enable students to find clarification for problems they were otherwise unable to solve either mentally or with the aid of pictorial models. Students also make accurate explanations and develops greater number of strategies when solving problems with physical materials and they were more likely to convey the learning into novel situations (as explained by West in the research entitled AUsing physical and virtual manipulatives with eight grade geometry students in 2012 https://news.unl.edu/newsrooms/csmce/article/action-research-using-physical-and-virtual-manipulatives-eighth-grade/).

1.3 Statement of the problem

Multimodality of representations in science teaching and learning have demonstrated benefits to students (Nordby et al., 2017; Siry, 2020; Tang et al., 2014; Williams et al., 2019) while learning challenges were also associated with the inability to combine representations or the lack thereof (Pun & Cheung, 2021; Tang et al., 2011). Hence, assuring that multimodality exists in every scientific genre in science classrooms is crucial in the teaching-learning process. Building therefrom, this study aims to determine the interplay between scientific genres and multimodal representations in classrooms based on teachers' practices. Additionally, an explanation as to how and why such representations are used in a genre is sought. Specifically, the following questions are answered:

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1. How often does each scientific genre occur in science classrooms?
2. How often do science teachers use multimodal representations across each scientific genre?
3. What is the most prevalent scientific genre and commonly used multimodal representations across each scientific genre in science classrooms?
4. Why do science teachers use a specific multimodal representation across each scientific genre?
5. How do science teachers use multimodal representations across each scientific genre?

2. METHOD

2.1 Research Design

This study follows the sequential-explanatory mixed methods research design which involves quantitative then qualitative inquiry to explain numerical results as well as increase validity of findings (as explained by Creswell et al. in the report entitled Designing and conducting mixed methods research in 2007). The purpose of the quantitative phase is to determine the frequency of use of representations across each scientific genre while the qualitative phase is to explain how and why these representations and genres occur in science classroom. Profiles of the respondents who completed the survey are presented in Table 1. Profiles and pseudonyms of the participants are presented in Table 2.

Online survey and interview were the means to collect data. Gathering of data online has been increasing and widespread in the field of research due to its several advantages. First is its potential to recruit larger number of participants (Barchard & Williams, 2008) from a wide geographical area which could have been more costly and time-consuming should it be held in-person. Second, some persons are just difficult to reach face-to-face due to their busy schedules (Harris & Porcellato, 2018), they find it easier to go online and participate in a study. Finally, the quality of data collected online is just as good and valid as the ones collected through in-person surveys or interviews (Braun et al., 2021; Ramsey et al., 2016). Thus, the use of online surveys and interviews not only warrants the possibility of this study due to travel restrictions and social distancing protocols brought about by the COVID-19 pandemic, but it also ensures quality and valid data collection.

2.2 Participants

High school and higher education science teachers in the Philippines were the participants in this study. The invitation to join was sent through emails, and social networking sites. However, out of more than 300 messaged science teachers, only 67 were able to complete the quantitative survey and only six agreed to be interviewed. Among the reasons of their inability to participate was their intermittent internet connection, a common occurrence in the study's locale.

Table 1. Profiles of the respondents in the online quantitative survey

Profile	Categories	f	%
Age	Gen Z (10-25)	6	8.96
	Millenials (26-41)	52	77.61
	Gen X (42-57)	9	13.43
	Boomers (58-67)	0	0.00
School Level	Junior High School	35	52.24
	Senior High School	21	31.34
	Higher Education	11	16.42
Teaching Experience	0 - 5 yrs	20	29.85
	6 - 10 yrs	24	35.82
	11 - 15 yrs	16	23.88
	16 and more yrs	7	10.45
Highest Educational Attainment	Bachelor's degree	8	11.94
	with MA or MS units	27	40.30
	MA/MS graduate	17	25.37
	with PhD units	11	16.42
	PhD graduate	4	5.97
	TOTAL	**67**	

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Table 2. Profiles and pseudonyms of participants in the interview

Pseudonyms	Sex	Teaching Institution	Highest Educational Attainment
Silang	Male	Junior High School	MS Candidate
Maddie	Female	Senior High School	PhD (ongoing)
Genie	Female	Higher Education	Bachelor’s Degree
Mary	Female	Senior High School	MA (ongoing)
Eddie	Male	Junior High School	MA units
Cherry	Female	Higher Education	MS (ongoing)

Most respondents belong to the “Millennials” group according to Colby in the report entitled The baby boom cohort in the United States: 2012 to 2060 in 2014 classification of generations, which means that their ages range from 26 to 41 years old at the time of writing (year 2022). Only few, about 16% of the science teachers are employed in higher education institutions, most of them are in secondary schools. While the respondents can neither be regarded as experienced nor new in their professions, they exert efforts to advance their professional growth as evidenced by their enrollment in graduate schools.

At the end of the survey, a question was asked whether the respondents are willing to be interviewed. Seventeen respondents answered “yes” in the survey, however, upon follow-up, only six confirmed their participation and were interviewed. The in-depth interviews to follow through their responses in the survey was conducted through video conferencing apps available to them.

2.3 Instrument

The instrument for quantitative survey was constructed based on Van Rooy and Chan's (2017) classification of multimodal representations and as Fang et al. in the book entitled Language and Literacy in Inquiry-Based Science: Classrooms, Grades 3–8 in 2010 classification of scientific genres in science classrooms while interview questions were based on the 3rd and 4th research objective, that is to explain how and why representations and genres occur. Both instruments were subjected for validation by four field experts. Two of them were PhD holders while the other two were PhD candidates in science education. All questions that scored four “highly relevant” during the validation process were included in the final instrument.

Prior to this study, several investigations on multimodal representations in classroom were conducted through case studies and classroom observations (Nordby et al., 2017; Pierson et al., 2021; Volkwyn et al., 2019). While these provided deep insights regarding the field, the use of survey also has some advantages. In self-score surveys, teachers would respond based on what they have been doing in their classrooms, which means that it has more time coverage. Class observation or case studies would only cover short time intervals and may only observe what the teachers and students want them to see. Furthermore, surveys capture more experience because it can reach out to more respondents while case studies and class observations can only focus on one teacher or one class. Indeed, a questionnaire on the use of representations in a biology class was developed (Nitz, Prechtl, et al., 2014) and used (Nitz, Ainsworth, et al., 2014) - the present study’s instrument is intended for teachers.

2.4 Data Analysis

Quantitative data collected were tabulated and analyzed using ranks and averages. To respond to the first statement of the problem, Further inquiries were initiated to spot significant differences on the frequency of occurrences of scientific genres and multimodal representations. Simple one-way analysis of variance (ANOVA) was performed in the software Statistical Package for the Social Sciences (SPSS 28.0). Post-hoc analyses were also run in the software using Tukey Honest Significant Difference (HSD). All results of post-hoc analyses are presented in the appendices.

Most of the qualitative data were extracted from audio recordings except from one participant who opted to just write their answers due. However, some participants opted to write their answers due to the weak internet reception in their area. Many of them responded in English while the rest in the mix of English and Filipino. Non-English responses were transcribed then translated into English language. The translation was checked by a teacher who specializes in the language. The translated transcript was then sent to the participants for them to check and verify that it is accurate. When we agreed on the transcript, we finally commenced deductive thematic analysis using the software Quirkos to answer the second and third statements of the problem.

Thematic analysis is a tool used in qualitative research for “identifying, analyzing, and reporting patterns within data” (Braun & Clarke, 2006). Our thematic analysis in this study was approached with theoretical perspectives in mind, the research questions. We followed Braun and Clarke’s (2006) six phases of thematic analysis: 1. Familiarization through several readings of the transcript; 2. Creation of codes; 3. Grouping the codes into themes; 4. Reviewing of the themes; 5. Naming of the themes, and 6. Reporting of the results.

3. RESULTS AND DISCUSSION

We envisioned to determine the frequency of occurrence of scientific genres and multimodal representations in science classrooms as well as the reasons and how these are used. To do so, we conducted an online survey and interview among science teachers in the Philippines. The result of our investigation is presented in this section. First, we presented and discussed the quantitative and qualitative data on separate sections then integrated them on another.

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RQ 1. Scientific genres occurred in science classrooms

Table 3. exhibits the occurrences of scientific genres in science classrooms. Except for argument, all scientific genres always occur in science classrooms. Information report occurs most often followed by explanation while argument occurs the least. Because this is a science classroom we are referring to, it is surprising that "Experimental Account" is only a third thing that occurs in terms of frequency when the nature of the subject matter is an inquiry performed by conducting and reporting of experiments.

Table 3. Occurrence of scientific genres in science classrooms

Scientific Genres	Frequency of Occurrence	
	Mean	Description
Information Report	4.64	Always
Experimental Account	4.37	Always
Explanation	4.51	Always
Argument	4.18	Frequently

Note: 1.00 – 1.80 (Never); 1.81 – 2.60 (Rarely); 2.60 – 3.40 (Seldom)
3.41 – 4.20 (Frequently); 4.21 – 5.00 (Always)

RQ 2&3. Multimodal representations across scientific genres in science classrooms

Table 4. demonstrates the frequency of science teachers using multimodal representations across each scientific genre in science classrooms.

Table 4. Occurrence of representations across scientific genres

Scientific Genres	Linguistic-Verbal	Mathematical-Symbolic	Visual-Graphical	Gestural-Kinesthetic	Material-Operational
Information Report	4.72	4.34	4.51	4.37	4.31
Experimental Account	4.70	4.33	4.52	4.36	4.18
Explanation	4.64	4.21	4.33	4.31	4.15
Argument	4.64	4.19	4.27	4.31	4.13

Comparisons of means using a one-way analysis of variance produced a significant result, F (3, 264) = 5.487, p = .001. Tukey post-hoc analysis showed that both "information report" (p=.001) and "explanation" (p=.032) significantly occur more frequently than "argument" in science classrooms. Mean frequency of occurrence for representations across genres is presented in Table 4. Numbers are highlighted such that the most frequently occurring representation are colored lighter (yellow) while the least occurring ones are darker (red). Generally, linguistic-verbal representations are the ones used most while material-operational is used the least.

It seems that all representations always occur during "Information Report". Linguistic-verbal occurs most often while mathematical-symbolic occurs the least. Comparisons of these means by one-way ANOVA implied that there are significant differences that exists, F (4, 330) = 3.552, p=.007. Post-hoc analysis by Tukey HSD showed that "linguistic-verbal" significantly occurs more frequently than "mathematical-symbolic" (p=.024), "gestural-kinesthetic" (p=.048), and "material-operational" (p=.012) during "information report" in science classrooms.

During "Experimental Account", all but material-operational representations were used "always" in the respondents' science classes. Linguistic-verbal occurs most often while material-operational are used the least. One-way analysis of variance showed that at least a significant difference appears between the occurrence of these representations during "experimental account" genre, F (4, 330) = 5.365, p<.001. Further investigation using Tukey post-hoc analysis showed that "linguistic-verbal" significantly occurs more frequently than "mathematical-symbolic" (p=.020), "gestural-kinesthetic" (p=.041) and "material-operational" (p<.001); visual-graphical representations are also used more frequently than material-operational (p=.041) during experimental accounts.

During "Explanation", linguistic-verbal, visual-graphical and gestural-kinesthetic representations always occur while both material-operational and mathematical-symbolic are used frequently during science classes. Linguistic-verbal occurs most often while material-operational occurs the least. Comparison of means across these representations showed a significant result, F (4, 330) = 4.209, p = .002. Post-hoc analysis using Tukey HSD reveals that only linguistic-verbal representations are used significantly more often than both mathematical-symbolic (p=.009) and material-operational (p=.002) during explanation genre in science classes.

Similar to the explanation genre, linguistic-verbal, visual-graphical and gestural-kinesthetic also occur "always" while mathematical-symbolic and material-operational occur frequently during arguments in science classes. Linguistic-verbal occurs most often while material-operational occurs the least. Further comparisons using

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one-way ANOVA suggests that a significant difference occurs across these representations, F(4, 330) = 4.512, p=.001. A Tukey post-hoc analysis is run to determine across which representations are significant. Results showed that linguistic-verbal is significantly higher than both mathematical-symbolic (p=.007) and material-operational (p=.001) during argument genre in science classes.

We presented the occurrence of representations across each scientific genre based on their frequency of use and ranks, but a more pronounced observation is that all representations occur at least "frequently" in seem to be employing multiple representations in delivering their lessons. Again, even with different methods and investigation, the result confirm that science teaching and learning is multimodal (Ainsworth, 2006; Yore & Hand, 2010).

The pattern suggests that linguistic-verbal representations are the ones commonly occurring in all genres in a science classroom. One may argue that the result is in disagreement with Tang's (2023) findings but we contend that they are not. Unlike in textbooks, the focus of Tang's investigation, in classrooms, teachers always speak. Whether they use figures, photographs, equations, or even when they provide instructions, answer questions, they always explain them in words. Thus, it is expected that teacher-respondents rank linguistic-verbal in the survey as the foremost representation they use. But when we look at the second mostly used representation across all genres, visual-graphical is common and agrees with existing literatures.

RQ 4. Strategies of using multimodal representations across each scientific genre

After analysis of the survey, we followed through in-depth interviews to teachers who expressed willingness to participate. All interviews were performed via zoom, a videoconferencing software. We asked how and why questions regarding the result of the quantitative survey. Results of the deductive thematic analysis are presented in this section. Scientific genres together with general observations were designated as themes.

Scientific Genres

We first asked the participants "Why must all the scientific genres occur in your science class?", then we asked them "How?" do they do it. We also expressed concern on the place of experimental account relative to other genres then we asked them to comment on it. Then we asked them to comment on why argument occurs least often of the genres. The participants seemed to have been constrained by standards, and availability of materials. We asked the participants why they use all scientific genres in their classes. First, they explained that they just conform to their syllabi and directives coming from the Department of Education (DepEd), the country's in-charge in the formal and non-formal basic education systems. Silang states "We are following this what we call the MELCs, the most essential learning competencies. These are competencies that were selected by the DepEd which are essential to the learner". Cherry, a higher education instructor on the other hand has different source of conformity: "It occurs because of how the syllabus and learning outcomes were designed." When teachers design their lesson plans or syllabi, they seem to naturally utilize most of the scientific genres.

Second, though the participants are not aware of the technical terminologies, they are aware that these genres are necessary because they support learning and improve students' skills. Maddie explains "These activities are needed to enhance the science process skills of the students and improve the teachers approaches and strategies in dealing science activities". Furthermore, they claim that these different genres are needed to address the many learning preferences of students, as Genie mentions "These four scientific genres should occur because we know that students have different learning modalities, thus as teachers, we should provide different teaching styles to cater the diversity of students"

We also asked how the participants use all genres in their classes. Eddie narrates how they do it: "I make sure that the examples I am using is organized. I also tell the objectives of the day. The explanation should be lively, and I always ask HOTS [Higher-Order Thinking Skills] questions". Participants also provided examples that follow inquiry-based lesson plans, one of the teaching approaches mandated by DepEd for science K to 12 instructions.

> *If you notice the DLL [Daily Lesson Log] we use, more so with us in science classes, we use lesson exemplars, it's either the 5Es or 7Es. First, the motivation and the review itself are IRs. You give grounds about the topic. Next, you have them experience certain concepts. For example, in lungs, they will create lung models before we move to explanation… they will explain the function based on the conducted experiment. Then, if there are additional information, what do we call this, ah during argument, not much, it depends if it fits the topic. Unlike the first three, it's part of the DLL, part of teaching. (Cyrille)*

Teacher Cyrille likewise expressed that argument genre does not happen as much as the rest of the genres in her science class. The result of the survey showed that it is the only genre that occurs "frequently", the rest occur "always". Participants seem to have no explanation why argument is less used in science class other than it is not appropriate to most of their lessons. Cherry tried to expound on their answer but ended just accepting the fact.

> *… my students rarely debate their opinion on the class, but I let them expound their answers or I am letting them to conclude and compare based on the result of the experiment or the answers to the activities. But yes, it seems that students rarely argue on ideas. (Cherry)*

Argumentation provides scientists with opportunities to practice and learn critical thinking skills, gaining new information (Passmore & Svoboda, 2012) and making sense of the world (Bricker & Bell, 2008; Lawson, 2003). In science classes, this also improves students' academic performance, critical thinking skills, and inquiry skills (Faize et al., 2017). However, its use in classroom teaching has not yet been fully realized. To do so, certain problems

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must be addressed such as the verifiability and testability of students ideas who often present ones that are against existing science practices (Duit & Treagust, 2010). Thus, it is but understandable that science teachers are hesitant and, consequently, rarely use arguments in their classes.

When we expressed some concern that experimental account was only ranked third of the four genres in terms of the frequency of occurrence in science classes, participants revealed that materials are mostly not available in their school and that they were limited by the social distancing protocols during the pandemic. Eddie casually replied: "…lack of facility and material". Genie on the other hand explains:

> *Experiments are very important to science classes, and I think there is a great impact of Covid-19 why experimental account listed as third, since students cannot go to school to conduct face-to-face classes or conduct the laboratory activities in the lab.*

Another one is the non-availability of resources at home during this online learning. Maddie even mentioned that not only are the materials unavailable but teacher competencies in conducting experiments is also an issue. Silang was more specific that he mentioned of expired chemicals and practically no microscope in their laboratories:

> *One of the factors that we have the challenge is that we don't have the availability of the materials, and these are what we want to solve. Even in this school you can see that we have no face-to-face classes, there are lots of chemicals or expired chemicals and we have no, for example, microscope. I think we have one microscope but it's not okay.*

Lack of available materials for science experiments is not an uncommon problem in the country (Hadji Abas & Marasigan, 2020; Noroña, 2021) and other developing worlds (Gökmen et al., 2021; Ngozi & Halima, 2015). In fact, these very studies likewise pointed out that even teachers are not fully equipped with competencies in handling equipments and designing an experiment for them – an alarming problem because it has been proven time and again that conduct of experiments in science improves skills and learning (Artun et al., 2020; Kapici & Akcay, 2020; Niazi et al., 2018) as well as attitudes towards taking science (Kalemkus et al., 2021; Kayacan & Sonmez Ektem, 2019).

Information Report

We asked how and why all representations must be used in information report and why linguistic-verbal is most commonly utilized. Their responses addressed both students and teachers' concerns. For teachers, it is just but natural for them to use linguistic-verbal since it is the easiest and that they are most comfortable with it, as Cyrille explains "Linguistic-verbal is really used most often because I can express myself easily through it, through the languages of science, unless the topic is physics where you use mathematical equation...". It seems that they also use multimodal representations during information report to address students' varying learning needs.

> *Every student is unique. They have multiple intelligence and some students, some students grasp symbols, some can understand language in verbal, in non-verbal. Meaning to say, we must be able to connect to the different types of students we have using these different kinds of representations. (Silang)*

Experimental Account

Like information report genre, in experimental account, all multimodal representations are also used at least frequently during the science teachers' classes. Maddie claims that these representations enhance critical thinking and communication skills. Linguistic-verbal is used most often while material-operational is used the least. Eddie has ideas why this occur: "…lessons and experiments can be discussed just by using language, material-operational is least because of lack of lab equipment". On the other hand, Silang specified how representations are embedded in each possible stages of experimental accounts:

> *There are lots to do during an experiment from pre-lab, to doing the lab, post-lab and reporting. In these activities, they use a lot of representations, and so am I. They will create tables to organize the data, create graphs for better visualization, use papers and pens to write the processes, use words to explain, and so on. So, every representation is used in these activities.*

However, they mentioned again that this genre does not actually happen very often in their class. Social distancing protocols but more importantly the lack of materials and equipment for experimentation are the problems they cite. We then followed through question on how they use multiple representations during experimental account. Cyrille specified how each representation is used:

> *First, I will present the facts to students and then, there are times, even when you are in the lab, you will demonstrate, you will use gestural-kinesthetic. If there are data to be collected, you will use visual-graphical, for example a table, a chart that they will use. If your topic is physics or chemistry, you will really use mathematical symbols where formula and chemical formulas are used to explain. So, you will really use these even in labs… sometimes you must also explain using linguistic-verbal to give instructions.*

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Explanation

First, we shared the participants the result of the survey that during explanation genre, all representations are used at least frequently then we asked them to comment on it. Second, we revealed that linguistic-verbal together with visual-graphical and gestural-kinesthetic are being used always but material-operational and mathematical-symbolic are used less frequently. Finally, we asked how and why these happen in science classes. Eddie expressed appreciation of the significance of this genre in science classes "Explanation is the most important part of teaching. I give more preparation in explaining the lesson by doing additional research/study".

Like the first two genres, they think that they employ these representations because they work and are appropriate for their lessons. Furthermore, they seem to have expected that linguistic-verbal must be used more frequently than the rest of the representations. Even when solving problems, they mention, one must always use linguistic-verbal representation because it would not matter to just present mathematical equations and symbols alone. Maddie gave distinction on when these representations are used: "It also depends on the subject being taught like earth science, biology requires linguistic- verbal for the discussion and explanation of concepts, only the physical sciences were mathematical operations applied the most".

Argument

We proceeded to asking how and why questions about the least used scientific genre, the argument. We asked them to explain how and why all representations are used during their science classes. Again, they started with linguistic-verbal representations – that during arguments, communication and speaking skills are required but other representations such as mathematical symbols and materials are used less often. Maddie provided a more detailed explanation:

> *Just like explanation, example in argument part, if you want to add emphasis on what you're saying, you will resort to different representation. You explain while you demonstrate to prove your point during argument, also to enhance the delivery of information to listeners. (Maddie).*

RQ 5. Reasons for using multimodal representations across each scientific genre

Finally, we presented the general observation on the result of the survey. Since much have been explained about the common uses of linguistic-verbal representations in every scientific genre, we focused their attention on the next most used, the visual-graphical. We asked why they always use the representation. They explain that it aids in students' understanding. Genie explains, "When spoken or written language is accompanied with photos, graphs, infographics and other visual aids, teaching in a science class becomes more effective and information is easily absorbed." Even a data itself are not readily understood, Silang noticed. They continued that if these datasets are presented as graphs such as line, bar, or pie charts, understanding becomes easier. Eddie was specific in how he use visual-graphical representations: "Sometime I print photo for better display only, I can draw in or even tell just by words"

There was one striking and impactful to supervisory practices revelation of the participants. That their use of visual-graphical representations was recommended by their observing supervisors.

> *That is always used even with generalization part of the lesson. You just don't state it in words. Use of concept maps, charts, Venn diagrams are also recommended. They find it in our lesson plans. You just don't have students explain, you must also use something they can remember, always. So that if the students prepare for exams, they will imagine the graphs, diagrams, tables you showed them. (Cyrille)*

Follow up questions revealed that the participants are referring to educational program supervisors who observe them in class. The ideas of using other representations especially visual-graphical were recommended by their supervisors after class observation. The practice has then become part of the participants' teaching repertoire.

Finally, the participants also find it but natural for visual-graphical representations to be used during science classes as Cherry explains: "…visual graphical since our subjects deals with a lot of figures, models, representations, photos the support the idea and concepts of the topic.". True enough, science is like a conglomerate of other disciplines such as language and mathematics but its method of study, the beliefs and practices in it make it produce disciplines different from the others. Indeed, meaningful teaching of science requires multimodal representations.

Integration

Though there seems to be no generally agreed definition on the integration or mixing of results in a mixed methods research design (Fetters & Molina-Azorin, 2017), we framed the current study such that the weaknesses of quantitative and qualitative data are complemented by each method (Dawadi et al., 2021; Stern et al., 2021). This results to the findings in the quantitative phase being explained by the qualitative phase, and the generalizability of qualitative findings made possible by the quantitative data. A controversial, but not new nor unique in this study, findings was also uncovered. For example, result of the survey suggests that experimental account is "always" used during science classes. However, analysis of the qualitative data implies that experiments, and so is the reporting of the results of it, do not happen that often due to lack of available materials and was worsen by the social distancing protocols during the pandemic. This issue made us rank the genres in terms of occurrences and discussed findings based on the ranks. Being fourth in the rank, we found that argument happen even less often than experimental account which was also confirmed by the qualitative findings as Cherry revealed "…my students rarely debate their opinion on the class… yes, it seems that students rarely argue on ideas".

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Invalidity of the controversial self-report data had been the concerns of several studies (Edwards, 2019; Lee et al., 2021; Spector, 1994). Some participants, similar to the current study, seem to be responding not based on their experiences and practices but probably based on how they want to be perceived by the researchers as Daniel (2016) doubted "The experiences gathered may not be that of the participants mind and opinion"; van de Mortel (2008) calls this phenomenon "socially desirable responding". Though Brenner and DeLamater (2016) have alternative explanations based on identity theory. A more pressing claim was that of Stephens-Davidowitz in the book chapter entitled Everybody lies: Big data, new data, and what the Internet can tell us about who we really are in 2017 after they found enough evidence to say that people do not really do what they say neither do they say what they do.

Although experimental account and argument are used less often, teachers use all scientific genres provided in this study. Qualitative findings suggest two explanations for these. First, because science teachers conform to standards. They do not necessarily design lessons with scientific genres in mind, they just follow the curriculum set by authorities, in this case, the Department of Education (DepEd) and the Commission on Higher Education (CHED). Silang, a JHS teacher shared "These are competencies that were selected by the DepEd which are essential to the learner". Second, because they believe that use of these scientific genres provides variations in their instruction and that these support learning. Cherry, a higher education instructor explained, "For us to achieve the learning outcomes and for my students to be scientific literate".

All representations are being used regularly by the science teachers in every scientific genre, further confirming studies that science teaching and learning is multimodal. Participants were able to explain in detail how these representations are used and that they do it because it helps their students understand meanings easier. They also explain that being multimodal with representations helps cater every unique student in their meaning-making.

4. CONCLUSION

The present study provides insights on the use of multimodal representations across different scientific genres in science teaching and learning. Using a mixed method sequential explanatory research design allowed us to dig deeper on the results of the descriptive survey which is prone to inaccuracies primarily because of the self-score methods. The study revealed the most prevalent scientific genre and commonly use multimodal representations across each scientific genre in science classrooms. Information and explanations genres are used "always" while experimental account and argument are used less often as suggested by the qualitative findings. Science teaching using these genres were multimodal primarily to address all students' meaning-making styles. Additionally, the content and activity employed in different types of representations cause students to communicate with learning objects in different roles/dimensions. The current study revealed the weakness of self-score surveys in which respondents may be biased in scoring their practices. These were spotted and corrected with a complementary qualitative method, thus mixed methods. Further use of mixed methods research to explore the interplay between scientific genres and multimodal representations would uncover more insights and improve science teaching and learning practices.

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