Fall 2016

Investigating the effect of science writing heuristic approach on students' learning of multimodal representations across 4th to 8th grade levels

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INVESTIGATING THE EFFECT OF SCIENCE WRITING HEURISTIC APPROACH ON STUDENTS' LEARNING OF MULTIMODAL REPRESENTATIONS ACROSS 4TH TO 8TH GRADE LEVELS

by

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A thesis submitted in partial fulfillment
of the requirements for the Doctor of Philosophy
degree in Science Education in the
Graduate College of
The University of Iowa

August 2016

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PH.D. THESIS

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I dedicated this thesis to myself
as I wrote a great thesis

ACKNOWLEDGEMENTS

This dissertation would not have been completed without the guidance, support, and encouragement of many individuals to whom I would like to express my insightful thanks.

First, I would like to express my sincere thanks to my thesis supervisor and advisor, Brian Hand, for his guidance and support. Thank you for guiding the choice of my research area and your countless support to my thesis and my doctoral studies. I also would like to express my special thanks to Deborah Linebarger as being my committee member, and contributing to my thesis from the time I started and finished. Thank you, for being such an advisor since I met with you, I learned many research skills from you. I am grateful and would like to express my deep thanks also to my other committee members, Soonhye Park, Andrew Forbes, and Mark McDermott.

Third, I would like to thank Turkish Ministry of Education for their financial support throughout my graduate program. I am grateful to Turkish taxpayers who made this scholarship possible.

I conclude by expressing my endless gratefulness for my family. I would like to thank to Mom, Dad, sisters, and brother for their supports.

ABSTRACT

This study was designed to examine the effect of Science Writing Heuristic Approach on Students' Learning of Multimodal Representations across 4^{th} Grade to 8^{th} Grade Levels. Multimodal representations in the forms of figures, tables, pictures, and charts are part of scientific language. A quasi-experimental design with control and treatment group of classes was used. Students completed the summary writing task by including multimodal representations in the both control and treatment classes. The students' writing samples were evaluated with four measures of multimodal categories, including sign, functional, conceptual and embeddedness structures. To examine the differences of treatment and control groups and the effect of age, the Hierarchical Linear Modeling (HLM) analysis was used in this study. Analysis of quantitative data indicated that the treatment classes significantly outperformed than the control classes on four measures of categories. Age also was a significant contributor to students' learning of multimodal representations. Three key points emerged from the results. Firstly, the SWH approach had positive effects on students' understanding of the multimodal representations. Secondly, the impact of the age was different for each category. Thirdly, the categories were used in this study had significant potential when exploring the students learning of multimodal representations. The study indicated some practical benefits that the strategy of promoting argumentative scientific language effectively was resulted in better communication, understanding of the topic with multimodal representations, and some transferring impacts of all these with the summary writing activities.

PUBLIC ABSTRACT

This study was designed to examine the effect of Science Writing Heuristic Approach on Students' Learning of Multimodal Representations across 4th Grade to 8th Grade Levels. Multimodal representations in the forms of figures, tables, pictures, and charts are part of scientific language. A quasi-experimental design with control and treatment group of classes was used. Students completed the summary writing task by including multimodal representations in the both control and treatment classes. The students' writing samples were evaluated with four measures of multimodal categories, including sign, functional, conceptual and embeddedness structures. To examine the differences of treatment and control groups and the effect of age, the Hierarchical Linear Modeling (HLM) analysis was used in this study. Analysis of quantitative data indicated that the treatment classes significantly outperformed than the control classes on four measures of categories. Age also was a significant contributor to students' learning of multimodal representations. Three key points emerged from the results. Firstly, the SWH approach had positive effects on students' understanding of the multimodal representations. Secondly, the impact of the age was different for each category. Thirdly, the categories were used in this study had significant potential when exploring the students learning of multimodal representations. The study indicated some practical benefits that the strategy of promoting argumentative scientific language effectively was resulted in better communication, understanding of the topic with multimodal representations, and some transferring impacts of all these with the summary writing activities.

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CHAPTER ONE

INTRODUCTION

The Next Generation Science Standards (NGSS) stress that practicing science is more effective for students than reading scientific information from textbooks (NGSS, 2013). The standard science practices utilize language intensive science learning including reading, writing, and visually representing the explanations with multimodal structures when arguing scientific ideas with inquiry (NGSS, 2103). The nature of scientific process also includes the demonstration of findings in a written format (Yore, Bisanz, & Hand, 2003). The written format includes multimodal representations that have a variety of functions for the development of science and science education (Bernsen, 1994). One of the functions is that scientific ideas are more effectively conceptualized and communicated by multimodal representations in the forms of figures, tables, and charts as part of the language of science (Ainsworth, 2006). Further, scientists combine text and other multimodal representations when negotiating and sharing their understandings of a process visually (Lemke, 1998; 2005). By doing so, scientists are able to construct and interpret their findings to allow effective discourse for new ideas and discoveries as a community through a written text with multimodal representations (diSessa, 2004; Halliday, & Martin, 2003).

Science writing is formed through multimodal representations which integrate verbal modes with visual modes (Mayer, 2003). Multimodal representations are required for effective communication in science writing, as the language of science is inherently diverse (Yore et al., 2003; Yore & Hand, 2010), and is best accomplished by a language that includes multimodal representations, mathematics, and natural language to produce a single visually unified system (Lemke, 1998). Multimodal representations range from basically structured verbal modes, such as text and numbers, to more complexly structured visual modes, such as graphics, figures, and taxonomies (Kress &van Leeuwen, 1996).

Additionally, Kress, Jewitt, Ogborn, and Tsatsarelis (2001) indicate integrated visual and verbal modes as “signs” which comes from the semiotic property of scientific language in which visual representations have a meaning by linking more than two modes together. Signs become necessary because verbal texts do not have adequate features to show the information and concept without visual modes. For instance, mathematical graphs do not represent the same construct as the mathematical equations because each of them displays the different information which cannot be shown by using only text. Frequently, icons, symbols and equations are used to form to explain and communicate scientific phenomenon and theories in addition to text. Because of the numerous use of different types of symbolic representations in science, Halliday and Martin (1996) similarly stress that scientific theories are constructed with mostly semiotic systems. For this reason, Kress and Van Leeuwen (1996) emphasize the importance of training students to be visually literate and to learn the grammar of visual design through sign-making, in order to draw attention to the semiotic structure of scientific language when using multimodal representations with different functions. Thus, practicing science in this multimodal system allows students to learn meaning making by communicating with different modes of scientific language effectively as the NGSS stress (Halliday, 1998).

Furthermore, Lemke (1998) explains connecting the visual mode with a verbal mode through meaning-making processes where the meaning in the text is represented in the visual mode which he similarly calls visual semiotics. He also states that meaning of signs depends on the meaning-making practices, also called sign making, which are essential for students to learn science. For this reason, instructing students on basic definitions and functions of modes is needed because students find the meaning making (sign making) process is complex when their teachers ask them to use visual modes such as graphs, equations, and tables in their science writing (Kress et. al, 2001).

Given that modes (charts, tables, pictures, etc.) are used in the text and they function as signs during the writing process, students need to construct knowledge meaningfully by integrating these signs into their writing (Schnotz, Bannert, & Seufert, 2002). This process can be difficult for students in the traditional learning environment because students have to memorize the content by replicating the information in textbooks in this learning environment. For example; students' representation of a flow chart in an energy topic requires them to connect meanings in the concept. Accomplishing this depends on understanding the concept by using their reasoning Therefore; students need to learn the structures and characteristics of the multimodal representations for the meaning making process. The method of applying this concept to teaching science is to include more non-traditional writing to learn activities, rather than the traditional method (Prain & Tytler, 2012; Waldrip, Prain, & Carolan, 2010).

One of the nontraditional methods is the Science Writing Heuristic approach that is a type of argument based inquiry approach. In this method, students can practice both argument and writing which can encourage them to construct their own discussion based on different views of the theory and practices. During this process, students can develop both formal and informal writing with multimodal representations; thus, students can learn to comprehend the relationships among ideas and process the information deeply (Mcdermott & Hand 2013; Prain, 2006; Yore & Hand, 2010).

Science text with multimodal representations enhances the students' comprehension of the subject matter in many ways. Multimodal representations develop the readers' interest and attention to science content because especially slow readers can learn from the pictures and diagrams better. Students can learn to show patterns and describe how a procedure is done when relating general knowledge to specific examples. Additionally, students can understand the content with a more detailed level of descriptions and explanations with visuals modes because they can comprehend to form relationships between the real everyday and the abstract scientific information by organizing disparate pieces of information in their writing (Chambliss, 2002).

Traditional teaching and learning activities are not effective to implement these NGSS standards and practices (Reiser, 2013). For these reasons, the NGSS stress of using of multimodal representations and implementing inquiry in science classrooms (NGSS, 2013). The Science Writing Heuristic Approach can fulfill these requirements because SWH approach is an argument based inquiry method in which argument based inquiry activities and non-traditional writing concentrate on using multimodal representations (McDermott &Hand, 2010). Due to using multimodal representations students improved their comprehension in many ways (Chambliss, 2002), research is necessary to identify how students use multimodal representations and in which structures they use those representations when practicing and learning science in SWH approach-based classrooms.

Problem of the Study

SWH approach-based classrooms, where learners can negotiate their ideas while integrating multimodal representations, promote students' understanding better than traditional writing tasks compared to traditional task (McDermott & Hand, 2010). Barrow (2006) explains that in traditional writing tasks, students do not construct their inquiry process and writing and only replicates the information in the textbook. However, replicating information in the textbook only leads to memorizing the text and the figures, but not understanding how the content integrates visual and verbal modes and their relationships. Van Leeuwen (2005) explains that the issue of integrating visual modes with verbal modes is the result of an inadequate understanding of how to create cohesive writing because the information in the text and the information on the representation should be logically consistent.

As students need to integrate the text with different kinds of representations, including mathematical terms, graphs, and science equations, students need to practice proper writing tasks, which can help them to compose a coherent text and coherent understanding. SWH approach is the one of them. However, previous research has shown that as the transition from traditional to inquiry based classroom is difficult for students to participate in; therefore, students cannot easily connect verbal modes to visual modes and consequently they cannot produce a coherent text about these multimodal representations (McDermott & Hand, 2010).

Moreover, some of the difficulties that students have faced in their writing include students' lack of experience with: (a) practicing multimodal writing and integrating the modes with the writings and producing a coherent text (Mayer & Moreno, 2003), (b) understanding functional and basic semiotic structures of different kinds of modes (Ainsworth, 2006), and (c) understanding conceptual structures of the modes (Kress & van Leeuwen, 1996). Therefore, students need to learn the grammar of the multimodal representations rather than using only specific type of visual representations (Kress & van Leeuwen, 1996).

However, most of previous research has focused on one type of mode instead of evaluating the visual representations' structures and their associations with the text. Among previous research, Yerushalmy's (1991) study showed that students had difficulties on integrating the visual with verbal modes. The participants were 35 8th grade students who attended a computer facilitated lesson for three months. In the learning environment, students were instructed to use multimodal representations with computer software. The tool enabled learners to easily integrate graphical representations by plotting the corresponding information from the text to graphs. The results showed that only 12% of students' answers included both verbal and nonverbal representations in their writing task, even though students were participating in an extensive multi-representational learning environment. In the study, most of the students' answers only included unimodal representations and the integration of verbal and nonverbal modes was quite low. The research concluded that students could not easily integrate multimodal representations into their text.

Friel, Curcio, and Bright's (2001) study produced parallel results of integrating graphs to text. Students could not easily display the content on the graphs. They especially struggled with plotting and understanding points of the graphs. These difficulties differentiated across grade levels above 6th grade to 8th grade (age 12) and below 6th grade (age lower than 12). The reason for this that at the 12 to 15 years old age group, students' multiplicative reasoning grows to understand relative frequencies and percentages and ratios. Zacks and Tversky's (1999) discovered that learners only used bar graphs when they represented discrete comparisons. The study concluded that students needed to be exposed to different kinds of conceptually structured multimodal representations through all grade levels especially from ages younger than 12. However, they could not use other kinds of graphs or representations because they were taught how to use only one type of graph. This shows that their understanding of the conceptual structure of the modes was inadequate because when students learn conceptual structures, they can have opportunity to differentiate between different kinds of modes with their structures and meaning (Kress & van Leeuwen, 1996; Kress et. Al, 2001).

Understanding a variety structures of multimodal representations is important. Even though the information in two different types of multimodal representations is the same, their semiotic attributes, conceptual, and functional structures affect the meaning making process of using multimodal representation because of the information retrieval in the cognitive process. Cognitively, constructing new information using more than one representation depends on the structures of the representations (Mayer & Moreno, 2003). Additionally, the structure of a representation determines whether the representation is easy to understand and necessary to use (Schnotz, 2002). Due to students' difficulties of using representations, Ainsworth (2006) stresses that there is a strong need for research in multimodal representations to show the effectiveness of constructing and determining functional structures when using different kinds of multimodal representations in science learning.

Given that multimodal representations are important factors for students' science achievement, a small number of studies have been conducted on this topic. Of this limited amount of recent research on learning with representations in science in particular, there has been a concentration on three areas. First, in order to improve students learning, the fundamental design organizations of using multimodal representations in writing were examined (Ainsworth 1999; Schnotz, 2002). Second, texts which had multimodal representations and without multimodal representations were compared (Mayer &Gallini 1990; Mayer, 2001). Third, the effects of the embeddedness strategy of using alternative modes on students' writing were investigated in specific teaching and learning environments (Hand &Choi, 2010; McDermott &Hand, 2013).

As the aforementioned information shows, there is a research gap in examining students writing with structural strategies for using multimodal representations in students' writing. The previous studies show that students can achieve a certain degree of practice in relating the visual modes to the text in a particular grade level, using one structure of multimodal representations and some semiotic properties (Kress et. al, 2001; McDermott &Hand, 2013). However, the emphasis was only on choosing a type of visual mode but not on what ways and structures these modes were chosen and used, and how the modes might help students to argue their ideas across different grade levels. Investigating structural strategies is an important and missing part of the previous research because when students integrate and translate the representations where students need to practice meaning making, they have difficulty (Kress et. Al, 2001). This study will address the gap in the literature by providing the reader supportive descriptions of the uses of multimodal representations with different structures in students' writings in the argument-based inquiry learning environment across different grade levels.

Purpose of the Study

The Science Writing Heuristic approach is an instructional learning strategy, which has shown some benefits for students' science learning with multimodal modal representations. The purpose of this study is to examine the effects of Science Writing Heuristic (SWH) classes on students' understanding of multimodal representations in elementary and middle schools. In order to examine the effects of the SWH, the study aims to (1) examine summary writing samples of students from 4^{th} grade to 8^{th} grade, focusing on the degree of integration among multimodal representations in writing samples in both treatment (SWH) and control classes, (2) determine functional, conceptual, embeddedness structural characteristics of the multimodal writings with a focus on sign (semiotic) structures in each grade level, and (3) test for differences between treatment and control classes.

The criteria of multimodal representations competency are evaluated with Halliday's (1985) explanation of meaning making with multimodal representations. Meaning making requires three criteria: (1), the representational system should make a connection between the aspects of the scientific concepts with the semiotic structure that was analyzed with the sign system, (2), representational systems should make a coherent relationship between context of the text and other visual components; this coherency requires the integration of the visual modes to verbal modes; therefore, the embeddedness structures of students' writing samples were determined, (3), multimodal representations needs to be presented in plausible pragmatic structures in order to communicate and establish a relationship among multimodal entities. In turn, students can use multimodal representations in different contexts based on their writing goal that was examined with functional and conceptual structures. Thus, in this study, the measures of effective multimodal representations were determined with (1) sign system (semiotic structure), (2) functional structure, (3) conceptual structure, and (4) embededdness structure to identify the degree of integration of multimodal representations.

First, the main representational characteristics of the mode were determined with a sign system that is the basic semiotic structure, in order to identify the mode itself. The previous literature showed that multimodal representations had particular functions and conceptual structures in writing (Ainsworth, 1999, Kress &van Leeuwen, 1996). As the conceptual and functional structures of the modes determine the integration of the visual modes to the verbal mode (Ainsworth, 2006), both conceptual and functional structure were used to analyze writing samples in this study. Based on students' writings and previous literature, five different functional structures were identified as the main focus of this study which are examples, description, comparison, explanation, and enriched explanation. These five functional structures were used to analyze the writing samples in this study.

The conceptual structure category was determined based on Kress and van Leuwen's study (1996) and by coding students' writing. Kress and van Leeuwen (1996) identified 3 conceptual structures: symbolic, analytical, and classificatory. As the analogical structure is more basic than symbolic (Yore et. al, 2003), it was also used to identify conceptual structure of multimodal representations because students use analogical structures often in their writing. Lastly, the embededdness structure, which is the degree of integration of visual modes to the text, was used to show how multimodal representations' structures are connected and necessary for meaning making (McDermott & Hand, 2010).

The process of meaning making requires sign making, engagement, and transformation of meaning in the text to the visual modes (Kress, 2012). Kress et. al., (2001) state that the way of using language is the main factor of making meaning with an image because the image corresponds to the meaning in the context. Modes have the function of making and changing meaning, because the modes can control the meaning. In general modes are used as an example. However, modes can be in different functions depending on the content, their usability, and purpose of the content during meaning making such as descriptive and explanatory representations; therefore, modes do not function only as examples (Kress &van Leeuwen, 1996). Emerging trends of implementation for using multimodal representations in science classrooms has developed from writing to learn strategies that have been employed to promote students' multimodal accomplishments (McDermott &Hand, 2013; Prain, 2006). Therefore, examining students' engagement with more structures of representations is necessary when students engage in writing to learn strategies.

In order to examine the connection between text and multimodal representations from 4th to 8th grade students, the following research questions were used to guide this study:

RQ 1: How does participating in SWH argument-based classrooms affect the development of students' multimodal accomplishment by measures of sign system, functional, conceptual, and integrative structures in multimodal products?

RQ 2: How are the differences between using multimodal representations in different structures from lower grades to upper grades (across 4th grade to 8th grades) grade levels in both SWH and non SWH classrooms?

Significance of the Study

New literacy studies in science education has been focused on more the use of multimodal representations in science learning because of the contribution of multimodal writing to learn activities on conceptual understanding of science (Jewitt, 2003). In response to changes of new literacies, research on multimodality has been increased in writing to learn activities (Jewitt, 2003). In order to instruct students with a multimodal writing task, it is crucial to instruct them with the meaning of modes, their functions, conceptual, and sign systematical structures, so that students will understand how to integrate visual modes into the text to make reasonable meaning with them (Ainsworth, 2006; Kress et. al, 2001; Mayer &Moreno, 1998; McDermott & Hand, 2013).

Multimodal representations include numerous structures and characteristics to promote learning in science (Jewitt, 2003). However, these numerous structures and characteristics in previous studies have been limitedly focused on a particular structure in narrow ideas such as examining only a sign system and its cognitive effects, or the effects of exploratory modes on cognitive development (Mayer &Gallini, 1990; Schnotz, 2002).

Examining modes with more structures holistically is necessary because students' writings can be built with different purposes and mechanisms in order to make meaning when integrating visual modes to verbal modes (Kress et. Al., 2001; Kress, 2009). The criterion for accomplishing this for them is to learn structural characteristics of multimodal representations and also procedures, rules, and assumptions of science writing when integrating multimodal entities into their writings (Prain, 2006). However, all these structures have not been determined and measured all together in the previous studies. Therefore, this study is important because in this study different kinds of structures of multimodal representation for meaning making were examined all together where students were required to integrate various types of multimodal representations into their texts for their summary writing tasks.

Integrating multimodal representations into text is important because students understand science better when there is an integration of multimodal discourses (Mayer, 2003). Learning a new concept means understanding what the concept means and how the concept is represented (Novak, 2010). The concepts of real and abstract information are presented in writing through integrating text (verbal mode) with other representations (visual modes) to make meaning based on the sign structure; therefore, separation of the two is not possible (Kress et. al., 2001). Thus, when students integrate the visual modes to the text, they can connect the ideas and make a meaning out of them; therefore, they understand a concept of science topics better and so they have authentic science learning (Kress et. al., 2001).

Coherent structure of a text is another significant factor for students when integrating visual modes to verbal modes. The degree of integration depends on the complementary relationship between visual and verbal modes by meaning making or sign making, which is determined by the relation the functional structures of modes have with text (Ainsworth, 1999). As a result, students can construct coherent texts. This is significant to investigate because the coherence of a science text predicts learning, that is, comprehension of the text is easier with a coherent text (Wade, 1992). Mayer and Moreno (1998) explain that students who produced coherent text, were 50% better in problem solving-transfer than who did not. van de Meij and de Jong (2003) stress that learners are better able to complete their representation writing tasks when they understand how to integrate visual modes to verbal modes coherently. Therefore, the expectation from students is to integrate the visual and verbal modes by constructing a coherent text.

Schnotz et al. (2002) argue that the coherency of the text is important for students because there are many examples of science texts with simple pictures which cause misleading meaning that impedes comprehension, due to the lack of coherency among multimodal representations in the writing. The coherency of the text requires a certain degree of integration (embeddedness) with the relevant meaning of text and visuals because the content of the text determines the meaning of the images, in other words semiotic codes (Kress et. al., 2001). Therefore, the strategies of learning and teaching with multimodal representations should include an understanding of cognitive demands and development of students learning with multimodal representations that enable students to understand how to integrate visual modes to verbal modes depending on their structural characteristics by making meaning (sign making) with them. (Kress et. al, 2001).

Another significant point of this study is that previous studies' findings do not show the relationship between cognitive developments effects on learning multimodal representations for grade four through grade eight. This is significant to investigate due to the lack of studies claiming that information processing speed and capacity increases with age and cognitive development (Ainsworth, 2006). Thus, students' grade levels are possible distinguishing factor for students when they translate between representations in this study because of the developmental factors. Halford (1993) claimed students under age 11 (grade 6) have difficulties understanding multi-dimensional structures as they do not have much opportunity to learn multimodal representations; therefore, these students need to engage in multimodal representational writing activities. However, these difficulties can be overcome with an appropriate instructional strategy that has potential to encourage students to engage in discussing and negotiating content through writing such as SWH approach (Danish & Phelps, 2011; McDermott &Hand, 2013).

Recent research has shown that when students engage with non-traditional writing tasks in argument based inquiry classrooms, which are an integral part of the SWH approach, their understanding of the targeted science topic improved (McDermott &Hand, 2010; 2013). However, the research only examined one type of structure, embeddedness, of learning with multimodal representations in 9^{th} grade, but not in the lower grades. The literature shows that there are multiple structures that students engaged in when learning with multimodal representations in science classrooms (Kress & van Leeuwon, 1996). Therefore, examining the structural features of multimodal representations is significantly necessary in lower grades to help students overcome possible difficulties of learning science with multimodal structures in the SWH approach based classes.

The SWH approach is an authentic scientific practice, in which students construct multimodal writing based on their argumentation inquiry laboratory practice; thus the SWH approach provides a multimodal learning environment (McDermott, & Hand, 2010; 2013). Multimodal learning environment requires students to construct their understanding by using verbal and nonverbal modes in their science content (Moreno & Mayer, 2007). This approach supports students constructing their knowledge through writing because students need to express, interpret, and think critically about how to represent scientific knowledge through their writing (McDermott, & Hand, 2010; 2013). Therefore, this instructional approach was chosen in this study because recognizing, expressing, and transforming the meaning of modes is used for the meaning making process of multimodal representations and is a fundamental feature of authentic science practice (Kress et. al, 2001). Additionally, learners engage in multimodal writing tasks in the SWH classes that require them to communicate, translate, and integrate the multiple representations, all of which are necessary to the criteria of meaning making by Kress and his colleagues and for multimodal learning environment (Kress, 2009; McDermott &Hand, 2010; Prain, 2006).

Specifically, how and why students select and integrate the specific structures of representations with the text and subsequently impact their learning were the central foci of this study. These foci were determined by examining the particular changes that occurred when students used different structural modes at each grade level (i.e., 4^{th} to 8^{th} grades) that led to show the trends of students' understanding of dimensional multimodal representations across these grade levels (Halford, 1993).

Schnotz et. al. (2002), asserts that there is a strong relationship between the mode type and the construction of mental models that requires a certain cognitive effort depending on the sign system of the representations. Text is a symbolic representation; therefore, it requires more cognitive effort than an analog representation, such as a depictive picture and their understanding of these types of modes differs during constructing mental representations from them. Schnotz (2002) also argue that learners give more attention to the text that is combined with more difficult modes such as circular diagrams than the easy modes such as simple diagrams like carpet shaped diagrams. However, their examples only covered two type of diagrams and students' retention results of the information exposed dissimilarities. Thus, research is needed to examine different mode structures and how use of them differs across targeted grade level through making meaning with them in writing tasks (Kress, 2009).

When students integrate multiple representations, they engage in meaning making processes whereby the modes' conceptual and functional structure are different when integrating visual modes to verbal modes (Kress et al., 2001; McDermott &Hand, 2010). All these different structures can support students becoming more creative and constructive while engaging in writing activities using representations and so they can understand the process of developing and creating scientific ideas (McDermott &Hand, 2013; Prain, 2006).

CHAPTER TWO

LITERATURE REVIEW

This chapter explores the theoretical framework that supports the use of multimodal representation writing tasks in science classrooms to promote students learning. The factors that influence students' learning must be considered to include the cognitive processes of multimodal learning and the learning approach when students engage in multimodal writing task in science classrooms, which is the Science Writing Heuristic (SWH) approach. The literature review will follow theoretical frameworks that explain multimodal representations' benefits in science development and learning and the structural characteristics and of sign making and structural categories when constructing multimodal representation in writing tasks.

Theoretical Framework

Cognitive Process of Multimodal Learning

Van den Broek, Virtue, Everson, Tzeng and Sung (2002) state that students can comprehend writing when they associate the text to their cognitive memory representation. In order to do this, students should connect each part of the text with their semantic knowledge. When constructing a semantic relationship between representation and text, students establish a network in their mind. Accomplishing this depends on the coherency of the text. In order to create a coherent text, students need to know how to write a coherent text with representations.

As there is a relationship between text and visual representations while constructing mental networks, researchers have been trying to explain this relationship with cognitive developmental theories, besides the effects of age (Halford, 1993). The age factor is considered in this research based on the Halford's point (1993). Halford (1993) explains that the developmental effect which is the maturations, have increases the score and the capacity of the long term memory. Three cognitive theories on multimodal representations have been presented in the previous research literature: the dual coding assumption, meaningful learning, and the generative theory of multimedia learning.

Paivio (1986) and Baddeley (1992) explain dual coding assumption theory of the cognitive function of multimedia learning in which visual and verbal modes are processed in separate systems; however, they are interrelated in meaningful learning theory. Wittrock (1990) argues that meaningful learning depends on coherency of verbal and visual modes. Learners are able to make decisions and choose the related modes by creating a reasonable connection between them. When learners engage in multiple modes, they mentally ingrate those modes together with their prior knowledge in order to construct a meaningful learning outcome while problem-solving.

Mayer's (Mayer & Moreno, 2003) generative theory of multimedia learning combines these two assumptions with a generative approach to learning by Paivio, Baddeley, and Wittrock, where learners actively select relevant visual and verbal information from the learning material and organize them in visual and verbal working memory, correspondingly, by constructing associative connections between them. Learners then integrate the mental representations with prior knowledge by constructing referential connections. These processes require cognitive resources and are completed within the limits of the capacity of our working memory (Mayer & Moreno, 1998).

The generative theory of multimedia learning explains the three steps of cognitive process are involved when learning with multimodal representations. First, learners select verbal information and modes and apply them according to information in the text. Second, learners organize the verbal and alternative model to constitute a visually-based mode of the explained system. Third, learners integrate the alternative mode and verbal mode through making a connection between them (Mayer, 2003).

Figure 1 explains these processes within the generative theory of multimedia learning. When learners integrate, organize, and retrieve the modes; all of these cognitive process occurs in the working memory and as the arrows show, the information turns into semantic or episodic knowledge in the long term memory (Moreno & Mayer, 2007).Thus, in order to reach the demands of the cognitive generative process when learning in a multimodal learning environment, the learning environments should enable students to engage within a multimodal representations, otherwise learners can face some challenges.

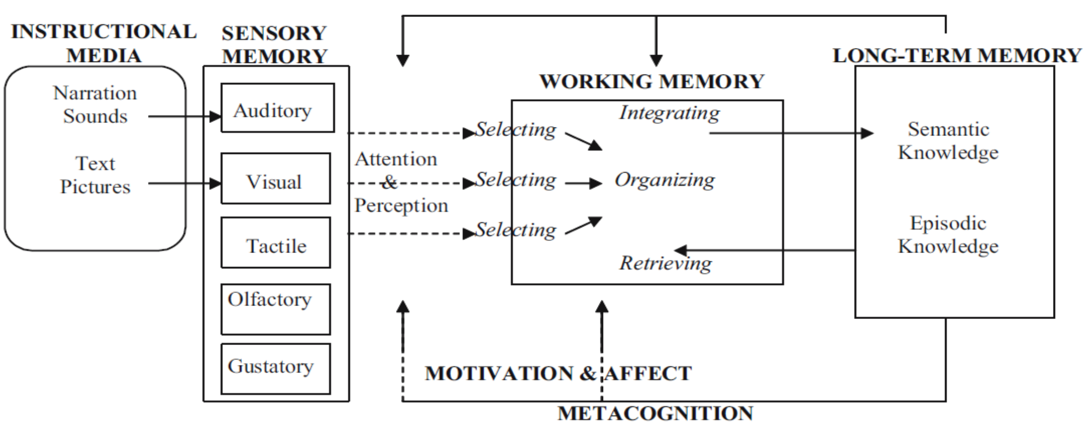


Figure 1. Cognitive affective model of learning with media (Source: Mayer &Moreno .2007. Nine ways to reduce cognitive load in multimedia. *Educational psychologist*, *38*(1), 43-52, p. 314).

Moreno and Mayer (2007) emphasize that these cognitive challenges may occur when learning with multimodal representations. In order to prevent this, understanding the four cognitive processes of multimodal learning conditions and environments is critical. These are: extraneous processing, representational holding, essential processing, and generative processing. The extraneous process is the consequence of a poorly designed learning task environment. The representational holding process refers to having a mental representation in the working memory during the meaning-making process. Consequently, the learning environment should enable learners to keep both of the extraneous and representational holding process short. Essential processing requires work on the part of the cognitive process when selecting the new information into the working memory. If learners are not familiar with the learning task and the task is complicated, learners can struggle with the required cognitive process. Thus, instructional design should be according to learners' prior knowledge and skills.

Lastly, the generative process means to make sense of new information such as integrating the representations and making a coherent structure where the instructional design should promote generative processing. In order to accomplish the cognitive process demands, the instructional design in the treatment group is the Science Writing Heuristic because the previous research showed that SWH has been effective on students' learning with multimodal representations (McDermott &Hand, 2010).

Review of Relevant Literature

Multimodal Representations in Science Learning and Development

Kress et al., (2001) explain that modes of representations are used for mostly illustrating similarities, presenting real objects and standing for an explanation of a process or a phenomenon that shaped and received meaning by the context of a topic, and by cultural, and social interactions. They can be images, texts, speeches, or animations and each has different characteristics. Text includes grammatical and graphical resources such as font types and punctuation systems. Images have shapes, colors, and lines. As each mode of representation has different characteristics, each has different potentials and constraints in learning while making meaning from them (Ainsworth, 1999). In general, more than one mode is used for meaning-making and in certain cases, a single mode does not function scientifically (Hand, 2010; van Leeuwen, 2005). Multimodal representations function differently depending on the kind of scientific inquiry and reasoning at hand, and according to scientific purposes; therefore, scientists use multimodal representations for developing scientific inquires and theories (Waldrip & Prain, 2010).

Multimodal representations are significant components for developing science, as science constantly demands visual structures that enable scientists to display their observations incorporating both actual images and abstract models (Martins, 2002). The reason is that communicating and conceptualizing scientific information with only text is difficult and limiting. Thus, using alternative modes or representations has supported scientists to overcome limitations of verbal modes that allows the visualization of the ideas more clearly. Lemke (1998) also stressed that the nature of science requires scientists to use multimodal representations; that is, science cannot be done thoroughly with only verbal modes. Scientists need to integrate diagrams, graphics, and photographs with text. Thus, using multimodal representations in scientific practices have been historically effective at conveying and explaining complex information.

Explanations and their representations are also important for science development and understanding because science progress is mainly accomplished by establishing explanatory schema of an observation or phenomena. When scientists articulate a schema of a phenomenon, they are able to explain it. There also needs to be causal links between articulated schemas of a phenomenon. For instance, physicists worked on Newtonian schema for about 200 years. Scientists explained the velocity and acceleration based on this schema by modifying it (Ohlsson, 2002).

Other examples of multimodal representations by earlier scientists include development of Watson and Crick's DNA molecule and Faraday's magnetic fields models. In addition to actual observations and abstract models, scientists structure particular topics via representations. Examples of these are taxonomies of species and the periodic table (Martins, 2002).

Given that developing and communicating science highly depends on the use of multimodal representations, science educators have been implementing teaching and learning strategies to enhance benefits of using multimodal representations (McDermott &Hand, 2013). The fundamental strategies involved when constructing science writing, include the spatial arrangement of an elements' component, explanation of the causal steps, and the planning and modification of the writing according to scientific purposes (Ohlsson, 2002). Given their demand of the incorporation of multimodal representations, Kess and van Leeuwen (1996) have argued for the use of multimodal writing for multimodal learning through meaning making or sign making.

Learning with Sign Making with Multimodal Representations

Kress (2001) explained learning as a dynamic process of sign making because the strategy of using language in the text, including multimodal representations, determines the learning strategies, conditions, and outcome of science learning. For instance, the modes can be a symbol or an analogue to represent an object. The given meaning of these objects depends on the text that the object is placed next to or a text on the mode, such as caption or a label, depending on the intention of the sign makers (Lemke, 1998). Therefore, these modes become the sign of that object according to the text and the sign makers' purposes. This process is called sign making or meaning making with multimodal representations.

Obviously, even though the mode and the sign represent the same meaning in general, in order to clearly describe the process of multimodal representations, Kress and van Leeuwen (1996), and Lemke (1998) explained meaning making more specifically as sign making by considering their semiotic structure. In this criteria, science learning is associated with making sufficient claims about a topic. The conditions of the sufficiency are also based on students' reasoning in choosing representations as students are required to make meaning with representations in their writing. When students write, their reasoning for engaging with knowledge development can be seen because students' writing is semiotic objects (signs). For instance, students need to explain why they choose a bar graph instead of a line graph. Therefore, to have and show better understanding of science depends on the students' understanding of the representations and meaning making (sign making) process with them.

Sign making is influential on students' conceptual understanding where students show their interests, thinking, and meaning making process when constituting knowledge through the construction of meaningful writing with multimodal representations (Galbraith 1999; Kress &van Leeuwen, 1996). In this process, students need to select and organize the modes depending on their interpretation and perception. For example, construction of the knowledge with representations in science classrooms can be through analogy, classification, and empirical evidence (Kress, 2001). Therefore, using different representations in the multimodal environment of science classrooms has different potentials of sign making and requires some substantial cognitive work. In the classroom setting, the rhetorical function of text and textual comprehension are not separated and so teachers and students constantly engage in a meaning-making process which requires them to understand external representation and construct internal representations from them while learning science.

Several multimodal representation theories also explain integrating visual mode to verbal modes in the meaning-making process (Kress & van Leeuuwen1996; Ainsworth 2006). Examining modes with the integration degree of visual and verbal modes is determined with the functional strategies of semiotics through of the text (Ainsworth, 1999). The conceptual structures of the visual modes also affect the degree of the relationship between the visual and verbal modes (Kress &van Leeuwen, 1996). Therefore, four strategies of using visual modes including functional, semiotic, integration (embedded), and the conceptual structures are the measures in this study.

The developing predispositions of identifying the functional, conceptual, integration (embedded) structures, and the semiotic relations have been studied separately (Kress & van Leeuwen, 1996); however, when using semiotic representational resources, the conceptual structures determine the functional structures that depend on the corresponding relationship between verbal and visual modes (Kress & van Leeuwen, 1996; Ainsworth, 2006). This affects students learning because they need to construct their knowledge by representing it in different ways in their writing. Therefore, these categories need to be studied together (Kress & van Leeuwen, 1996; Ainsworth, 2006; McDermott & Hand, 2013). In order to explain this, four structural categories of sign system for sign making, sign structure, functional structure, conceptual structure and integrative structures of the multimodal representations were discussed.

1. Sign Structure of Multimodal Representations

Sign structure is a part of semiotic expressions, which is accomplished by using mode to show students' point of interest in writing based on sign making. Signs are modes that can be either visual or verbal. Using different visual modes (sign) in a text is an especially common method in writing to express complex ideas because students translate the information in the text to visual modes. In other words, the visual modes function as the transformed sign that is the image in the text. Proper multimodal writing is accomplished by meaning making (sign making) with these signs depending on how the signs are used in the text (Kress &van Leeuwen, 1996; Schnotz et. al, 2002).

Sign making is not a simple process because it requires making plausible meaning with both kinds of modes, and depends on the interaction between what is shown and what is said in both visuals and the text. There is not a sequential order from one mode to another. Selecting appropriate modes is another key requirement of the sign making process in which organizing the modes depends on functional, communicative, and audience structures. This process tries to answer how to use the best mode to represent the text (Kress &van Leeuwen, 1996 & Kress et al., 2001; Lemke, 1998).

Choosing the appropriate modes depends on the type of sign system (Schnotz et. al, 2002). Kress and van Leeuwon (1996) stated that there are two types of sign systems structure: depictive and descriptive. Depictive representations show regular structural features of the text with pictures and which do not have any other information or any symbol to represent the text. The picture below is among to student's writing which shows a depictive representation (Figure. 2) because the picture does not have a sign or text that can give more information about the representation of a great white shark.

Figure 2. Example of a depictive representation.

Descriptive representations have a relationship between the content through some symbols. Examples of symbols are mathematical representations and text that can also be combined with a picture to make meaning. The picture below is a descriptive representation (Figure. 3), retrieved from a student's writing. The picture below is a descriptive because the student used the text to describe the habitat of the great white shark.

Figure 3. Example of a descriptive representation.

Overall, the roles of depictive and descriptive representations are different in text. Depictive representations show known content of a representations. For example, a simple picture of a triangle does not provide any information by looking at the representation. Moreover, when a triangle is used as an alternative mode and one of the sides is not equal to the others, the reader can logically conclude that is a triangle by only looking; however, the triangle itself does not provide the information of the content with any other caption or labels, it does not carry out the meaning of the text; therefore, depictive modes are limited to supporting the argument of the text. On the other hand, descriptive representations carry out the meaning of the content in the text with symbols that enable negotiation of the content, such as explaining information of a geometric object by adding labels of sizes and degree of angles (Schnotz et. al, 2002).

Schnotz (2002) explains the sign system by associating each with cognitive processes to explain how students learn with different signs (Figure 4). As pictures and text represent different sign systems, the processes of these systems consist of semantic processing of a mental model and a propositional representation (descriptive representations) of the subject matter. Figure 2 describes the mental processes model of the sign system. As it is shown in the figure, the analogical structure mapping is the comprehension of the picture between a system of visuo-spatial relations and a system of semantic relations. In order to have a semantic process, learners need to understand the picture or other alternative modes instead of just perceiving it.

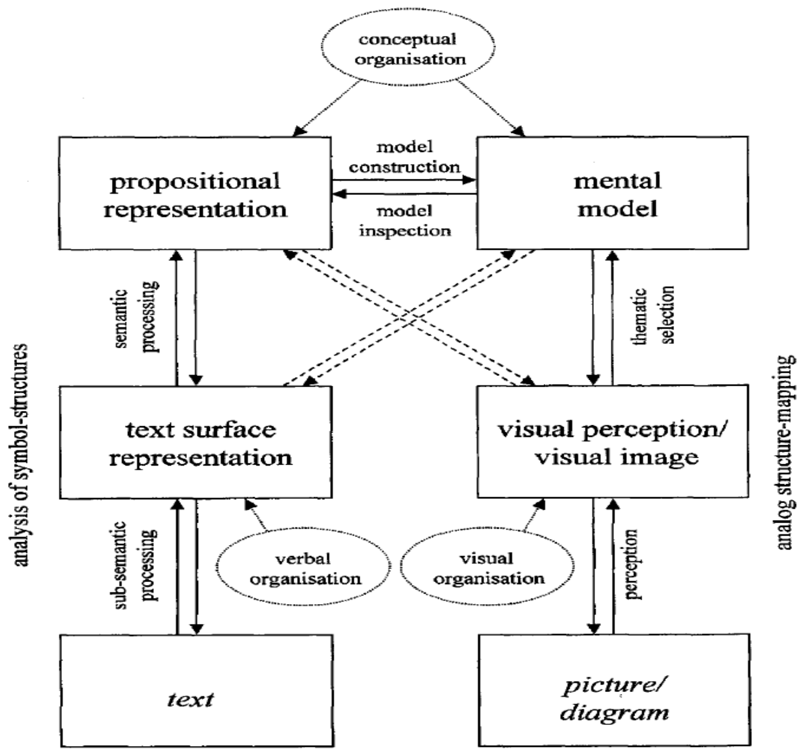


Figure 4. Schematic illustration of integrated model of text and picture comprehension (Source: Schnotz, W. 2002. Commentary: Towards an integrated view of learning from text and visual displays. *Educational psychology review*, *14*(1), 101-120, p. 109).

Thus, the above figure represents the interactions between the propositional (descriptive) representation, the mental model, the text surface representation and the visual perception. Constructing a mental model depends on the information and orientations of the representation and task. Therefore, mental representations are the complementary form of the text and picture comprehension. However, comprehension of the text requires more cognitive effort than the comprehension of a picture because text comprehension requires the transformation of symbolic propositional representations to analog representations. Text is a descriptive representation. Thus, there are differences in comprehension of easy representations such as depictive representations and difficult representations such as descriptive representations.

2. Functional Structure of Using Multimodal Representations

The functional strategy of using alternative modes depends on the degree of figures' corresponding to the text that shows the role of integrating visual modes with the text (Mayer, 2002). The degree of integration of visual modes to verbal text changes depending on the degree of the information and meaning in the text that corresponds to figures (Mayer &Gallini, 1990). Therefore, this enables students' understanding through students' purposes of using visual representations in appropriate functions conceptually and meaning making.

A functional combination of a visual mode to verbal text such as scientific explanation with related images are used in science text as development for meaning making (Lemke, 1998). Kress (2001) also indicates that students need to evaluate the potentials of visual representations including their functions and qualities when they integrate visual modes to verbal modes. Based on the variety of functions defined in the literature, the functional structure, in this study, means the way in which a visual representation is linked to the text depending on the text and representation information structure. Simply, the functional structure seeks to answer this question: what is the role of the visual representation in the text?

Ainsworth (2006) shows that visual modes have different kinds of functional combinational structures. Considering literature and students writing samples, the functional structures are examined, in this study including four categories: examples, descriptions, comparisons, and explanations. Across these categories, the most sophisticated functional structure of using multimodal representation includes the explanatory representations, on the other hand, the simplest and common type is examples (Mayer & Gallini; 1990). The literature defines the descriptive and the comparative representations are as the sub-dimension of explanation. Therefore, the categories of the functional structure have a hierarchical order. The reason for this order is that explanatory representations demonstrate the causal relationship within a concept, with this, students' reasoning used in attempt to construct explanatory representations can explain the concept with its causes. However, examples only show the basic illustrations of an object commonly with analogies such as a picture of an atom but do not lead to strong understanding of the concept (Chambliss, 2002; Goldman & Bisanz, 2002). The reason is that the learning criterion with representations in science includes to develop semiotic decision making by using interpretation to relate the representations meaningfully into the text so that why students chose the representations and their reasoning can be seen. Thus, students construct their knowledge based on their representational understanding as units, and network them as a whole unit parts (Mayer & Moreno, 2003).

Exemplary representation

An example functional structure is a simple visual sample of a broader category that is a picture that helps visualize the content. Visual modes mostly function in the writing as an example. This is the most common method used by authors to illustrate the text and shows analogical pictures of the object (van der Meij, & de Jong, 2006).

Therefore, a science text, at least needs to include exemplary modes which can be accomplished with an everyday analogy of the scientific model (Mayer, 2002). In the following figure, an example of functional structure is used which is among to a student's writing sample (Figure 5).

Natural Selection

Speed is an example of natural selection of the sea turtle. If their parents are fast swimmers, it would be more likely for the baby sea turtles to make it to sea without being eaten by their predators.

Figure 5. Example of an exemplary representation.

The figure only illustrates the baby turtles without giving any information related to text; even though there is an explanation of the topic in the text because it shows only the natural manner and physical structure of a baby turtle. Thus, using text without visual representation is limiting in developing students' understanding, as the text does not have adequate capacity to show dimensional structures of an object (here the visualization of the turtles is placed next to the text) or symbolic properties of the information (Mayer, 2002). In addition, communicating visual representations with verbal ones provides students a visualization of the science content because they can make connections between visual and verbal structures through translating the meaning into visual components (Ainsworth, 2006). For this reason, Lemke (1998) examined science text and counted the visual representations in which pictures had the highest number among other representations. With these, students can make connections between abstract knowledge of science text with an actual physical knowledge through a picture. Especially, ecologist utilize real pictures of an environment so that the information in the text which is what we know and, information in the picture which is what we see is connected (Veel, 1998).

Descriptive representation

A descriptive representation highlights the structure or pattern or individual characteristics of a whole object or topic of an observation. When students use descriptive representations they often use them in a descriptive text. Descriptive text is a sub-dimension of explanatory text. Descriptive text gives such information related to what an object is made of and how it is shaped. Similar to descriptive text, descriptive representations exhibit subsequent information, patterns, structures, and functions of an observation (Paivio, 1990). The common way of showing a structure of an object is by using a diagram. In a diagram the main structures are labeled in order to give more detailed information about the concept within the text. Therefore, adding a descriptive representation of given information, such as diagrams, promotes students' understanding and learning (Mayer, 2003). The figure 6 shows a descriptive representation where students chose the visual mode including the different color of arrow to show Madagascar in a map of Africa. The figure is among to a student's writing sample from the data was used in this study. The description of the visual mode is both placed in the text and on the visual mode that shows the student can practice utilizing the visual according to the purpose of writing.

Madagascar: Madagascar is an island off the east coast of Africa. It has many amazing plants and animals there!

Figure 6. Example of a descriptive representation.

Comparative representation

As similar to descriptive texts, comparisons are the sub dimension of explanations. In comparative text, two or more objects' dimensions are compared. Similar to the functional structure of comparative text, comparative representations encompass two different topics, contrasting to each other information to help students comprehend similarities and differences that also promotes students' understanding of how to establish relations among the two concepts (Milikan, 2002). Therefore, in science writing, comparisons of topic entities with representations are widely used (See figure 7). The figure is among to a student's writing sample from the data was used in this study. The students chose this figure to compare the color of the owls by using an arrow with text which corresponds to the information in the text and to differentiate the owls' physical structures visually with real pictures of them.

The female snowy owl is not plain white like the male snowy owl.

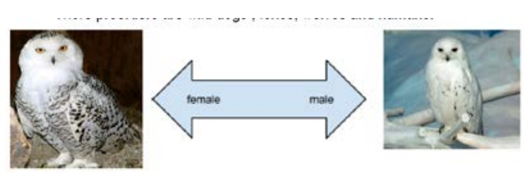


Figure 7. Example of a comparative representation.

Explanatory representation

Explanations present causality or generative descriptions of a phenomenon. Science presents information about how the world works with its causes. In order to do this, scientists develop explanations to argue content. According to early philosophers, explanations are a kind of deductive argument. Psychologists argue that explanations require a high cognitive effort because explanations are the way to provide a mind' eye with capability to think through and show the reasoning of an argument. Even though explanations assemble descriptions, descriptions are not the explanations because descriptions are certain information without interacting related information and evidence. (Horwood, 2002). The following figure shows the explanatory representation in the same way described in the research of Mayer and Gallini (1990).

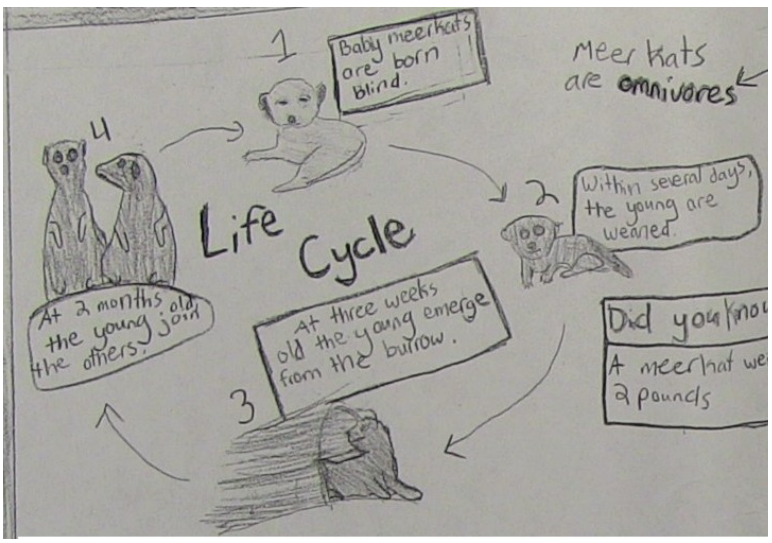


Figure 8. Example of an explanatory representation.

Figure 8 shows the explanatory representation of how a meerkats' life cycle is. The figure is among to a student's writing sample from our representation data. The student explained the meerkats' life cycle in 3 steps and described each cycle. It is very clear that the student was able to demonstrate his or her understanding using different images of the animals in each cycle. This category is adapted to the research of Mayer and Gallini (1990) that investigated the effects of using explanatory representations on students' science learning. These researchers showed that students understood the science topic and showed important cognitive skills when using these representations.

These cognitive skills mainly included problem solving skills, transferring student's learning, and conceptual recall; however, not verbatim recall. Therefore, students need to learn to develop their writing with explanatory representations for better understanding (Mayer & Moreno, 2003).

Linking the explanation with the schema is not a simple process in that it requires substantial cognitive demand because explanation involves remembering, decision making, and reasoning cognitive processes. Therefore, when a science text includes explanations with related, promotes understanding these explanations by showing the cause and the effect of the content. According to cognitivists, students can better understand an explanation when they construct the explanatory representations themselves (Chambliss, 2002). Because of the positive outcome of research, the goal of multimodal representation writing tasks should enable students to construct and integrate explanatory visual modes into their writing as students need to use their reasoning to explain why and how the process is happening (Mayer & Gallini, 1990).

3. Conceptual Structure of Multimodal Representations

Kress and van Leeuwen (1996) developed a framework of representations. One of the structures they identified is the conceptual structure. The conceptual structure shows the established or permanent relationships and characteristics of representations that can be either abstract or realistic. Based on this framework, the conceptual structure is identified in four categories in this study. The first category is the analogy that was constituted based on the related theories and the students writing (Goldman &Bisanz, 2002). The rest of the three categories are retrieved from Kress and van Leeuwen's study

(1996). These are symbolic, analytical, and classificatory. The conceptual structure was determined with a hierarchical structure. The lowest degree is the analogy (Goldman &Bisanz, 2002). Other categories are listed as ranked from, low to high: symbolic analytical, and classificatory.

Analogical structure of representation

Analogies can be icons, or pictures which are basic visuals. The reason the analogy is the lowest degree is because analogies' conceptual structure is limited as they do not improve comprehension all the time because analogies do not provide enough information about the concept, such as they do not show similarities and differences of a concept (Goldman &Bisanz, 2002). In consequence, analogies can cause cognitive conflict. In this case, alternative explanations are necessary which can be through captions or more descriptive modes such as analytical modes (McDermott &Hand 2010; Kress & van Leeuwen, 1996). The following representation shows an analogical illustration which is among to a student's writing sample from the data that was used in this study (Fig 9). In this figure the student only used a picture of an animal part without providing any captions or label to identify or explain the animal part, name of the animal and what this picture represented or why the students chose this picture. However, symbolic, analytical and classificatory representations provide this information (Kress & van Leeuwen, 1996).

Figure 9. Example of an analogical representation.

Symbolic structure of representation

Kress and van Leeuwen (1996) explain that the symbolic representation is an abstract representation and mostly shows what a representation is and means. Therefore, this category shows the relation to text and it's meaning with symbolic attribution. This can be practiced using exaggerated size of an image or using images in different forms. This category also promotes connection between the conceptual domain of a representation by making explicit relationships and discussing an image. For instance: the following image (figure 10) is among to a student's writing sample from the data that was used in this study. The image is a cartoon of an atom that represents the symbolic property of an atom in which the atom does not display the exact image of the atom; however only represents symbolic properties of the atom with its electrons which cannot be seen in real life so that scientists need to use symbolic representations of it.

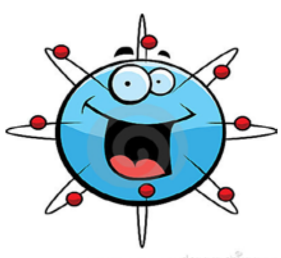
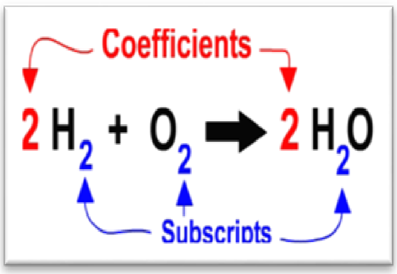


Figure 10. Example of a symbolic representation.

Analytical structure of representation

This structure enables learners to relate each part of a visual object with its whole structure. The representations mostly include labels to show particular parts inside of a picture and is supported by a caption as well (Kress & van Leeuwen, 1996). This type of structures is based on basic diagrams that can be found commonly in typical science texts (Novak, 2010). For instance: diagrams of biological organs, maps and charts in which the parts of the representations are mostly labeled and identified. For example, the following figure 10 is an example of an analytical structure of representation where students labelled the coefficients and subscripts and explained these labels in the text. The figure is among to a student's writing sample from the data that was used in this study.



When balancing equations, you have to use coefficients and subscripts. The coefficient is used to multiply atoms for an example. (See red in equation 1) Subscript just tell you how many chemical you have.(See blue in equation 1)

Equation 1. a problem with coefficient and subscript shown

Figure 11. Example of an analytical representation.

The analytical feature depends on the purpose for the meaning makers. For instance, maps are often represented analytically. Some maps only focus on political boundaries and some of them only concentrate on geographical features so mountains and rivers are distinguished by color and labeled. All of these enable the clear vision of how learners connect and represent the concept of the topic written in verbal mode with visual modes. These structures represent the interconnections between parts. For example, these type of symbols, lines and arrows, provide the association between variables such as "a" means "b" or "a" goes with "b" so that collocation of the parts can be accomplished (Halliday, 1996)

Classificational structure of representation

Kress and van Leeuwen (1996) indicates that this category displays the hierarchical order of a concept which provides a connection to show relation, contrast, and comparison of the concept categories in a classification. Most common examples of these in scientific texts include evolution trees, taxonomies, flowcharts, pyramids, and diagrammatic tree structures. In these kinds of representations, similar or different characteristics and hierarchical relationships of a concept's parts can be represented with different shapes or colors. Taxonomies are the most commonly used classificational structures in science which do not only consist of simple groups of words. They are highly organized classification system. Halliday & Martin (2013) explains similar ideas. They used the figure to display a classification structure in which the processes of the geological change are described using a diagrammatic tree structure through classifying the change with its subordinates. The diagram does not simply show the name of the change parts; it shows the flowing process of the change in which structures are also called "generative grammar". These structures form the relationship between the surface and deep structures of the diagram. Utilizing this type of representation allows students to understand the concept of the change instead of simply memorizing the parts of the change from the text. Based on their explanations the following figure is used to show the classificational structure, which is among to a student's writing sample from our representation data (Figure 12). The figure's conceptual structure is classificatory because students classified meerkats' life cycle and provided related information.

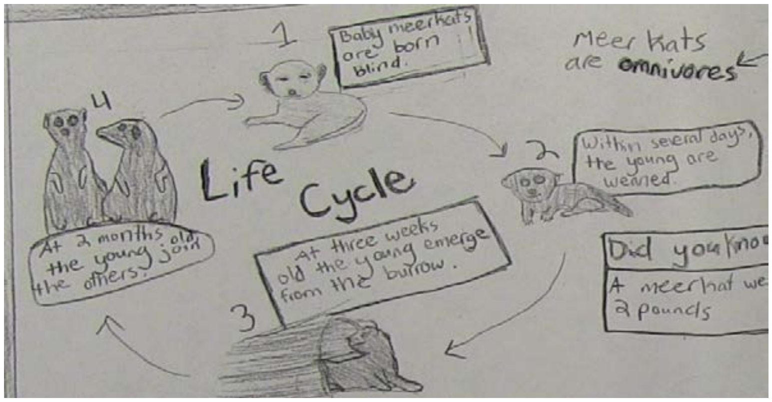


Figure 12. Example of a classificational representation.

Concept maps are one of the commonly used representational structure in this category. Concept maps represent meaning through connecting parts to construct knowledge (Novak, 2010). Even though in the example above is not a concept map, the student provided relational information about meerkats. Therefore, this category is not restricted in only using concept maps. Kress and van Leeuwen (1996) also signifies the importance of using such structures in that they can provide the highest degree of understanding of conceptual structures like taxonomies and flowcharts, which are similar to concept maps. The first reason is that these two types of diagrams provide hierarchical order so that learners can conceptualize a phenomenon as a single unified system. These representations help learners by constituting ranking parts, which is the highest power of generalizing generalization. Second, these types of structures are constituted from an actively pursued process as they are formed based on a goal oriented process to show the sequential progression of input, output, source, destination, and finished products with a clear beginning and an end.

4. Embeddedness Structure of Multimodal Representations

Kress (2009) explains that writing is a way to present information. The language that is used in writing represents information so that using the language only in a written mode is not enough to communicate; thus, scientific communication requires the use of alternative modes. Therefore, students need to embed visual modes into their verbal modes. However, using an alternative mode next to the text is not as effective as integrating these two modes together because during the integration caption or labels to explain or describe the mode related to text that gives meaning to the image (Kress & van Leeuwen, 1996). The degree of integration of a visual mode within a verbal mode is referred to as “embeddedness” because it shows how these two modes are associated.

Using embedded representations in a writing task has many benefits for students’ conceptual understanding. One of the examples is McDermott and Hand’s (2013) study. Their study examined the effect of using embedded multimodal representations on high school students’ chemistry learning. For this purpose, students from treatment classes were instructed to use multimodal representations in their writing to learn tasks in a specific instruction design. Control classes were chosen accordingly without instruction and centered on the traditional science classes. The results of this study showed that using multimodal representations with the treatment was effective for students’ chemistry learning and their conceptual understanding of the topic.

With the guidance of the aforementioned information, the embeddedness structure will be one of the measuring criteria in this study. McDermott and Hand’s study (2013) showed that students can embed alternative modes in their writing. During this process, students generated three degrees of embeddedness: low, medium, and high. These degrees were defined depending on the degree of integration of visual and verbal modes and based on the degrees, the names were called as next to text, related to text and explained in the text (McDermott & Hand, 2013). The following table has been generated to summarize the categories and the subcategories for this study (Table 1).

Table 1: The summary table of learning with multimodal representations criteria

Category	Definition
1. Sign System	Showing students' point of interest in writing based on their comprehension of the modes, which includes depictive and descriptive representations.
2. Functional Structure	The strategy of using a visual representation that is linked to the text based on students' purpose of using multimodal representations, including exemplary, descriptive, comparative, and explanatory structural representations.
3. Conceptual Structure	The conceptual structure shows the established or permanent relationships and characteristics of a science concept with representations that can be either abstract or realistic. This category includes analogical, symbolic, analytical and classificatory representational structures.
4. Embeddedness Structure	The degree of integration between a visual mode and verbal mode to show how they are integrated. This category includes next to the text, referred in the text and explained in the text integrative structures.

The Science Writing Heuristic (SWH) Approach

Hand and Keys (1999) established the Science Writing Heuristic approach (SWH) as a framework, which emphasizes the importance of language use in learning, and integrates argument and writing with scientific inquiry. The SWH approach designs learning activities using written and oral arguments in laboratory and classroom settings. The research shows that students are not capable of participating in scientific argumentation because they have inadequate knowledge about its goals and processes (Hand, Wallace, & Yang, 2004). Yore and Hand (2010) explain that understanding the process and the nature of the argument based inquiry is significant for learning science because argument based inquiry has many characteristics that support students' effective science learning These benefits are specified by scholars as mainly: argumentation enhances students' communication skills with critical reasoning, fosters science literacy, practice, and culture because when scientists develop scientific theories, they constantly negotiate and argue their findings with other scientists. This practice has been placed in some school settings for these important reasons and has developed by including writing with the SWH approach.

The SWH approach stresses that scientific argumentation is accomplished with the collaborative nature of scientific activity in which learners are involved in a constant cycle of negotiating and clarifying their ideas with their peers and teachers (Martin, & Hand, 2009). Accordingly, during and at the end of this practice, students develop scientific reasoning and meaning (Hand, et. al, 2004). In consequence, the SWH approach is designed to promote classroom discussion whereby students' personal explanations and observations are tested against the perceptions and contributions of the broader group (Martin, & Hand, 2009).

In the SWH classroom, students are also able to participate in argument based inquiry by negotiating their ideas using a particularly structured science inquiry process with writing. This process starts with posing a big question and writing claims about the question. After writing their claims, students continue the inquiry process by collecting appropriate data to produce evidence to support their claims. When students engage in inquiry as a part of argumentation, students practice dialogical interactions, collaborative work, and active investigations (Hand et. al, 2004). By participating in these learning experiences, students can elaborate on canonical scientific thinking, comprehend the relationship between claims and evidence, and eventually understand the nature of the scientific process and practice. In contrast to traditional classrooms where teachers do not have students engaged in argumentation, the SWH approach creates an environment where teachers provide instructions to students for argumentation that enable them to talk about science (Akkus, Gunel, & Hand, 2007).

During the inquiry process, students can use the SWH writing template for guidance and summary writing to develop their understanding of the science topic. The SWH template offers a semi-structured form of lab report. The template provides, to both teachers and students, a guide to generate questions, propose claims, design procedures, collect and interpret data, support evidence, and reflect on changes in their own thinking (Martin, & Hand, 2009). Akkus et. al., (2007) compares template of the SWH process with the traditional one in the following table (Table 2). With the guidance of the SWH template, students start their inquiry activities with posing their big questions, then test their questions with required procedures and perform observations. After observations, students write their claims and produce evidence by using the data they collect during the test and the observations. In the last two steps, students compare their findings with other scientific ideas and reflect on their ideas. This structure of inquiry process leads students to think critically and use their scientific reasoning and meaning to interpret the data using their claims to construct evidence (Hand et al., 2004). However, the traditional laboratory format only requires students to describe the procedure and write in verbatim by following text content without using their reasoning (Akkus et. al., 2007).

Table 2: The SWH laboratory template versus traditional format

SWH Laboratory Format	Traditional Laboratory Format
Beginning questions or ideas	Title and purpose
Tests and procedures	Outline of procedure
Observations	Data and observations
Claims	Discussion
Evidence	Balanced equations, calculations, or graphs
Reflection	No equivalent for Reflection

As the table shows, writing is a strategic component of the SWH approach because it promotes science learning when students are talking and presenting claims and evidence. One of the writing strategies in the SWH classroom is the summary writing task. Students produce summary writing at the end of each unit that help them to construct an argument to understand scientific concepts using multimodal representations (McDermott &Hand, 2013). Galbraith (1999), who introduced one of the cognitive models of writing, emphasizes that the interaction between the writer's content knowledge and his or her rhetorical knowledge is the best way to produce new knowledge. With respect to this, the SWH writing activities provide students an avenue to grow in science knowledge by combining multimodal representations and the rhetorical demands of a writing task with their knowledge of science concept.

The research on the SWH approach with multimodal representations has focused on three major areas (1) The connection between embeddedness scores and argumentation scores was tested by using the SWH template (Hand &Choi 2010; Chen, Hand, McDowell, 2013) (2) The relationship between embeddedness scores of summary writing and conceptual understanding of a targeted topic was compared in both traditional and SWH classes (Hand, Gunel &Ulu, 2009; Jang, 2010; McDermott &Hand 2013) (3) The effects of writing to different audiences was tested using embeddedness scores of either summary writing or SWH template based-writing, including multimodal representation (Hand et. al., 2009, Chen et. al, 2013).

Among these research areas, Hand and Choi (2010) investigated how students developed arguments with multimodal representations in their writing in an SWH learning environment. They fundamentally examined the relationship between multimodal representations and argument based inquiry. For this study, an organic laboratory chemistry class was chosen from a Midwestern university. Students used the SWH template to develop their argument and embedded multimodal representations into their writing. The results showed a positive correlation between having a high embedded multimodal representation score and constructing high quality arguments in the evidence section, which requires students to support explaining their claims with strong reasoning. The implication of the study was that the use of multimodal representations fostered stronger arguments. However, the study only examined one topic at one college grade level. Because the study showed significant results for student learning, more research is necessary in this context to expand the use of multimodal representations in various science classrooms. Therefore, investigating a variety of grade levels of topics would provide more patterns and generalizable information.

Similar to Hand and Choi's study (2010), Chen et al. (2013) examined fourth grade students' writing in the same assessment context of using the SWH template and embedding multimodal representations to test the students' conceptual understanding of force and motion. The research context was that 4th grade students were asked to complete SWH template based-writing tasks that would be given to 11th graders to read. The template prompted students to embed multimodal representations in their writing. In order to show the effectiveness of the task and SWH, treatment and control groups were tested using pre and posttests. The results showed that embedding multimodal representations supported students' argument practice to overcome explaining and connecting claims to evidence with a coherent argument. Thus, the results were consistent with Hand and Choi's (2010) study in which the implication was to embed multimodal representations for an effective argument and scientific communication.

Hand, et.al, (2009) investigated the sequential effect of linking multimodal representations, including mathematical and graphical types to the writing to learn task for 10th grade physics class students. The task was to develop the end of unit summary writing to the younger peers (9th graders). The results showed that using multimodal representations in the writing promoted conceptual understanding of the physics topic when compared to using only text. Their findings revealed that embedding mathematical representations to the writing showed a significant effect on students learning of the concept but not the graphical representations (Hand, et.al, 2009). According to Kress and van Leeuwen (1996), this result showed students were able to understand symbolic mathematical elements, but not the conceptually more advanced representations like analytical (graphics). Therefore, one goal in this study was to investigate students' understanding of conceptually advanced representations in SWH learning environments.

McDermott and Hand (2013) examined the effect of embedding multimodal representations in chemistry writing tasks. The writing task was to integrate multimodal representations into the summary writing at the end of the unit in the both control and SWH treatment groups. The embedded representations in student writing was evaluated with three degrees, low, medium, and high, based on the quality of the connection between the representation and the content of the text. The findings revealed that using a higher degree of multimodal modal representations generated better conceptual understanding in both groups and the treatment grouped performed better in the writing task.

This reviewed research shows one measure of using multimodal representations, which is embeddedness. The embeddedness research demonstrates a need for further exploration in the SWH context because it promotes science learning and argumentation. Besides research in SWH learning environments, this topic was explored in other nontraditional science classrooms where the emphasis was on investigating the effect of multimodal representations on students' science learning and understanding in general without a particular instructional strategy.

Nontraditional Writing to Learn Strategies with Multimodal Representations

Non-traditional writing to learn activities focusing on multimodal representations have been effective in promoting students' learning compared to traditional writing activities. These methods require students to consider and construct information in an appropriate structure when integrating visual modes in their text. When students participate in these activities, they engage in self-discovery of knowledge and are able to generate new understandings (Hand et. al., 2004). The traditional writing task, on the other hand, only leads to transmission of knowledge in that students only replicate what is written in the text in their own writing (Yore et al., 2003). However, learning is not the transmission of a body of knowledge to students, instead, it involves creating a disposition and orientation of adopting a special language with an epistemological approach. There is significant agreement in the literature regarding the benefits of this method (McDermott & Hand, 2013).

Emig (1977), one of the pioneers of using writing as a learning tool, also described the non-traditional writing with multimodal task as an effective tool for learning because writing involves a particular process and product that brings out the representation of the world more visibly. In contrast to traditional writing, when learning with multimodal writing, learners' previous knowledge and experiences, are promoted and they can engage in multiple strategies for tackling a task and knowledge development (Jewitt, 2003). Furthermore, when students engage in the process of writing, they are able to make meaning with numerous multimodal representations, particularly in argumentative environments where learners can negotiate their understanding of scientific knowledge (Kress & van Leewon 1996; Hand et al., 2004).

Given the importance of using representations in the writing-to-learn activities, much research has focused on writing-to-learn activities in which integrating nonverbal modes into verbal modes in specific learning tasks was one of the main goals. For example, Sherin's (2001) study examined the relationship between learning physics and using physics equations. The results showed that understanding equations led to deeper understanding of physics.

Another example to show the benefits of using visual representations on conceptual understanding is the research of Scaife and Roger (1996). They stressed that the combination of representations promoted understanding of the content. In the study, using diagrams was effective because when students integrated diagrams into their text, they needed to link the text with the corresponding points in the diagrams, which then required them to apply their conceptual understanding from the text to visual components. Subsequently, students developed a deeper understanding of the content.

In a related study, Mayer and Gallini (1990) compared students' conceptual understandings of scientific devices while working with and without illustration in elementary science classrooms. The results showed that students learned better when there were visual modes in the text, especially diagrams in which labeled parts and steps were shown. Diagrams represent one of the analytical structures that demonstrate relationships between modes and their effects on students' understandings need to be examined. (Kress & van Leeuwen, 1996)

Narayanan and Hearty's (2002) study was based on spatial skills when integrating graphics into the text. Their argument is based on constructing a mental mode when encoding information from texts to graphs. The experimental study results suggest that comprehension, construction, and communication, and integration efficacy of multimodal representations depend on an interactive and dynamic processes of an instructional design. Consequently, choosing an appropriate instructional design to teach multimodal representations effectively can promote students' science understanding more competently.

Overall, integrating verbal and nonverbal modes is one of the main goals in nontraditional writing tasks. As Kaput (1989) explains, multimodal representations provide an opportunity for students to comprehend complex ideas, because students need to connect ideas from text to visual representations. This demands understanding of the topic more than replicating the topic from text. Thus, students develop a deeper understanding of the science topic. Non-traditional writing with multimodal representations are better suited than traditional tasks to meet these learning goals because in the traditional task, the emphasis on the textbooks' content and instructions. However, the previous studies discussed earlier have not employed a particular teaching and learning approach. Therefore, the SWH approach was chosen because the research in this approach showed significant improvement on students' multimodal competencies utilizing various structures of multimodal representations in various grade levels.

Summary

The theoretical frameworks and the related literature were reviewed based on improvements of students' scientific understanding through multimodal writing to learn tasks. Students' science learning criteria in this study were determined through identifying the students' writing based on the degree of using multimodal representations according to learning with sign making and the structural categories of the sign system. All these categories show the degree of comprehension of the multimodal representations in varied measures, depending on the explained cognitive theories in the theoretical framework.

CHAPTER THREE

METHODS

This chapter provides the methodology that was used to answer the research questions and hypothesizes. In order to answer the research questions, the quantitative research design was used because the quantitative research design enables to test the variables and show the relationships among them numerically this design also examine the relationship between cause and effect. In this study, the effects of the treatment group and ages of students in both treatment and the control groups on students learning of multimodal representations were examined. Therefore, the quantitative design was appropriate for this proposed study. For this, among quantitative designs the quasi-experimental design was used because this design was more useful to test the cause and effect relationship, and enabled to use of non-random sampling. Non-random sampling was more useful for this study because researchers were able to assign preexisting classes as treatment and control groups which was more appropriate for school settings (Creswell & Clark, 2011). With this regard, this chapter described the data collection and participants, the research design, research procedure, the rubric, and the data analysis procedures in order to answer research questions and hypothesizes.

The research questions and hypothesizes that were used to guide this study are:

Research Question 1: How are the differences between using multimodal representations in different structures across 4th grade to 8th grade levels in both SWH and non SWH classrooms?

Hypothesis1: Upper grade students (6th-8th grade) will use more descriptive and less depictive representations than lower grade students (4th-5th grade).

Hypothesis 2: Upper grade students (6th-8th grades) will use more sophisticated functional representations than lower grade students (4th-5th grades).

2a: Upper grade students (6th-8th grades) will use more descriptive representations than lower grade students (4th-5th grades).

2b: Upper grade students (6th-8th grades) will use more comparative representations than lower grade students (4th-5th grades).

2d: Upper grade students (6th-8th grades) will use more explanatory representations than lower grade students (4th-5th grades).

2e: Upper grade students (6th-8th grades) will use more enriched explanatory representations than lower grade students (4th-5th grades).

Hypothesis 3: Upper grade students (6th-8th) will use more sophisticated conceptually structured representations than lower grade students (4th-5th grade).

3a: Upper grade students (6th-8th) will use more symbolic representations than lower grade students (4th-5th grade).

3b: Upper grade students (6th-8th) will use more analytical representations than lower grade students (4th-5th grade).

3c: Upper grade students (6th-8th) will use more classificational representations than lower grade students (4th-5th grade).

Hypothesis 4: Upper grade students (6th-8th) will use higher order embeddedness representations than lower grade students (4th-5th grade).

4a: Upper grade students (6^{th}-8^{th}) will use more "related to text" degree of representations than lower grade students (4^{th}-5^{th} grade).

4b: Upper grade students (6^{th}-8^{th}) will use more "explained in the text" degree of representations than lower grade students (4^{th}-5^{th} grade).

Research Question 2: How does participating in SWH argument-based classrooms affect the development of students' multimodal accomplishment by measures of sign system, functional conceptual and integrative structures in multimodal products?

Hypothesis 5: SWH students will use more descriptive modes than non-SWH students and less depictive representations than non-SWH through all grade levels.

Hypothesis 6: SWH students will use more sophisticated functionally structured representations than non-SWH students among all grade levels.

Hypothesis 7: SWH students will use more sophisticated conceptually structured representations than non-SWH students among all grade levels.

Hypothesis 8: SWH students will use more sophisticated embeddedly structured representations than non-SWH students among all grade levels.

Participants

Participants included students in grades 4, 5, 6, 7, and 8 from a total of 30 pre-existing classes. Classes were selected as treatment were taught by teachers who had attended professional development focused on the Science Writing Heuristic approach (SWH) and who had used this approach in their classes. Control classes were taught by teachers in the same district who did not use the SWH approach. However, there was not control classes in the 6th grade. Therefore, for the research question1 related to age, 6th grade students were used; however, 6th grade students ‘data were not used for the second research question. Participants attended schools in the same Midwestern school district in the United States. The demographic characteristics of students in this school are Caucasian (81.16%), followed by African American (11.5%), Hispanic (5.6%), and Asian (1.74%). The student gender breakdown of this middle school is 50.6% male and 49.4 female.

Teachers

In the beginning of the semester, both control and treatment groups’ teachers participated in the professional development (PD) workshops. The PD instructor worked with them on how to teach students to use multimodal representations in their writings. Teachers’ experiences of using this method varied as each of them has different time experiences with it. In this workshop, teachers were taught what the multimodal representations were, which core standards required to use multimodal representations. Also teachers were trained to teach students how to use multimodal representations in their writing. For this, different strategies of using multimodal representations were taught with the examples. These included unimodal, next to text, and how to integrate or embed the visual representations in to the text. All these strategies were practiced with all teachers. However, the treatment group teachers employed the SWH approach in their classrooms. In order to this, they were required to do laboratory activities based on the SWH template. For this, the format of questions, claims, evidence was followed. Both traditional and the SWH based classrooms were not observed by the researcher.

Data

The data consist of students' summary writings. Students were asked to write their understandings of the unit and developed summary writings by embedding multimodal representations into writing as a writing to learn part of the SWH approach. The time period of completing the summary writing task was the first 2 weeks in March. This time period was given in order to allow all grade levels to complete their writing task in the same time period on completion of the unit. Given the variability of completion time across the grade levels, the researcher believed this would enable a flexible but a fixed time period for the task completion.

The Multimodal Summary Writing Task

As a part of SWH approach, students developed their writing task based on their inquiry activities. At the beginning of the unit, all students received identical instruction designed to promote effective communication using multiple representations, in which students would be assigned a multimodal writing task. Students in the traditional classes then participated in regular classroom activities throughout the unit of study as control group students. Students in the treatment group, participated the SWH approach based classrooms. At the end of the unit in March, students were asked to produce writing samples summarizing their understanding of the targeted concepts. Students were asked to consider the instruction about effective writing using multiple representations when developing their written summaries. Students generated unimodal (text only) and multimodal (text tied to alternative modes of representation including pictures, tables, graphs, diagrams, drawings or videos) writing samples (See appendix).

Time Period of the Data Collection

The data was collected in two school years. The first data set was collected in March of 2013 and the second year data set was collected in March of 2014. In total, 897 students' writing samples were collected. Among these, 559 writing samples were from treatment (SWH) classes and 338 writing samples were from control (non-SWH) classes. Table 3 provides a description of this study participants, units, and the number of data in each grade level across the two-year period:

Table 3: Description of participants and study context

Participants	SWH Classes	Non-SWH Classes	Topics	SWH Samples	Non-SWH Samples
4th grade	8	4	Animals and disasters	178	82
5th grade	3	2	Solar system and planets	155	92
6th grade	3	0	Human system	113	0
7th grade	3	3	Cell process and DNA	51	70
8th grade	2	2	Reactions and heat	62	94
Total	19	11		559	338

Research Design

A quasi-experimental design was used because pre-existing classes are assigned to groups. This design was appropriate for this study because the effect of treatment with non-random assignment was used. Random assignment does not apply to the quasi-experimental design and the advancement of the research is also provided. Creswell & Clark (2011) also indicate that random assignment is not promising for all studies. In this study, both control (traditional classes) and treatment (SWH classes) groups were distributed non-randomly. To examine the differences of treatment and control groups and the effect of age, the HLM analysis was used in this study. This analysis was used to examine for differences between the treatment and control groups, grade level impacts on the use of multimodal representations. The grade levels were from 4th to 8th grade for the first research question with the related hypothesis. The effect of the SWH approach examined overall by controlling the grade levels for the second research question with the related hypothesis. The categories were used to assess students' writing samples were: sign, functional, conceptual and embeddedness structures. Overall, the data analysis included three steps (Figure 13).

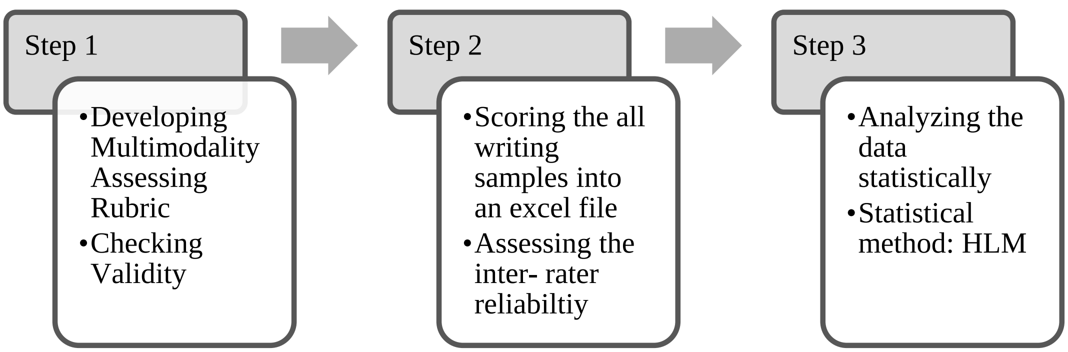


Figure 13. The steps of the data analysis.

Step 1. Development of the Rubric

The multimodal structural rubric designed to assess the written products consisted of five main coding categories: Type of Mode, Sign System, Functional Structure, Conceptual structure, and Embeddedness structure. Each main category had multiple subcategories to evaluate structures of modes and their relationships to the writing. The development of codes was based on the literature review, open coding, and thematic coding of the students' writing samples from the previous work because the students' writing samples provided more subcategories (Miles & Huberman, 1994). In order to do this, 5 to 10 students writing samples were selected from every grade level. During the open coding, some of the subcategories were developed by thematic coding and added to the main categories according to their structures. This was followed by developing scores to each code. The scores were determined to each codes because the structure of the categories were constituted from the basic structure of modes to the more sophisticated modes. Overall, the criteria were designed to evaluate students' understanding of the modes based on the targeted topic through selecting appropriate modes other than verbal mode, and cognitive ability associated with integrating modes together to effectively communicate in a multimodal way. As a pilot analysis, more students' writing samples were scored by using all these categories. By doing this the last version of the rubric that enabled to code the modes with appropriate scores were developed. The rubric is used as the code book in this study. Table 4 shows the all categories with their explanations and the examples. The processes of developing categories were explained after the table 4.

Table 4: The rubric of sign system

Category Subcategories	Definition	Score	Example
1. Sign System	Showing students’ point of interest in writing based on their comprehension of the modes.		
Depictive	Shows regular content	1	A plain picture
Descriptive	Shows the content with symbols or signs	2	A picture with a cross sign
2. Functional Structure	The strategy of using a visual representation in different purposes.		
Example	The modes that are used for an example.	1	A plain picture
Descriptive	The modes that represent the description of the topic.	2	Diagrams that show part of a plant
Comparative	The modes that represent comparison of topic	3	A Comparison of acids and bases
Explanatory	The modes which gives detail information about the topic	4	A mode or modes with a detailed explanatory caption.
3. Conceptual Structure	Shows the established or permanent relationships and characteristics of a science concept		
Analogue	Shows the basic visuals or icons	1	A plain picture
Symbolic	Shows the symbolic attributes	2	Equations
Analytical	Shows the mode with identifying structures	3	Diagrams
Classificatory	Shows the organization, part and relations of the subjects	4	Ph. scale
4.Embeddedness Structure	The degree of integration of a visual mode to verbal mode in order to show how they are associated.		
Next to text	Making no connection of visual mode to text with text or a sign	1	A picture without labels or caption
Related to text	Making some connection of a visual mode to text with text or a sign	2	A picture with caption or labels partly explained in the text.
Explained in the text	Making an entire connection of a visual mode to text with text or a sign.	3	A picture with a caption or labels and their explanation in the text

The following explanations provide where and how these categories and subcategories were constituted for the rubric:

1. Sign system was adapted from a study by Schnotz (2002). The purpose of using this category was to identify a mode' semiotic structure semantically because semiotic structure of modes requires to understand the given meaning in the kinds of modes and the integrative structure of both the text and the mode (Ainsworth, 2006). This category had two subcategories: depictive and descriptive. Table 5 at below describes the definitions, scores and examples from the students' writing samples of this category and subcategories.

Table 5: Descriptions of sign system with subcategories, scores, and examples

Category Subcategories	Definition	Score	Example
1. Sign System	Showing students' point of interest in writing based on their comprehension of the modes.		
Depictive	Shows regular content	1	A plain picture
Descriptive	Shows the content with symbols or signs	2	A picture with labeled parts

2. Functional structure: The first subcategory, example, was formed from the literature review (van der Meij, & de Jong, 2006). The fourth subcategory, explanation, was adapted from Mayer and Gallini's study (1990). The rests of the subcategories were adapted from the literature (Schnotz, 2002) and formed by open and thematic coding methods of students' writing (Miles & Huberman, 1994). The designed order of the modes was based on the cognitive demands of using different structural types of visual modes. Table 6 at below describes the definitions, scores and examples from the students' writing samples of this category and subcategories.

Table 6: Descriptions of functional structure with subcategories, scores, and examples

Category Subcategories	Definition	Score	Example
2. Functional Structure	The strategy of using a visual representation in different purposes.		
Example	The modes that are used for an example.	1	A plain picture
Descriptive	The modes that represent the description of the topic.	2	Diagrams that show part of a plant
Comparative	The modes that represent comparison of topic	3	A Comparison of acids and bases
Explanatory	The modes which gives detail information about the topic	4	A mode or modes with a detailed explanatory caption.

3. Conceptual Structure: The subcategory, analogy, was adapted from the literature (Bernsen, 1994) and developed by the open and the thematic coding methods of students' writing (Miles & Huberman, 1994). The remaining three subcategories were formed from the work of Kress and van Leeuwen (1996). Table 7 at below describes the definitions, scores, and examples from the students' writing samples of this category and subcategories.

Table 7: Descriptions of conceptual structure with subcategories, scores, and examples

Category Subcategories	Definition	Score	Example
3. Conceptual Structure	Shows the established or permanent relationships and characteristics of a science concept		
Analogue	Shows the basic visuals or icons	1	A plain picture
Symbolic	Shows the symbolic attributes	2	Equations
Analytical	Shows the mode with identifying structures	3	Diagrams
Classificatory	Shows the organization, part and relations of the subjects	4	Ph. scale

4. Embeddedness Structure: The categories were adaptived from McDermott's dissertation study (2009) and coded based on the Lemke's (1998) explanation of multimodal representation integration into the text. This category showed the integration degree of a visual modes in the text. The category included three subcategories which were next to text, the related to text and the explained in the text. Table 8 at below describes the definitions, scores and examples from the students' writing samples of this category and subcategories.

Table 8: Descriptions of embeddedness structure with subcategories, scores, and examples

Category Subcategories	Definition	Score	Example
4.Embeddedness Structure	The degree of integration of a visual mode to verbal mode in order to show how they are associated.		
Next to text	Making no connection of visual mode to text with text or a sign	1	A picture without labels or caption
Related to text	Making some connection of a visual mode to text with text or a sign	2	A picture with caption or labels partly explained in the text.
Explained in the text	Making an entire connection of a visual mode to text with text or a sign	3	A picture with a caption or labels and their explanation in the text

Validity of the Rubric

The face validity was the measure to obtain validity of the rubric (Creswell, 2014). The process of the face validity was to consult with two professors who have worked in this kind of research study and experienced with developing multimodal rubric. During the process of developing the rubric each of the categories were checked and revised with two professors who have background in the related literature. Regarding to their revisions, the last version of the rubric was developed.

Step 2. Scoring the Data

The data consisted of the students' writing samples. For this reason, the data analysis included two steps. The first step was the qualitative analysis of the student's writing samples and each of them was scored with the designed rubric. The second step was to analyze the data statistically.

An excel matrix file that included each student's code, grade level, and the other mode categories was prepared for the scoring of the rubric. Then, the scoring was processed by analyzing the following four categories. After all samples were coded, reliability analysis was completed before running the statistical analysis.

The tables from 3 to 6 explain the definitions of categories and subcategories of the rubric with their scores and examples. With this regard, the scoring was completed according to this order. The first category, sign system, consisted of two subcategories: depictive and descriptive, accordingly the scores were given as 1 for depictive and 2 for descriptive visual modes. The next category, the functional structure was scored from 1-5. The category had hierarchical structure from the first subcategory to fifth one, so each category was assessed based on this. The fourth category, conceptual structure, had the score scale from 1-4. Similarly, the modes' conceptual structure was assessed based on the sub categories' hierarchical structure. The fifth category, embeddedness structure, was scored from 1-3 which was evaluated on the degree of visual modes' embeddedness in the text.

Reliability Analysis

Inter-rater reliability for this study was calculated by randomly selecting 10% of the writing samples (Creswell, 2014). Two external raters coded the 10% of the data for the interrater reliability. The external raters in this study were two doctoral students, who were experienced with coding, were trained to analyze students' writing samples. The data to be scored for interrater reliability was stratified by grade and SWH condition randomly. After the training was completed. 10 writing samples were coded independently and the matching percentages were calculated for the training purposes and each writing samples were discussed. When the reliability was reached at an adequate point, 10% of the writing samples were coded for the real reliability calculations. After the reliability was completed, the whole data set was scored. The calculation of the inter-rater reliability was calculated in this way: the number of agreements in scores divided by the total number of scores. Matching percentages of the coders were used to find the inter-rater reliability. The interrater reliability between the students were 94%.

Step 3. Data Analysis

After the scoring was completed into an excel file, the excel file matrix of the scores were used to run statistical analysis. Data analyses was carried out using the Hierarchical Linear Modeling (HLM). In order to run the analysis, the statistical file by using the SPPS were prepared. All scores were transformed to a long data file from the wide file according to the four categories. This method enabled to analyze the data according to four categories for overall comparison.

Hierarchical Linear Modeling

Hierarchical Linear Modeling (HLM) is an advanced version of the ordinary least squares (OLS) regression where hierarchical levels have different levels of analyzing each variable and also outcome variables are not the same as in the OLS which has different linear combinations of the predictor variables (Woltman, Feldstain, MacKay, &Rocchi, 2012). For instance, in the school settings, data is gathered in related levels and nested at student, classroom, school, and school district levels. These levels are not placed in the ordinary regression model which only measures one level of variables (Woltman et al, 2012).

The essential reason for using the HLM was that the linear mixed model takes into account the random effects at different levels, holding the effects of grouping of observations under higher units; for instance, students by classroom and schools Raudenbush, & Bryk, 2002). As the HLM model is built with the random effect, indicating that each group has their own overall mean and variance and so the intercepts varied in different groups, in the data set, which made this analyzing method appropriate for this study. It was expected in this study that students in each grade level and group would use different numbers of modes with different orders. Thus, running HLM with the random effect eliminated any bias of order and the number of variance across the groups and grades through clustering each mode as one observation into the student, groups, and grade levels. For these reasons, the HLM with the random effect was used to analyze the data.

Process of HLM Analysis

Variables

The following variables were determined and analyzed based on the research questions and the rubric for analyzing the writing samples. Two levels model of analyzing structure were used to analyze the writing samples statistically. The level 1 model contained four student levels of multimodal scores: sign, functional, conceptual and the embeddedness. The Level 2 model included both classroom and the grade level information. Level 2 variables included treatment group.

Dependent Variables

The categories in the rubric scores nested within students were the dependent variables. For this, sign structure, functional structure, conceptual structure, and embeddedness structure were analyzed and scored for each student. Each student's multimodal sample was scored for each category and placed in an Excel file. Each students' multimodal writing scores placed accordingly the grade level and the group.

Independent Variables

The grade levels and the group type were determined as independent variables. The type of group variables was scored accordingly 0 for non-SWH classes and 1 for SWH classes. Grade level included in this study from grade 4 to grade 8 and each group's effect was analyzed into level 2 model.

Data Analysis

Hierarchical linear modeling (HLM) provides an opportunity to use statistical models that account for nesting of the data. Nesting occurred because each student could include multiple representational modes (i.e., picture, drawing, diagram, equation, video, table) in their summary writing task. The mean number of modes included in each sample was 2.90 (SD = 1.91; Range 1 – 10). Descriptive statistic of the number of the modes provided in the table 9.

Table 9: Descriptive statistics for the number of modes

Mean of # of Modes	Both SWH and non-SWH	SWH	Non-SWH
4	3.13 (2.11)	3.24 (2.13)	2.34 (1.81)
5	2.89 (1.88)	3.05 (1.99)	2.52 (1.56)
6	2.54 (1.51)	2.54 (1.51)	_
7	2.12 (1.16)	1.87 (.92)	2.37 (1.51)
8	3.19 (2.05)	3.63 (2.14)	2.41 (1.62)
Total	2.93 (1.93)	3.08 (2.00)	2.42 (1.59)

Each mode was coded in one of 4 ways: sign system, functional, conceptual, and text relation. Zero-Order Correlations between four codes were calculated whether there were relationships between the four categories significantly. The results showed that there were statistically significant relationships between four categories (Table 10).

Table 10: Zero-order correlation between four categories

Categories	Sign system	Functional	Conceptual	Embeddedness
Sign system	1	.592**	.757**	.583**
Functional		1	.566**	.453**
Conceptual			1	.500**
Embeddedness				1

*p<.05. **p<.01.

To account for the nested data, random-intercept HLM models were computed separately for each of the 4 codes. In a random-intercept model, only the intercept parameter is included in the Level-1 model unconditional model (Equation 1).

Equation 1: Outcome = $\tau_{00} + u_0 + r$

Estimating an unconditional means model provides information about the heterogeneity between students as a means to establish a rationale for using a multi-level mixed model. That is, if there was very little or no variability between students, conducting a multi-level analysis would not be advised. This analysis provided an estimate of the intercept (or mean) averaged across all level 2 predictors (i.e., SWH, grade) and then partitioned that variance into between- and within-participant variances. The between-student variance is represented by the intra-class correlation coefficient (ICC). The ICC is the maximal amount of total variance in the outcome variable that is explainable by Level 2 predictors (Equation 2).

Equation 2: $ICC = \rho \quad \frac{\tau_{00}}{(\tau_{00} + \sigma^2)} \quad =$

Next, conditional models for each code were fitted such that two Level-2 predictors were included: grade centered at the grand mean and group (no SWH, SWH). From this analysis, it is possible to determine the percentage of variance accounted for by the two Level-2 predictors (Equation 3) as well as test the effects of the intervention (SWH) on each of the four codes.

Equation 3:

$$\% \text{ Variance Explained} = \frac{\tau_{00}\,(\text{unconditional}) - \tau_{00}\,(\text{compositional model})}{\tau_{00}\,(\text{unconditional})}$$

Summary

This study employed a quantitative approach with the Hierarchical Linear Modeling (HLM) technique as the methodology to address the research questions and hypotheses. This chapter explained the context of the study, data analysis with the rationale for the use of HLM to investigate the effect of SWH approach and age on students' multimodal learning. The categories that were used in this study explained with the construction processes and their sources; subsequently, these categories were used as variables in the analysis. Each of the categories was analyzed separately to answer the research question. The next chapter will present statistical results and their interpretations of these categories.

CHAPTER FOUR

RESULTS

The results are presented according to analysis of each category. Firstly, the descriptive statistics were provided for both level 1 and level 2 variables. Secondly, the unconditional analysis and secondly the conditional analysis for each category are provided. The interclass correlation coefficient was calculated based on the unconditional model. In the conditional model, each of the variances for each category was calculated and interpreted. Level 1, level 2, and mixed model formulations are demonstrated for each category, in addition to the table of analysis.

Descriptive Statistics

Firstly, level-1 descriptive statistics were calculated including each category, grade level, class, mode type, and modenum. The table below shows the descriptive statistics for level 1 variables (Table 11). Mean, standard deviation (SD), minimum and maximum numbers were calculated for each variable.

Table 11: Level-1 descriptive statistics

VARIABLE NAME	N	MEAN	SD	MINIMUM	MAXIMUM
CLASS	2319	0.77	.0.42	0.00	1.00
GRADE	2319	5.72	1.57	4.00	8.00
MODENUM	2319	2.93	1.93	1.00	10.00
MTYPE	2319	2.36	0.88	0.00	6.00
SIGN	2319	1.59	0.55	0.00	3.00
FUNC	2319	1.78	0.94	0.00	5.00
CON	2319	2.04	1.07	0.00	4.00
EMBED	2319	1.94	0.77	0.00	3.00

Secondly, level-2 descriptive statistics were calculated for level 2 variables, including class and grade levels. The table below shows the descriptive statistics for level 2 variables (Table 12). Mean, standard deviation(SD), minimum and maximum numbers were calculated for each variable.

Table 12: Level-2 descriptive statistics

VARIABLE NAME	N	MEAN	SD	MINIMUM	MAXIMUM
CLASS	605	0.46	0.00	0.00	1.00
GRADE	605	0.71	1.56	4.00	8.00

Conceptual Category

Unconditional Model: An unconditional model for conceptual representations was estimated (Table 13). Average performance across all students was significantly different from zero (2.01, p< .001)>

Level-1 Model: $CONCEPTUAL_{ij} = \beta_{0j} + r_{ij}$

Level-2 Model: $\beta_{0j} = \gamma_{00} + u_{0j}$

Mixed Model: $CONCEPTUAL_{ij} = \gamma_{00} + u_{0j} + r_{ij}$

Table 13: Unconditional analysis of conceptual structure

Fixed Effect	Coefficient	Standard error	t-ratio	Approx. d.f.	p-value
For INTRCPT1, β_0					
INTRCPT2, γ_{00}	2.005533	0.030217	66.370	604	<0.001
Random Effect	**Standard Deviation**	**Variance Component**	***d.f.***	**χ^2**	***p*-value**
INTRCPT1, u_0	0.51443	0.26464	604	1333.38027	<0.001
level-1, r	0.94655	0.89596			

$$\text{Conceptual ICC} = \rho = \frac{\tau_{00}}{(\tau_{00} + \sigma^2)} \quad \frac{.265}{(.265 + .896)} = .228$$

The random-intercepts Level-1 model indicated that 22.80% of the variance in conceptual category scores was between students. The average conceptual category score was 2.0 (SE = 0.03, p < .001).

Conditional Model: The conditional model for the conceptual category was estimated (Table 14).

Level 1 Model: $CONCEPTUAL_{ij} = \beta_{0j} + r_{ij}$

Level-2 Model: $\beta_{0j} = \gamma_{00} + \gamma_{01}*(GROUP_j) + \gamma_{02}*(GRADE_j) + u_{0j}$

Mixed Model: $CONCEPTUAL_{ij} = \gamma_{00} + \gamma_{01}*GROUP_j + \gamma_{02}*GRADE_j + u_{0j} + r_{ij}$

Table 14: Conditional analysis of conceptual structure

Fixed Effect	Coefficient	Standard error	*t*-ratio	Approx. *d.f.*	*p*-value
For INTRCPT1, β_0					
INTRCPT2, γ_{00}	1.324773	0.058504	22.644	602	<0.001
GROUP, γ_{01}	0.923724	0.065734	14.052	602	<0.001
GRADE, γ_{02}	0.135532	0.017600	7.701	602	<0.001
Random Effect	Standard Deviation	Variance Component	d.f.	$\chi 2$	p-value
INTRCPT1, u0	0.37337	0.13940	602	1011.25024	<0.001
level-1, r	0.93611	0.87631			

There were significant differences in conceptual category scores. Students in the SWH group had conceptual l category scores 0.92 points higher than their non-SWH peers (p <.001). Each subsequent grade higher was associated with a 0.14-point increase in conceptual scores. The conditional model accounted for 47.3% of the explainable between-subjects variance.

Conceptual % Variance Explained:

$$\frac{\tau_{00}\,(\text{unconditional}) - \tau_{00}\,(\text{compositional model})}{\tau_{00}\,(\text{unconditional})} = \frac{(.265 - .139)}{.265} = .473$$

Functional Category

Unconditional Model: An unconditional model for functional representations was estimated (Table 15). Average performance across all students was significantly different from zero (1.70, p< .001)>

Level-1 Model: $FUNCTIONAL_{ij} = \beta_{0j} + r_{ij}$

Level-2 Model: $\beta_{0j} = \gamma_{00} + u_{0j}$

Mixed Model: $FUNCTIONAL_{ij} = \gamma_{00} + u_{0j} + r_{ij}$

Table 15: Unconditional analysis of functional structure

Fixed Effect	Coefficient	Standard error	t-ratio	Approx. d.f.	p-value
For INTRCPT1, β0					
INTRCPT2, γ00	1.7023373	0.029869	56.994	604	<0.001
Random Effect	**Standard Deviation**	**Variance Component**	**d.f.**	**χ2**	**p-value**
INTRCPT1, u0	0.58791	0.34564	604	2010.71882	<0.001
level-1, r	0.74926	0.56139			

Functional Structure ICC= $\frac{\tau_{00}}{(\tau_{00} + \sigma^2)} = \frac{.346}{(.346 + .561)}$ $\rho = .38$

The random-intercepts Level-1 model indicated that 38 % of the variance in functional category scores was between students. The average conceptual category score was 1.70 (SE = 0.03, p < .001).

Conditional Model: The conditional model for the functional category was estimated (Table 16).

Level 1 Model: $FUNCTIONAL_{ij} = \beta_{0j} + r_{ij}$

Level-2 Model: $\beta_{0j} = \gamma_{00} + \gamma_{01}*(GROUP_j) + \gamma_{02}*(GRADE_j) + u_{0j}$

Mixed Model: $FUNCTIONAL_{ij} = \gamma_{00} + \gamma_{01}*GROUP_j + \gamma_{02}*GRADE_j + u_{0j} + r_{ij}$

Table 16: Conditional analysis of functional structure

Fixed Effect	Coefficient	Standard error	*t*-ratio	Approx. *d.f.*	*p*-value
For INTRCPT1, β_0					
INTRCPT2, γ_{00}	0.976998	0.048607	20.100	602	<0.001
GROUP, γ_{01}	0.995543	0.059783	16.653	602	<0.001
GRADE, γ_{02}	0.099922	0.018454	5.198	602	<0.001
Random Effect	Standard Deviation	Variance Component	d.f.	$\chi 2$	p-value
INTRCPT1, u_0	0.44113	0.19460	602	1426.33674	<0.001
level-1, r	0.74260	0.55145			

There was a significant difference in functional category scores by group. Students in the SWH group had functional category scores 0.9 points higher than their non-SWH peers (p <.001). Each subsequent grade higher was also associated with a 0.10-point increase in functional scores. The conditional model accounted for 44 % of the explainable between-subjects variance.

Functional % Variance Explained:

$$\frac{\tau_{00}\,(\text{unconditional}) - \tau_{00}\,(\text{compositional model})}{\tau_{00}\,(\text{unconditional})} \qquad \frac{(.35 - .19)}{.35} \qquad = .44$$

Sign Category

Unconditional Model: An unconditional model for the sign system used was estimated (Table 17). Average performance across all students was significantly different from zero (1.54, p< .001).

Level-1 Model: $SIGNSYSTEM_{ij} = \beta_{0j} + r_{ij}$

Level-2 Model: $\beta_{0j} = \gamma_{00} + u_{0j}$

Mixed Model: $SIGNSYSTEM_{ij} = \gamma_{00} + u_{0j} + r_{ij}$

Table 17: Unconditional analysis of sign structure

Fixed Effect	Coefficient	Standard error	t-ratio	Approx. d.f.	p-value
For INTRCPT1, β_0					
INTRCPT2, γ_{00}	1.535500	0.018107	84.800	604	<0.001
Random Effect	**Standard Deviation**	**Variance Component**	***d.f.***	**χ^2**	***p*-value**
INTRCPT1, u_0	0.35356	0.12500	604	1821.89431	<0.001
level-1, *e*	0.46188	0.21333			

Sign System ICC = $\rho \quad \frac{\tau_{00}}{(\tau_{00} + \sigma^2)} \quad \frac{.125}{(.125 + .213)} \quad = \quad = .369$

The random-intercepts Level-1 model indicated that 36.9% of the variance in the sign system used was between students. The average conceptual category score was 1.54 (SE = 0.018, p < .001).

Conditional Model: The conditional model for the sign system used was estimated (Table 18).

Level 1 Model: $SIGNSYSTEM_{ij} = \beta_{0j} + r_{ij}$

Level-2 Model: $\beta_{0j} = \gamma_{00} + \gamma_{01}*(GROUP_j) + \gamma_{02}*(GRADE_j) + u_{0j}$

Mixed Model: $SIGNSYSTEM_{ij} = \gamma_{00} + \gamma_{01}*GROUP_j + \gamma_{02}*GRADE_j + u_{0j} + r_{ij}$.

Table 18: Conditional analysis of sign structure

Fixed Effect	Coefficient	Standard error	*t*-ratio	Approx. *d.f.*	*p*-value
For INTRCPT1, ψ_0					
INTRCPT2, γ_{00}	1.133981	0.045549	24.896	602	<0.001
CLASS, γ_{01}	0.550608	0.047100	11.690	602	<0.001
GRADE, γ_{02}	0.031242	0.010231	3.054	602	<0.002

Random Effect	Standard Deviation	Variance Component	d.f.	$\chi 2$	p-value
INTRCPT1, u_0	0.29122	0.08481	602	1539.11572	<0.001
level-1, *e*	0.45578	0.20773			

There was significant difference in sign system scores by group. Students in the SWH group had the sign category scores 0.55 points higher than their non-SWH peers (p <.001). Each subsequent grade higher was associated with a 0.03-point increase in sign system scores. The conditional model accounted for 32.1% of the explainable between-subjects variance.

Sign System % Variance Explained:

$$\frac{\tau_{00}\,(\text{unconditional}) - \tau_{00}\,(\text{compositional model})}{\tau_{00}\,(\text{unconditional})} \quad \frac{(.125 - .085)}{.125} \quad = \quad .321$$

Embeddedness Category

Unconditional Model: An unconditional model for the text relation category was estimated (Table 19). Average performance across all children was significantly different from zero (1.85, p< .001).

Level-1 Model: Embeddedness $_{ij} = \beta_{0j} + r_{ij}$

Level-2 Model: $\beta_{0j} = \gamma_{00} + u_{0j}$

Mixed Model: Embeddedness $_{ij} = \gamma_{00} + u_{0j} + r_{ij}$

Table 19: Unconditional analysis of embeddedness structure

Fixed Effect	Coefficient	Standard error	t-ratio	Approx. d.f.	p-value
For INTRCPT1, β_0					
INTRCPT2, γ_{00}	1.853802	0.021374	72.516	604	<0.001
Random Effect	**Standard Deviation**	**Variance Component**	***d.f.***	χ^2	***p*-value**
INTRCPT1, u_0	0.50738	0.25744	604	1938.12294	<0.001
level-1, *e*	0.63020	0.39715			

$$\text{ICC} = \frac{\tau_{00}}{(\tau_{00} + \sigma^2)} \quad \frac{.257}{(.257 + .397)} \quad \rho \quad = \quad = .393$$

The random-intercepts Level-1 model indicated that 39.3% of the variance in embeddedness category was between students. The average conceptual category score was 1.85 (SE = 0.02, p < .001).

Conditional Model: The conditional model for the text relation category was estimated (Table 20).

Level 1 Model: Embeddedness $_{ij}$ $= \beta_{0j} + r_{ij}$

Level-2 Model: $\beta_{0j} = \gamma_{00} + \gamma_{01}*(GROUP_j) + \gamma_{02}*(GRADE_j) + u_{0j}$

Mixed Model: Embeddedness $_{ij}$ $= \gamma_{00} + \gamma_{01}*GROUP_j + \gamma_{02}*GRADE_j + u_{0j} + r_{ij}$

Table 20: Conditional analysis of embeddedness structure

Fixed Effect	Coefficient	Standard error	*t*-ratio	Approx. *d.f.*	*p*-value
For INTRCPT1, β_0					
INTRCPT2, γ_{00}	1.252860	0.054147	23.138	602	<0.001
GROUP, γ_{01}	0.820454	0.058576	14.007	602	<0.001
GRADE, γ_{02}	0.022760	0.013834	1.645	602	<0.001
Random Effect	**Standard Deviation**	**Variance Component**	**d.f.**	**$\chi 2$**	**p-value**
INTRCPT1, u_0	0.41410	0.17148	602	1620.14806	<0.001
level-1, r	0.61883	0.38295			

There were significant differences in functional category scores by group. Students in the SWH group had functional category scores 0.8 points higher than their non-SWH peers (p <.001). Each subsequent grade higher was associated with a 0.023-point increase in embeddedness scores. The conditional model accounted for 33.3% of the explainable between-subjects variance.

Text Relation % Variance Explained:

$$\frac{\tau_{00}\,(\text{unconditional}) - \tau_{00}\,(\text{compositional model})}{\tau_{00}\,(\text{unconditional})} \quad \frac{(.257 - .171)}{.257} = .333$$

Summary

The HLM analysis showed the differences between the SWH and non-SWH classes and the grade effect on learning with multimodal representations. The SWH approach had positive effect on the use of visual representations. The ICC calculations showed that students' use of the multimodal representations differed from zero that means that students attached at least one visual mode into their texts. This results showed that students in the traditional group also provided visual representations in their text. Therefore, it is important to look at the discussion for each research question and the related hypothesis to explore the possible reasons of these findings.

CHAPTER FIVE

DISCUSSION AND IMPLICATIONS

The purpose of this study was first to investigate the impact of the Science Writing Heuristic approach on students' multimodal learning across grades 4 through 8. The second focus was to investigate the age effect, based on the grade levels, on learning multimodal representations. Results of this study showed that student participation in the SWH classes promoted students' multimodal learning. The results also showed that increasing grade levels also supported understanding multimodal representations according to the gain scores.

This chapter starts with some brief discussions of the research questions and the related hypothesis. For this, the discussion starts with the grade effect question and the related hypothesis; consequently, the effect of the SWH is discussed. In the overall discussion, extensive explanations for the possible reasons of the findings are discussed. Lastly, the implications for the future studies and the limitations of this study are explained.

Answers to Research Questions and Hypotheses

Research Question 1

How are the differences between using multimodal representations in different structures from lower to upper grade levels (across 4th to 8th grades) in both SWH and non-SWH classrooms?

Hypothesis1: Upper grade students (6^{th}-8^{th} grade) will use more descriptive and less depictive representations than lower grade kids (4^{th}-5^{th} grade).

Hypothesis 2: Upper grade students (6^{th}-8^{th} grades) will use more sophisticated functional representations than lower grade students (4^{th}-5^{th} grades).

2a: Upper grade students (6^{th}-8^{th} grades) will use more descriptive representations than lower grade students (4^{th}-5^{th} grades).

2b: Upper grade students (6^{th}-8^{th} grades) will use more comparative representations than lower grade students (4^{th}-5^{th} grades).

2d: Upper grade students (6^{th}-8^{th} grades) will use more explanatory representations than lower grade students (4^{th}-5^{th} grades).

2e: Upper grade students (6^{th}-8^{th} grades) will use more enriched explanatory representations than lower grade students (4^{th}-5^{th} grades).

Hypothesis 3: Upper grade students (6^{th}-8^{th}) will use more sophisticated conceptually structured representations than lower grade students (4^{th}-5^{th} grade).

3a: Upper grade students (6^{th}-8^{th}) will use more symbolic representations than lower grade students (4^{th}-5^{th} grade).

3b: Upper grade students (6^{th}-8^{th}) will use more analytical representations than lower grade students (4^{th}-5^{th} grade).

3c: Upper grade students (6^{th}-8^{th}) will use more classificational representations than lower grade students (4^{th}-5^{th} grade).

Hypothesis 4: Upper grade students (6^{th}-8^{th}) will use higher order embeddedness representations than lower grade students (4^{th}-5^{th} grade).

4a: Upper grade students (6th-8th) will use more "related to text" degree of representations than lower grade students (4th-5th grade).

4b: Upper grade students (6th-8th) will use more "explained in the text" degree of representations than lower grade students (4th-5th grade).

In this research question, the related hypotheses are explained overall. The findings indicated that there are significant increases in the multimodal scores in all categories through upper grade levels. The gain effects of the grade levels were in descending order: conceptual, functional, sign, and embeddedness structures. These findings mostly confirmed the related hypothesis about the age which would foster the use of representations from lower grades to upper grades. However, the results showed that his hypothesis was rejected. Even though Halford (1993) stressed that the students under age 11 would not engage in using multimodal representations like their upper grade peers, the findings of this study showed that students could achieve using multimodal representations in their writing in this age group in both the SWH and non-SWH groups.

Students throughout the upper grade levels received better scores on the conceptual structure while the text relations category had the lowest score. The age added to the multimodal' scores, including conceptual .14, functional .1, sign .03, and the text relation .023 points. These findings may be related to the school science content in addition to cognitive growth because the concepts become more complex in the upper grade levels.

Given that in school settings students learn science concepts and content from a basic to more complicated nature as students move up through grade levels, this is also true for visual representations. Therefore, the results of the conceptual category are consistent with the nature of science concepts in the school setting. In the earlier grade levels, science content in textbooks contains visuals of real objects, including real pictures of animals and plants (Keys, 1999). However, in the upper grade levels, the visuals include more symbolic and analytic structures, such as equations, formulas, and diagrams according to the topic (Slough, McTigue, Kim, & Jennings, 2010). The concepts in the textbooks become more complex through upper grade levels, which also drives the intricacy of visual representations in students' writing. This probably explains why the conceptual structure score in both classes was the highest.

The second increase was in the functional category. In this category, students needed to provide representations, according to their interests, for a meaning-making process when integrating the visuals into their texts. The information in the text and in the visual representations needed to be consistent. The findings also showed that sign category is higher than the text relation. This shows that students were better at using semiotic visuals according to their interests; however, the integration of these semiotic representations was low.

Research Question 2

How does participating in SWH argument-based classrooms affect the development of students' multimodal accomplishment by measures of sign system, functional, conceptual, and integrative structures in multimodal products?

The findings showed that students' multimodal scores in the SWH classes were significantly better in all categories than the students in the non-SWH classes when controlling the grade level. This finding confirms the related hypothesis in this question.

The functional structure has the highest. Other categories followed in order: conceptual, text relation, and sign structure. In contrast to the first research question, the SWH students scored the least on the sign system, however, the other categories showed similar results. In order to examine the findings on the categories, further explanations are provided for each hypothesis for this research question.

Hypothesis 5

SWH students will use more descriptive modes than non-SWH students and less depictive representations than non-SWH students through all grade levels:

The findings showed that the students in the SWH classes scored better in this category than the students in the non-SWH classes. Thus, the hypothesis of this category is confirmed. The students in the SWH classes scored .55 point higher than the students in the non-SWH classes in this category. This category assed the basic representational structure of a visual representation which was the sign structure of a visual representation. In order to assess this category, two subcategories were used including depictive and descriptive representations. The depictive representations do not provide additional information like the descriptive representations such as simple pictures. However, descriptive representations provide more information semantically. This finding supports the hypothesis that sign structure of the visual representations were better engaged in the treatment classes. Schnotz’s (2002) study showed that using descriptive representations promoted constructing mental representations and so students could easily comprehend the topic. Slaugh et al. (2010) indicate that multimodal representations in the textbooks are not connected semantically. Thus, using the sign structure appears to be an important measure to assess students understanding of the multimodal representations, and the literature supports that communicating with scientific representations requires learners to understand the meaningfully.

Hypothesis 6

SWH students will use more sophisticated functionally structured representations than non-SWH students across all grade levels:

The findings showed that the students in the SWH classes scored better in this category than the students in the non-SWH classes. Students in the SWH group had functional category scores 0.9 points higher than their non-SWH peers. In the functional structure category, students needed to use the representations according to their interests, purposes, and understandings of the concept. This category has four sub categories to measure representations from easy to complex structures in the following order: example, descriptive, comparative, and explanatory representations. Among these representations, the exemplary representation was the most simply structured representation and the one type is mostly used in the textbooks. Furthermore, descriptive representations are the second most common type that can be found in textbooks when defining basic diagrams or equations. The textbook language consists of definitions and the basic description of the theories and visual representations are placed as “look at the example on the figure x”. As the textbooks often do not go beyond descriptions, students in the traditional classes do not learn to discuss different ideas and negotiate them as in the SWH classes. The findings of this study show that in the traditional classes, students’ language is limited to writing basic definitions of the content with attached related visual representations. In contrast to traditional methods of teaching, the SWH approach promoted students to use the scientific language effectively as the findings demonstrated.

Hypothesis 7

SWH students will use more sophisticated conceptually structured representations than non-SWH students across all grade levels:

Students in the SWH group had conceptual category scores 0.9 points higher than the students in the non-SWH group. This finding showed that students' engagement in the conceptual structure of the visual modes are better than the traditional group. This category assessed the visuals by the conceptual structure in four subcategories according to the science concept, including analogy, symbolic, analytical, and classificational. The previous research showed that using multimodal representations in the writing developed conceptual understanding within the SWH approach based learning environment (Hand, et. al., 2009; McDermott &Hand 2013). However, these studies did not assess the concept of visual representations but only assessed the text; therefore, from the previous studies, it was not clear whether students understood the conceptual structures of scientific representations such as equations and formulas which students often have difficulties to understand. Also, the degree of the understanding was not measured that might lead students who developed until a certain level of understanding, was measured as "not understood". This study's finding also shows that students' conceptual understanding is not limited only understanding the text but they also can develop better conceptual understanding using more complex conceptual structures. The science concept is highly complex and this is the same for the visuals. In the textbook, in the lower grade levels, the visuals include mostly real pictures. However, the eventual goal of the science is to have students develop an understanding of more complex structures such as equations and taxonomies. Halford (1993) explains that understanding a concept is associated with having a mental model of a concept structure; resulting in the previous studies based on the concept maps (Novak, 2010). Those studies demonstrated that when students construct concept map as they need to associate related and different ideas into a concept map with reasonable connections, they could develop conceptual understanding (Novak, 2010). However, expecting all students to have this ultimate understanding in the same level is not possible. Concept maps are the highest degree of the conceptual structures which is a significant example of the highest degree of the measure used in this study: classificational (Kress & van Leewuen, 1996). Therefore, this study measured the representations' conceptual structure within four categories that provided the degree of the conceptual understanding of scientific representations. By doing this, the degree of the understanding of students could be evaluated. The researcher would support that it is important to use this measure of conceptual category that was used in this study as this structure can better assess the conceptual structure compared to the previous studies.

Hypothesis 8

SWH students will use more sophisticated embedded structured representations than non-SWH students among all grade levels:

The embeddedness category was the third category that showed significant differences between the SWH and the non-SWH classes. In this category, students needed to make clear connections between the text and the representations. For this, students were required to translate the information in the text to visual representations.

The embeddedness structures' results were consistent with the previous studies (Hand &Choi 2010; McDermott & Hand, 2013). In the previous studies, students in the SWH classrooms engaged in the practice of embedding representations successfully into their texts and showed a positive outcome on understanding the topic. Moreover, when students used representations they constructed better arguments. Therefore, they understood the topic deeply. In this approach students needed to use scientific language to argue the concept effectively. In order to do this, they needed to negotiate meaning to construct meaningful knowledge. In the SWH learning environment, students needed to discuss scientific process and make meaningful connections between claims and evidence (Hand et. al., 2004). Students are able to learn how to link together various components of modes using meaning making and are unrestricted in able to demonstrate their own understanding at the end of the unit in the summary writing activity (Hand &Choi 2010; Chen, et. al., 2013). This implementation is not part of the traditional laboratory format where learners describe what happened according to the information in the textbooks. As traditional laboratory practices describe what students will see in the experiments, students check the description and write accordingly (Keys, 1999). Thus leads that students to report based on the describing the process of the laboratory activity in step base information instead of explaining. Additionally, every group have to follow one type of laboratory activity according to textbook instruction that cause on students to find out one correct answer of the activity. However, in the SWH approach students' can integrate visuals without depending on the textbook content by making logical connection across different representations with critique during and after the inquiry by using the SWH template based inquiry process (Akkus et. al, 2007). Because each group needed to produce the inquiry based on their claims and evidences, each group can practice different inquiry processes. The previous research showed that the prior knowledge and experiences of practicing SWH was correlated with understanding of multimodal representation (Jang, 2010). Thus, students could use better transfer practicing to integrate different multimodal representations with meaning-making into their summary writing according to their purposes of argument.

Discussion

Three key points emerged from the results. Firstly, the SWH approach has positive effects on students' understanding of the multimodal representations. Second, the influence of the age is different for each category. The third point is that the categories are used in this study have significant potential when exploring the students learning of multimodal representations.

Firstly, the SWH approach was effective in promoting students' multimodal understanding in the categories where students needed to argue the content through using multiple representations and construct their argument through the writing to learn strategy. The argumentation part of the SWH tests whether the claim and the explanation in the evidence explain the observation and inquiry with the related scientific theory based on a logical dialog. This process is completed by students often to find out the association between the evidence and the related theories based on the arguments and conducting inquiry. As students consistently practice this process in the SWH classrooms, it appears to be that students benefited by finding out the association between the theory and the inquiry practice with argumentation and produced explanations out of them in their summary writing tasks. In the embeddedness category, students need to link the text with appropriate visual modes with clear connections. Therefore, the process of the argumentation and the writing tasks and practicing them may explain why students achieved better than the control group in the embeddedness category. The significant findings on the functional and embeddedness in the SWH classes also is related to cognitive process of multimodal learning which suggests for meaningful learning the visual and verbal modes need to be connected. Jang's study (2011) also support these finding. In that study, the results her studies showed that correlations between practicing claims and evidence, cohesiveness score of multimodal representations in summary writing and students' science standardized test scores; however, she did not have traditional groups as a control. Correspondingly, in this study students carried out their practice of the science during the SWH approached based activities to their summary writing tasks; thus, it appeared to be that students were able to engaged in transfer what they achieved better structures of multimodal representations in their final task; even though, students were not instructed to use different structures of representations.

Conversely, in the traditional classrooms, the laboratory activities are also based on the report but not the explanations (Keys, 1999). As students in the traditional classrooms are highly predisposed by the textbooks and their instructors' directions, students do not go beyond of the language of the textbooks and mostly they tended to replicate the content of the textbook. Thus, it appeared that students used the visual representation based on the textbooks' structures in this study. However, the comparative and the explanatory representations are more complexly structured and explanations are formed in a logical order (Mayer & Gallini; 1990; Martins, 2002). When constructing these representations, students need to provide their explanations of concepts in detail based on their reasoning in a logical order that requires them to construct their own sentences and integrate related visuals depending on their discussion. However, they cannot follow the textbook instruction as it is presented. Thus, students in the SWH approach showed better success in the functional category than the traditional group as they were able to transform their understanding into the visual representations.

Furthermore, in the functional category, the highest degree type of the representations was the explanatory. Mayer and Gallini (1990) indicate that explanatory representations require reasoning on the visual mode with verbal explanation. However, the verbatim information is not included in the explanatory modes, which is a common practice in the traditional learning environment, but not the SWH approach. Therefore, this result explains why a connection between the evidence and the claim section was found in the previous studies. In the previous studies, a positive correlation between having a high embedded multimodal representation score and constructing high quality arguments in the evidence section was found (Chen et al, 2013; Hand & Choi, 2010). Even though, in this study the SWH template was not used, students wrote their summary writing after SWH template based activities. The researcher would argue that the cumulative effect of practicing SWH promoted the students' accomplishment in this category. Moreover, in the evidence section of the SWH, students need to explain their claims with strong reasoning. In these studies, the measure of the representations was embeddedness. Using the measure of functional type in this study explains better the relationship between SWH and using multimodal representations in the evidence section.

Therefore, it may be concluded that understanding and practicing the functional structure category of multimodal representations is necessary to promote students' understanding of multimodal representations because students need to learn how to explain causal relationships among the theories and the practice and communicate accordingly with an appropriate scientific language like other scientists do.

Secondly, the findings of this study indicate that including multimodal representations tin the instructional method by integrating texts and pictures together was effective for promoting students understanding and communicating through the use of scientific language. The measures that are used in this study, were also effective in showing the variances of the structures that students engaged in across grade levels in both treatment and control classes. Hence, multimodal representations should be considered according to the structural strategy, and rather than be based on only adding a picture next to the text does not show comprehension in many ways because adding simple pictures to a text does not show the logical connection; however, when students use more sophisticated representations like explanatory representations, they can demonstrate their logical connection based on scientific language (Mayer & Gallini, 1990).

In science, visual representations describe a process or a phenomenon. However, using a simple picture does not show what the process or a phenomenon is. When students use more sophisticated representations, they use labels and captions to describe and explain the process or the object. Also, sometimes students use more than one visual representation to describe or explain the process or product. By doing this, the level of their understanding can be seen explicitly. Similarly, scientists use visual representations to show the components of scientific objects and materials. All of this requires more sophisticated visual representations but not restricted by using one type of visual representation. The findings are also consistent with the Schnotz's (2002) research, which revealed using only a text with a simple picture did not help students construct mental models from the representations and understand the concept completely. The criteria used in this study to examine text and pictures were able to provide more information about the concept.

The traditional group often utilized their textbooks for the visual representations in their writing. Science concepts consist of more complex theories and related visual representations such as complex equations and formulas. The science texts of the upper grade levels are structured with detailed concepts and difficult vocabularies, and become more complex, according to the nature of science concepts. Hence, the information in the science text includes more abstract information and uses more symbolic properties to describe each topic. However, textbooks do not provide detailed process information of a concept and even sometimes visual representations are used for decorative purposes (Slough, 2010). Controversial information is not included in the textbooks; whereas, the abstract information is provided as real objects without a structured organization (Keys, 1999). Therefore, this may explain why the gain score in the conceptual category was the highest.

Even though a visual representation is complexly structured, students in the traditional group did not always explain the visuals in depth in the text. From the researcher's point, sometimes they just described the topic at a base level, such as, what a chemical reaction is and they add any representations next to the text without trying to integrate them. In this case, even if the visual representation is complex, the visual representations' embeddedness structure is low. This may explain why the conceptual category is higher but not the functional and text relation in the traditional group. Thirdly, the effects of age also may enlighten the students' learning of multimodal representations. Age increased scores of representations in all the categories. The conceptual structure had the second highest gain score in the upper grade levels and functional structure is the second. This may be the result of the students' cognitive growth by the upper grade levels. In the hypothesis, lower grade students would have fewer complex structures compared to higher grade levels because integrating multimodal representations requires a high cognitive effort. However, the score increase by age stayed in small numbers and the means were not high and the SWH added higher scores than the age. Thus it appeared to be that that non-traditional instructional strategies like SWH have more potential to promote multimodal learning regardless of the provided age group.

Moreover, the findings disclosed that lower grade students could use also complexly structured representations. Even though the age has an impact, this impact is lower than the SWH effect in all categories. The generative process of learning multimodal representations stress that meaning making with representations requires integrating the representations and making a coherent structure where the instructional design should encourage generative processing (Mayer & Moreno, 2003). From this study findings, the SWH approach appeared to foster the cognitive demands which emphasizes practicing science with scientific language.

In conclusion, it appears to be that students were able to transfer some of their earlier experiences of using effective scientific language with multimodal representations in their summary writing. Some emerging points give the idea that the strategy of promoting scientific language effectively is resulted in better communication, understanding of the concept and influence of transferred experiences of earlier SWH template based activities into the summary writing. Thus, the SWH approach fostered better students' learning of multimodal representations in different structures with the language of argument compared to the traditional group because the traditional group mostly replicated information and visuals of textbooks.

Implications

The NGSS stress that argument based inquiry supports science practices that promote explaining and making connection between different ideas and theories (NGSS, 2013). The findings of this research support also these practices. Learning science is often the result of understanding problem solving strategies through inquiry which requires scientific reasoning. Heuristics, problem solving, and logical connection are necessary to construct scientific reasoning from evidence (Hand et. al, 2009). As this research showed, the SWH approach as one of the science inquiry practices can fulfill these science learning demands. Therefore, more related research into other related learning strategies is important to better understand how to promote students' science learning.

The SWH approach provides students an opportunity to discuss, negotiate, investigate, and write their ideas while using their reasoning to test the claims and explain the evidence accordingly. This procedure is not entirely processed using only verbal modes. This approach is one of the science practices where students need to communicate and construct their information like other scientists do. This includes the use of multimodal representations, often in the discussions of writing. Instead of replicating what is in the textbook, students find opportunities to search for other types of representation, construct their own representations and use all of them in their writings. From this study's researcher's point of view, it appeared that students in the traditional groups mostly used the same pictures or diagrams from their textbooks. However, in the SWH writing samples, the visual representations varied. As this study is quantitative, the trends and the comparison of the writing samples were not explicitly explained. Therefore, for future studies, more qualitative studies on this topic can show these differences between student writing in traditional and non-traditional classrooms based on the sign system to provide better explanations of students' multimodal practices.

The findings showed that the functional and the embeddedness categories were better in the SWH approach. The relationship among these categories shows that students can better communicate and comprehend scientific ideas within their nontraditional writing. The textbook restriction often causes students' language limitations and errors (Slough et. al., 2010). For instance, Warner and Wallace's (1994) study indicated that students mostly used descriptive words including "chiseled" and "expertise: in the science class. However, they did not use scientific words like pulley and force and the meaning of these words were not discussed. This study did not explore the text structure such as evaluating the use of the scientific words. However, the functional and embeddedness structures required students to use scientific language semantically. As students used explanatory representations and their embeddedness structures corresponded, students could construct their explanations based on their understanding and went beyond of the textbook structure. Therefore, more studies are needed to examine the text structures to show how nontraditional and the traditional classrooms use the scientific text through upper grade levels in addition to the visual modes. Such studies can provide better explanations of how the SWH affects students' cognitive growth by the use language of science when integrating visuals into text.

Another potential study could show the relationships of the categories. In this type of study, how the categories effect the embeddedness structure could be examined. As the ultimate goal of the writing research is to have students learn in a cohesive system, with this type of future research, we can illuminate the relationship between the categories. This research will provide information on how the students understand the multimodal representations and how their understanding can be improved. Examining the relationship between the embeddedness with the other categories can develop better findings to promote science understanding based on multimodal representations.

The SWH approach has been implemented for more than a decade and it is an effective method promoting in students' science understanding through writing and argument (McDermott, Hand, 2013). As this approach is very effective, it is important to show the long term effect of students' understanding of multimodal representations. Therefore, the last future research point is a longitudinal study to examine the students' growth and better test the first research question by tracking the students through tracking upper grade levels in this research topic. Therefore, multimodal representations' effects on students' understanding can be better explored.

Limitations

Some limitations occurred in this study. These limitations consisted of the differences on the teachers' experiences, and the students' science achievement scores. Lastly, using different students in each grade levels limited this study's findings.

Firstly, there were differences in topics being studied. Students in different grade levels involved in different science topics among biology, chemistry, and physics. The analysis of the representations was not dependent on the type of the representations and topic. Results may yield better growth differences if the topics were in the same discipline in every classes.

Secondly, teachers' experiences can be another factor that impacts the results. Some of the teachers have been teaching the SWH approach more than other teachers. As they are more familiar with the approach, they may have a better influence on the students' learning in the treatment classes. Therefore, in order to understand the teachers' effect, more analysis can give better explanations for the results.

Thirdly, this study did not measure the prior and post knowledge of the students. Some of the previous studies showed that using multimodal representations differed among the low and high achievement students (Mayer &Gallini 1990). Lastly, in this study, in each grade level, there were different students. Also, there was not control group in the 6^{th} grade. There are also many factors which affect the cognitive growth is the limitation in this study. Therefore, for the future studies, more factors can be used to explore the age effect on learning with multimodal representations. Lastly, for better results of age effect, tracking the same students through upper grades can provide better explanations of the age effect when comparing with the effects of the SWH in this study context.

APPENDIX

Example of Summary Writing Task

Shark Adaptations

By 222737

<u>Structural Adaptation #1</u>

The Great White shark has teeth that can help them rip apart their prey so the shark can swallow the food fast to get more prey.The diet of the Great White shark is fish, dolphin, and whale. The Great White shark has 300 teeth and if the the

shark loses a tooth than they grow another tooth. That is why the Great White Shark has 300 teeth.

Structural Adaptation 2#

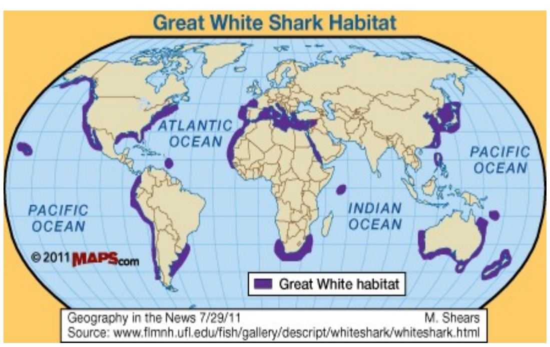
The Great White shark has jaws that are one of the most powerful things in the shark's body that can help the Great White with chewing its food faster and faster to eat or to get to their pups. The jaws of a Great White is a huge adaptation. Sharks can go without eating for months or more because their digestion takes so long.

An adaptation is what helps the animal stay alive like the nose of an animal can help the animal stay alive.

Pups are shark babies when they are first born.

Information Processing Adaptations

The sense of smell is the best sense for the Great White. Because the Great White can smell from miles away to get fish or any type of food to get.



The Great White shark lives in cold water so when the shark swims away from something like a whale, it can be cold and not hot.In the ocean the shark swims around.The Great White shark lives in every ocean and lots of rivers and some lakes.

Great White Sharks are silent so that they get prey easier to get and they survive longer.

REFERENCES

Ainsworth, S. (1999). The functions of multiple representations. *Computers & Education*, *33*(2), 131-152.

Ainsworth, S. (2006). DeFT: A conceptual framework for considering learning with multiple representations. *Learning and instruction*, *16*(3), 183-198.

Akkus, R., Gunel, M., & Hand, B. (2007). Comparing an Inquiry-based Approach known as the Science Writing Heuristic to Traditional Science Teaching Practices: Are there differences?. *International Journal of Science Education*, *29*(14), 1745-1765.

Baddeley, A. (1992). Working memory. *Science*, *255*, 556–559.

Bernsen, N. O. (1994). Foundations of multimodal representations: a taxonomy of representational modalities. *Interacting with computers*, *6*(4), 347-371.

Barrow, L. H. (2006). A brief history of inquiry: From Dewey to standards. *Journal of Science Teacher Education*, *17*(3), 265-278.

Chambliss, M. J. (2002). The characteristics of well-designed science textbooks. In J. Otero, J.León, & A. C. Graesser (Eds.), The psychology of science text comprehension (pp. 51-72). Mahwah, NJ: Lawrence Erlbaum Associates.

Chen, Y. C., Hand, B., & Mcdowell, L. E. A. H. (2013). The Effects of Writing-to-Learn Activities on Elementary Students' Conceptual Understanding: Learning About Force and Motion Through Writing to Older Peers. *Science Education*, *97*(5), 745-771.

Creswell, R. (2014). Research design: qualitative, quantitative, and mixed methods approaches. USA: Sage Publications.

Creswell, J. W. & Plano Clark, V. L. (2011). Designing and conducting mixed methods research (2nd Ed.). Thousand Oaks, CA: Sage Publications.

diSessa, A. (2004) Metarepresentation: Native competence and targets for instruction. *Cognition and Instruction 22* (3), 293-331.

Emig, J. (1977). Writing as a mode of learning. *College composition and communication*, *28*(2), 122-128.

Friel, S. N., Curcio, F. R., & Bright, G. W. (2001). Making sense of graphs: Critical factors influencing comprehension and instructional implications.*Journal for Research in mathematics Education*, 124-158.

Galbraith, D. (1999). Writing as a knowledge-constituting process. *Knowing what to write: Conceptual processes in text production*, *4*, 139-164.

Goldman, S. R., & Bisanz, G. L. (2002). Toward a functional analysis of scientific genres: Implications for understanding and learning processes. In J. Otero, J. A. León, & A. C. Graesser (Eds.), The psychology of science text comprehension (pp. 19-50). Mahwah, NJ: Lawrence Erlbaum Associates.

Halliday, M. A. K. (1998). Things and relations. *Reading science: Critical and functional perspectives on discourses of science*, 185-235.

Halliday, M. A. K., & Martin, J. R. (2003). *Writing science: Literacy and discursive power*. Taylor & Franscis.

Halford, G. S. (1993). *Children's understanding: the development of mental models*. Hillsdale, N.J.: Erlbaum.

Hand, B., & Choi, A. (2010). Examining the impact of student use of multiple modal representations in constructing arguments in organic chemistry laboratory classes. *Research in Science Education*, *40*(1), 29-44.

Hand, B., Gunel, M., & Ulu, C. (2009). Sequencing embedded multimodal representations in a writing to learn approach to the teaching of electricity.*Journal of Research in Science Teaching*, *46*(3), 225-247.

Hand, B., Wallace, C. W., & Yang, E. M. (2004). Using a Science Writing Heuristic to enhance learning outcomes from laboratory activities in seventh-grade science: quantitative and qualitative aspects. *International Journal of Science Education*, *26*(2), 131-149.

Horwood, R. H. (1988). Explanation and description in science teaching.*Science education*, *72*(1), 41-49.

Jang, J. Y. (2011). *The Effect Of Using A Structured Reading Framework On Middle School Students' conceptual Understanding Within The Science Writing Heuristic Approach* (Doctoral dissertation, The University of Iowa).

Jewitt, C. (2003). Re-thinking assessment: Multimodality, literacy and computer-mediated learning. *Assessment in education: Principles, policy & practice*, *10*(1), 83-102.

Kaput, J. J. (1989). Supporting Concrete Visual Thinking in Multiplicative Reasoning: Difficulties and Opportunities. *Focus on Learning Problems in Mathematics*, *11*, 35-47.

Keys, C. W. (1999). Revitalizing instruction in scientific genres: Connecting knowledge production with writing to learn in science. *Science Education,83*(2), 115-130.

Kress, G. (2009). *Multimodality: A social semiotic approach to contemporary communication*. Routledge.

Kress G., Jewitt, C., Ogborn, J., & Tsatsarelis, C. (2001). Multimodal Teaching and Learning: the rhetorics of the science classroom. *Londres, BookEns Ltd*, *Royston Hests*, 188.

Kress, G. R., & Van Leeuwen, T. (1996). *Reading images: The grammar of visual design*. New York, NY: Psychology.

Lemke, J. L. (1998). Resources for attitudinal meaning: Evaluative orientations in text semantics. *Functions of Language, 5(1),* 33–56.

Lemke, J. L. (1998). Metamedia literacy: Transforming meanings and media. *Handbook of literacy and technology: Transformations in a post-typographic world*, 283-301.

Lemke, J. (2005). Multiplying meaning. *Reading science: Critical and functional perspectives on discourses of science,* 87-114.

Martins, D. (2002). *Elementary science methods: A constructivist approach*. Cengage Learning. . In J. Otero, J.León, & A. C. Graesser (Eds.), The psychology of science text comprehension (pp. 51-72). Mahwah, NJ: Lawrence Erlbaum Associates.

Martin, A. M., & Hand, B. (2009). Factors affecting the implementation of argument in the elementary science classroom. A longitudinal case study.*Research in Science Education*, *39*(1), 17-38.

Mayer, R. E., & Gallini, J. K. (1990). When is an illustration worth ten thousand words?. *Journal of educational psychology*, *82*(4), 715.

Mayer, R. E., & Moreno, R. (1998). A cognitive theory of multimedia learning: Implications for design principles. *Journal of Educational Psychology*, *91*(2), 358-368.

Mayer, R. E., & Moreno, R. (2003). Nine ways to reduce cognitive load in multimedia learning. *Educational psychologist, 38*(1), 43-52.

McDermott, M. A., & Hand, B. (2010). A secondary reanalysis of student perceptions of non-traditional writing tasks over a ten year period. *Journal of Research in Science Teaching*, *47*(5), 518-539.

McDermott, M. A., & Hand, B. (2013). The impact of embedding multiple modes of representation within writing tasks on high school students' chemistry understanding. *Instructional Science*, *41*(1), 217-246.

Miles, M. B., & Huberman, A. M. (1994). *Early steps in analysis*. In M. B. Miles & A. M. Huberman (Eds.), Qualitative data analysis: An expanded sourcebook (2nd ed). Thousand Oaks, CA: SAGE.

Moreno, R., & Mayer, R. (2007). Interactive multimodal learning environments. *Educational Psychology Review*, *19*(3), 309-326.

Narayanan, N. H., & Hegarty, M. (2002). Multimedia design for communication of dynamic information. *International journal of human-computer studies*, *57*(4), 279-315.

Novak, J. D. (2010). *Learning, creating, and using knowledge: Concept maps as facilitative tools in schools and corporations*. New York, NY: Routledge.

Ohlsson, S. (2002). Generating and understanding qualitative explanations. In J. Otero, J. A. León, & A. C. Graesser (Eds.), The psychology of science text comprehension (pp. 91-128). Mahwah, NJ: Lawrence Erlbaum Associates.

Otero, J., Lecentsn, J., & Graesser, A. C. (Eds.). (2002). *The psychology of science text comprehension*. Routledge.

Paivio, A. (1986). *Mental representations: A dual coding approach*. Oxford, UK: Oxford University Press.

Paivio, A. (1990). *Mental representations*. Oxford University Press.

Prain, V. (2006). Learning from writing in secondary science: Some theoretical and practical implications. *International Journal of Science Education*, *28*(2-3), 179-201.

Perkins, D. N., & Salomon, G. (1992). Transfer of learning. *International encyclopedia of education*, *2*, 6452-6457.

Raudenbush, S. W. & Bryk, A. S. (2002). Hierarchical linear models: Applications and data analysis methods (2nd ed.). Thousand Oaks, CA: Sage Publications Inc.

Reiser, B. J. (2013, September). What professional development strategies are needed for successful implementation of the Next Generation Science Standards. In *Washington, DC: Paper presented at the Invitational Research Symposium on Science Assessment. K-12 Center at ETS*.

Scaife, M. &Rogers, Y. (1996). External cognition: how do graphical representations work?*International Journal of Human-Computer Studies*, 45, 185-213.

Schnotz, W. (2002). Commentary: Towards an integrated view of learning from text and visual displays. *Educational psychology review*, *14*(1), 101-120.

Schnotz, W., Bannert, M., & Seufert, T. (2002). 16. Toward and integrative view of text and picture comprehension: visualization effects on the construction of mental models. In J. Otero, J. A. León, & A. C. Graesser (Eds.), The psychology of science text comprehension (pp. 385-416). Mahwah, NJ: Lawrence Erlbaum Associates.

Sherin, B. L. (2001). How students understand physics equations. *Cognition and instruction*, *19*(4), 479-541.

Slough, S. W., McTigue, E. M., Kim, S., & Jennings, S. K. (2010). Science textbooks' use of graphical representation: A descriptive analysis of four sixth grade science texts. *Reading Psychology*, *31*(3), 301-325.

The Next Generation Science Standards. *Retrieved September, 14, 2015 from,* http://www.nextgenscience.org/

Wade, S. E. (1992). How interest affects learning from text. *The role of interest in learning and development*, 255-277.

Warner, J., & Wallace, J. (1994). Creative writing and students' science learning in a science and technology context. *Australian Science Teachers Journal*, *40*(4), 71.

Wittrock, M. C., & Alesandrini, K. (1990). Generation of summaries and analogies and analytic and holistic abilities. *American Educational Research Journal*, *27*(3), 489-502.

Woltman, H., Feldstain, A., MacKay, J. C., & Rocchi, M. (2012). An introduction to hierarchical linear modeling. Tutorials in Quantitative Methods for Psychology, *8*(1), 52-69.

van Den Broek, P., Virtue, S., Everson, M. G., Tzeng, Y., & Sung, Y. C. (2002). Comprehension and memory of science texts: Inferential processes and the construction of a mental representation. *The psychology of science text comprehension*, 131-154.

van Leeuwen, T. (2005). *Introducing social semiotics*. Psychology Press.

van der Meij, J., & de Jong, T. (2006). Supporting students' learning with multiple representations in a dynamic simulation-based learning environment. *Learning and Instruction*, *16*(3), 199-212.

Yerushalmy, M. (1991). Student perceptions of aspects of algebraic function using multiple representation software. *Journal of Computer Assisted Learning*, *7*, 42-57.

Yore, L. D., & Hand, B. (2010). Epilogue: Plotting a research agenda for multiple representations, multiple modality, and multimodal representational competency. *Research in Science Education*, *40*(1), 93-101.

Yore, L., Bisanz, G. L., & Hand, B. M. (2003). Examining the literacy component of science literacy: 25 years of language arts and science research. *International Journal of Science Education*, *25*(6), 689-725.

Zacks, J., & Tversky, B. (1999). Bars and lines: A study of graphic communication. *Memory & Cognition*, *27*(6), 1073-1079.