Available online at https://tjmr.org
Transatlantic Journal of Multidisciplinary Research
p-ISSN: 2672-5371
e-ISSN: 2735-9808

DOI: 10.5281/zenodo.4841660 Volume 3 | Issue 1 | 2021

IMPROVING THE TEACHING OF ORGANIC CHEMISTRY AT THE SENIOR HIGH SCHOOL LEVEL USING MULTIMODAL INSTRUCTIONS: A META-ANALYSIS

Joshua Kwabena Owiredu
Abetifi Presbyterian College Of Education,
Abetifi-Kwahu, Eastern Region, Ghana
** Corresponding author: joshua.owiredu@stu.ucc.edu.gh

Abstract
The students we teach learn differently and the way they learn is influenced by how teachers teach. West Africa Examination Council (WAEC) has documented that the performance of students in West Africa Examination keeps declining in chemistry paper, especially in the aspect of Organic Chemistry. There are severally studies that provide designs of intervention for curbing this problem. Again, in this digital environment, there are several ways of presenting information. This study sought to synthesis and analysis studies conducted on the impact of multimodal instructional approaches on senior high students' performance in Organic Chemistry. For this reason, a total of 15 studies were analysed including 5 theses and 10 published articles from 2009-2019. A purposive sampling method was used in the selection of theses and articles. This enabled the researcher to put in measures to include and exclude studies that do not meet the criteria. The criteria used for the review of studies were summed up to 10. They were key words, sample size, the year of publication, research scope, methodology, reliability and the validity of instrument, educational level and implications. Other criteria include method of data collection and data analysis techniques. Data was interpreted based on effect size. The results were presented using tables. The result indicated a moderate effectiveness of this multimodal instructional approach using Cohen's ranges. The moderators' analysis showed a statistically significant among the effect sizes of the studies ($d= 0.649$, $p=0.001$) on the impact of multimodal instructional on teaching Organic Chemistry.

Keywords: Multimodal Instruction, Effect Size, Meta-Analysis, Organic Chemistry

Introduction

Several studies in education focused on how to improve students' performance or learning output using varied modes of lesson deliveries in order to enhance effective gains in instructions (Bawa, 2014; Sakyi-Hagan, 2013; Owiredu, 2013; Al-Balush & Al-Hajri, 2014; Ngozi-Oleh, Duru, Uchegbu, & Amanze, 2018). This may be due to the fact that single modes of lesson delivery have not yielded intended results in science instructions. For this reason, multimodal instruction (MI) was used for this study. MI is documented to be effective in science teaching (Bennett, 2011; Chen & Fu, 2003; Jewitt, Kress, Ogborn, & Tsatsarelis, 2001; Piccinini, 2003).

p-ISSN: 2672-5371
e-ISSN: 2735-9808

Despite the benefits facilitators and students derive from multimodal instructions, several researchers have come out with different results emerging from the same study in the same area addressing the same question (Riding & Rayner, 2012). Felder and Brent (2005) averred that factors such as period, technology level used by researchers and the academic environment pertaining around the settings, could create such results. They further stressed that it could be caused by increased knowledge in recent times.

Recently, several studies have been done in the area of multimodal instructions for learners at different stages of the academic ladder. However, for this study, the attention was at the senior high level. Multimodal Instructional (MI) approaches of teaching refer to the combination of several modes of instruction during lesson delivery within the same concept, context or topic and presenting them to learners as a whole (Vaughan & Bruce, 2008). The purpose MI is to enhance learners' understanding of concepts. Students appear to respond to information differently (Fleming, 1997). Student learning may be classified according to the sensory modalities by which one prefers to take in information. According to Fleming (1997), these sensory modalities are classified into four modes which are visual, aural, read or write mode and finally Kinesthetic. These four modes of instruction have been abbreviated as VARK (Fleming, 1997). The video includes animations and simulations while the audio includes audio recordings, talking or discussions. The read or write mode deals with searching for information through reading and then documenting the information through writing. The final mode which is kinesthetic, deals with hand-on activities or practical work.

Theoretical Framework

All these modes of instructions align themselves with constructivism, situated cognition and cognitive flexible theory.

Constructivism

This is a theory that posits that learners must be guided to discover knowledge by themselves. This theory explains that learners create their own knowledge based on interactions with their environment and people (Woolfolk, 2016). Palincsar explains that constructivism holds the idea that individual learners acquire new cognitive structures when they are provided with an opportunity that would require of them interpretation of a particular situation (Palincsar, 1998).

Situated Cognition

The second theoretical framework of this study is situated cognition. Gee explains that knowing cannot be separated from doing (Gee, 2005). He further argued that all knowledge can be traced to activities that are culturally, socially and physically bound in contexts. Cognition and Technology Group at Vanderbilt (CTGV) hypothesized that teaching must be anchored by children's personal experience. This kind of experiences results in acquiring 'inert knowledge' (CTGV, 1990, p. 2). This is a kind of knowledge that is based on the situation.

Cognitive Flexibility

The final theoretical framework is known as learning as representation (Cowan & Albers, 2006). The theory of representation can also be classified as cognitive flexibility theory. This theory explains that concepts become very easy for assimilation and accommodation by learners when these concepts are represented in different forms (Keegan, 1990). Keegan averred that the perspectives of representation must be compatible with one another in that they should link up with each other in terms of science theories and subject that need to be taught honestly.

The reason for this study is to synthesis and analysis the effect sizes of several studies addressing the impact of multimodal instruction on students' performance in Organic Chemistry. This was also the main question that guided the study.

Empirical Framework of the Study

A search in science literature shows that several studies have been conducted on multimodal learning. In a study carried out with a sample of students who were undergraduate, offering various programmes at the University of Southern Queensland (USQ) by Sankey, Birch, and Gardiner (2010) it was found that only four out of the sixty participants preferred to be instructed using aural mode. The majority of the students appreciated multimodal instructional approaches. The authors connected students' results received to the performance before and after the intervention. The quantitative results clearly indicated that learners perceived that learning concepts with additional representations of content, assisted their understanding, comprehension and their ability to remember content studied. The additional representations also made content more interesting and enjoyable to them. The study revealed that students articulated a strong preference for a combination of several modes of instruction of learning resources and options than a single mode of instruction. It is an indication of their interest. Interest also produces results. The authors further explained that the importance of improving learners' progression and retention should be done by engendering the joy of learning. Learning that is made enjoyable results in permanent change of behaviour of learners. Instructors should be motivated to continue to search for other multimodal instructions.

To understand further, the interaction learners engaged in with their learning preferences should be capitalized upon in our classrooms. This phenomenon should be worked at. Mayer (2005) stressed the benefits of using as many modes as possible in the teaching process. Mayer conducted an experiment that exemplifies this study. The study involved three groups of learners. The first group received information delivered through the

p-ISSN: 2672-5371
e-ISSN: 2735-9808

sense of hearing. The second group received the same information through the sense of sight, and the last group, the same information that was given using a combination of sense of hearing and sight. The results confirmed that multimodal group did better than the single group. According to Mayer (2005), the students who were taught with different modes had better understanding and more accurate retention and had better perspective, which lasted longer. He further indicated that the advantages were not just confined to a combination of the two senses. There are a number of studies of that are consistent with Mayer's study, which stated that when students manipulate learning materials combined with visual representation, it makes these students become 30% better than those who were instructed in a single mode (Mayer, 2005; Owiredu, 2013; Chen & Fu, 2003). It was found that there was a difference in performance between the experimental and control groups. The students in the experimental group performed better in post-test than the control group in Mayer's experiment.

There is a paradigm shift in instructions whose foundation explains why multimodal instructions are effective and accurate in capturing the students 'attention. According to Mayer (2005), in East African homes, formal educators saw the need to present the world to their young learners using a multisensory view. The approach multimodal instruction is what is being champion by researchers that it prevails in the classroom. The more the learning environment is augmented, the more multiple modes the better the environment becomes relevant. However, the revise is also true; learning is less attractive in a single mode paradigm (Mayer, 2005).

From this literature reviewed, research has been done into how to instruct effectively using multimodal approaches. However, none of this research has investigated the effectiveness of the Multimodal Instructional approaches in teaching Organic Chemistry.

METHODOLOGY

Research Design

The study is meta-analysis conducted on a quantitative study. This design combines several primary studies of multimodal instructional approaches and then analysis the analysis of these studies. Cohen, Manion and Morrison termed it as analysis of analysis (Cohen, Manion, & Morrison, 2007).

Data collection

The study searched for data through journals, unpublished thesis and dissertations. Data from secondary sources were collected from 2009-2019. The reason for selecting data from 2009 was that there were a few studies that had been done in the area of multimodal instruction prior to that year. Data was collected also collected up to 2019 because in this year, 2020, the world is hit with a very deadly virus called Covid-19 Virus that has made primary data difficult to be collected to be used for meta-analysis.

Available online at https://tjmr.org
Transatlantic Journal of Multidisciplinary Research
p-ISSN: 2672-5371
e-ISSN: 2735-9808

In order to collect data for this study for meta-analysis, key words such as multimodal instruction, animations, Organic Chemistry and science education were used to search the University of Cape Coast (UCC) Library database, Google Scholar, Google, ERIC database, unpublished thesis and dissertation. Other areas that were searched included journal papers from UCC, UEW (University of Education, Winneba) and in international journals. In all 30 articles were found. The full texts of 5 articles were not accessible to certain institutions outside their boundaries. Among the 25 articles that were found, 10 of them were from unpublished theses and dissertations. 10 of them were not having data that can be analysed. The study took early three months in data collections. In all these studies, 15 of them did not meet all the criteria.

Detailed Analysis of Inclusion criteria

a. The materials that were used for the meta-analysis should a published article of master's thesis or dissertation.
b. It must be in the area of Organic Chemistry.
c. It must be at the senior high level
d. The design of the study must be true or quasi experimental
e. The study must consider one dependent variable, which is students' outcome or performance.
f. The mean, standard deviations must be stated in the finding of this study.
g. The research instrument must be validated by seasoned lecturers or expert in the field of study.
h. The reliability coefficient of these assessment tools must fall with the accepted range of greater than 0.7.
i. For the multimodal instruction was selected as the mode and its impact on performance

Data coding

Coding of data was so significant in meta-analysis that the researcher decided to use three columns. The first part contains the study name. The second part consists of experimental work and the final Column comprises the effect size of each study. The researcher entered the coding by himself.

Data analysis

Studies that met the set criteria were coded into the Comprehensive Meta-Analysis (CMA) software programme (Hunter & Schmidt, 2004). The basic measurement used for meta-analysis conducted in quantitative studies is effect size. For this reason, the effect sizes of 15 studies were analysed. Cohen (1988) classified the effect size in ranges. The ranges were (0- 0.2), (0.21-0.5), (0.51-1.0) and greater than 1. Cohen gave the meaning to these ranges as weak, small, moderate and strong respectively. The random effect model was used for data analysis. This was preferred to the fixed effect model for analysis because the effect sizes of the studies identified were varied.

Results of the Study

To be able to present the result of this study using meta- analysis, the effect size of all the studies were computed using Comprehensive Meta-Analysis (CMA) software. The summarized findings were presented in Table 1.

Table 1: The summarized effect sizes of the fixed and random effect sizes of all the studies.

Model	Standard mean difference	SD	Homogeneity level (Q)	Z	Standard error	I^2	Lowest mean difference	Highest mean difference
FEM	0.739	0.1386	77.089	14.066	0.053	81.839	0.636	0.842
REM	0.649			4.741	0.137		0.380	0.917

The average effect size of the fixed effect model (FEM) size recorded a value of 0.738. This value is considered to be a moderate according to Cohen (1988). Again, the average effect size from the random effect model (REM) was 0.649. This value also falls within range of moderate effect size. The CMA tool helped to calculate the lower and the upper limit of the standard mean difference of various studies and the values were 0.636 and 0.842 respectively for the FEM and 0.380 and 0.917 respectively for 0.917 for the REM. The graph below shows how the effect sizes were distributed.

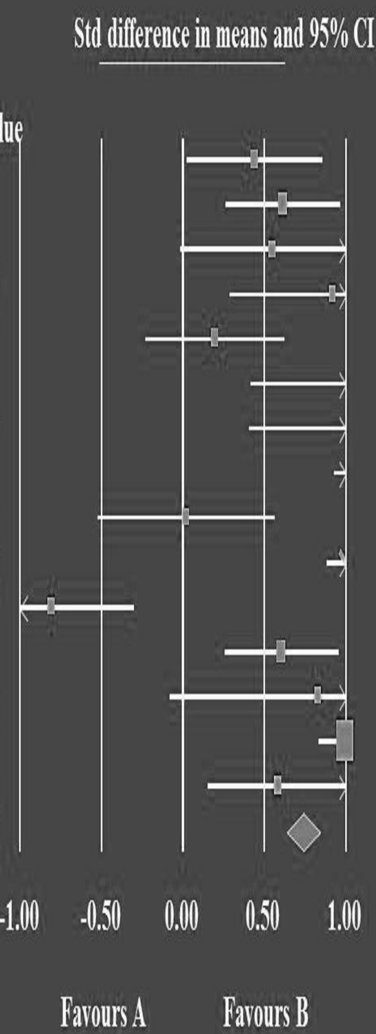
p-ISSN: 2672-5371
e-ISSN: 2735-9808

Table 2: A meta-analysis showing the standard mean differences

Meta Analysis

Statistics for each study

Study name	Std Difference in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Arokoyu &Obunwo, 2014	0.440	0.213	0.046	0.022	0.858	2.064	0.039
Ngozi-Olechi, 2018	0.614	0.181	0.033	0.259	0.969	3.392	0.001
Al-Balushi& Al- Hajri,2014	0.550	0.290	0.084	-0.019	1.119	1.896	0.058
Hansen, 2014	0.919	0.325	0.106	0.282	1.556	2.830	0.005
Anene, 2013	0.197	0.219	0.048	-0.232	0.625	0.899	0.369
Schilline, 2009	1.116	0.358	0.128	0.414	1.818	3.114	0.002
Coelho, 2012	1.017	0.313	0.098	0.403	1.631	3.245	0.001
Obumnenye, 2013	1.319	0.202	0.041	0.924	1.715	6.537	0.000
Serin, 2011	0.020	0.277	0.077	-0.524	0.564	0.072	0.942
Taliba,2012	1.601	0.369	0.136	0.878	2.323	4.340	0.000
Ferreira, 2019	-0.807	0.260	0.068	-1.316	-0.297	-3.103	0.002
Demirbag, 2014	0.605	0.180	0.032	0.252	0.959	3.359	0.001
Stieff,2011	0.830	0.466	0.217	-0.084	1.743	1.780	0.075
Keles, 2016	0.998	0.086	0.007	0.829	1.167	11.575	0.000
Bos,2009	0.586	0.223	0.050	0.149	1.023	2.628	0.009
	0.739	0.053	0.003	0.636	0.842	14.066	0.000

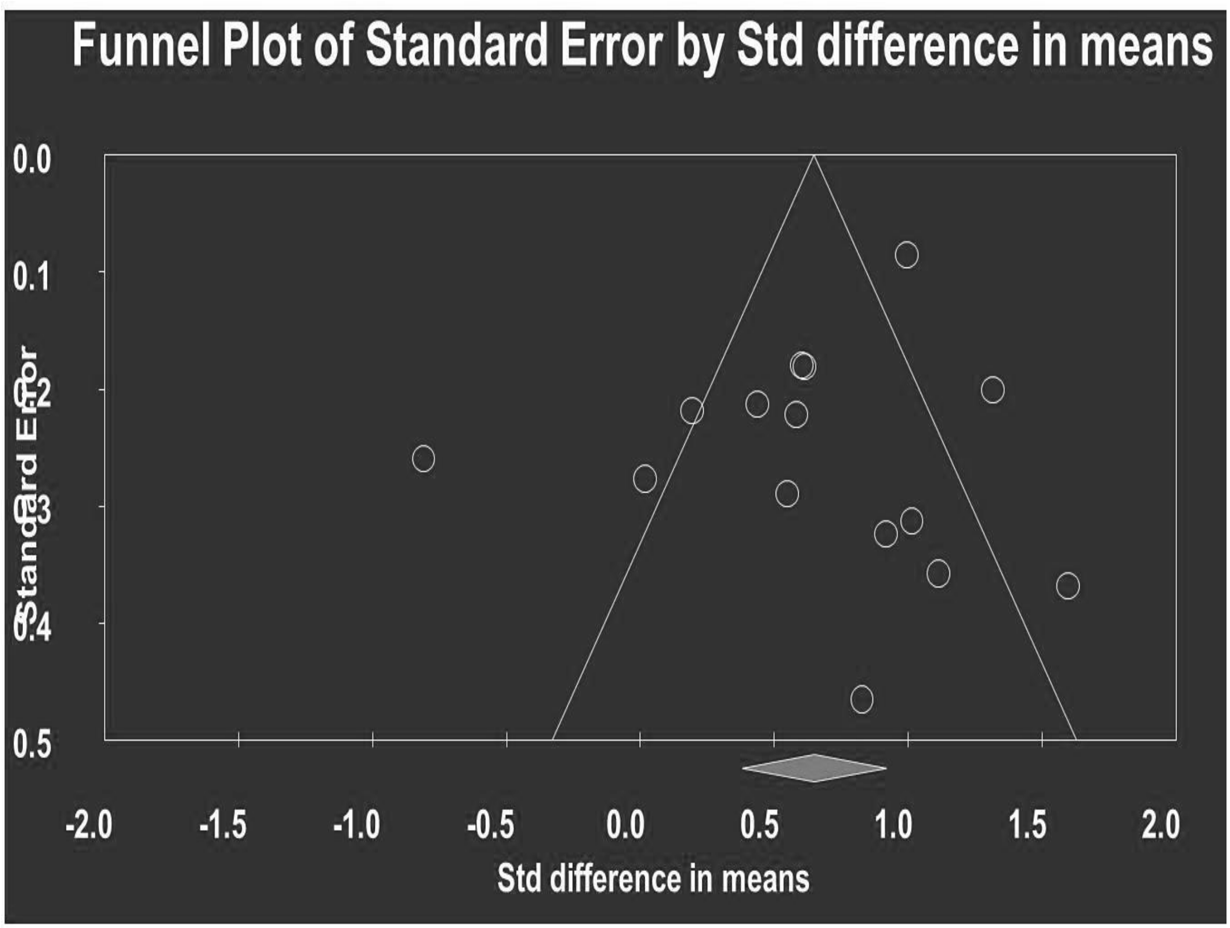


p-ISSN: 2672-5371
e-ISSN: 2735-9808

Figure 1: The forest plot of the effect sizes of multimodal instruction on teaching and learning of Organic Chemistry

The graph of funnel plot shows how the standard mean differences were distributed in study.

Figure1: Funnel plot showing the publication bias.



The Funnel plot was included in the reporting because the researcher wanted to determine the publication biases. Again, the analysis is significant because it shows how various studies deviate from the normal. Studies analysed is seen as symmetrical. This means that most of the effect sizes seemed to be concentrated at a single space as shown in Figure 1. From the funnel plot, it could be concluded that there was no publication bias found among these studies. If there was a bias the funnel plot would have shown asymmetrical range.

Available online at https://tjmr.org
Transatlantic Journal of Multidisciplinary Research
p-ISSN: 2672-5371
e-ISSN: 2735-9808

Discussion

In this study meta-analysis was used to find the impact of multimodal instruction in the teaching of Organic Chemistry. The basic measurement used for meta-analysis conducted in quantitative studies is effect size. For this reason, the effect sizes of 15 studies were analysed. The effect sizes were heterogeneous as shown in Figure 1. For this reason, the random effect model was used for this particular study and analysis. The researcher analysed 15 studies addressing the same research questions. The studies were experimentally designed where the experimental groups were instructed using multimodal instruction (MI) and the control group instructed using a single mode of instruction. The impact of this MI was ascertained using the effect sizes of summarised studies.

In a similar vein, Ainsworth (2006) revealed that developing understanding of inert knowledge through Multimodal Instructional Approaches (MIAs) goes beyond the traditional mode of instruction. Fadel (2008) also stated that when students engaged in learning that incorporates multimodal designs, on the average; outperform those who learn using aural approach that is appealing to only the sense of hearing.

Again, lessons of this nature where students' sources of stimulus were varied breaks monotony in the lesson and makes class livelier. According to Jewitt, Kress, Ogborn, and Tsatsarelis (2001), multimodal approaches satisfies for a range of students with different learning styles and provided students with an option on how they can access key concept, and therefore may be considered a more inclusive response or stimulates cognition to the needs of learners. These results reaffirm the findings of a study of Russell and McGuigan (2001) that suggest that students need to generate different modes of representations of a concept and recode the representations in various modes. Multimodal Instructional Approaches might have helped them to re-define and make more explicit their understanding of a particular concept. This is because Russell and McGuigan (2001) explained that an engagement of students in lessons effectively enhances students' performance and improves attitudes more than conventional classroom instruction. These results are also congruent with Picciano (2009) who identified the benefits of multimodal designs by saying that it allows students to experience learning in ways that they are more comfortable with and challenges them to experience and learn in other ways as well. According to Russell and McGuigan (2001) and Picciano (2009) Multimodal Instructional approaches allows students to concentrate on the physical meaning of abstract concepts, hence, obtaining an in-depth understanding of the theory. All these attributes of Multimodal Instructional Approaches may have contributed to broader perspective of concepts leading to a high performance. These findings have significant implications on the approach to teaching since they suggest that incorporating varied instruction into Integrated Science courses may be a valuable tool for improving the performance of students.

Finally, outcomes of this study support current research on maximizing the effectiveness of instructional designed environments by focusing on the need to take into account the individual diversity of learner background knowledge, expectations, preferences, and interpretive skills (Dolin, 2001; Russell & McGuigan, 2001). The procedures that students use in constructing their own multimodal representations, and the developmental pattern of these procedures (DiSessa, 2004), provided insight into design features that could be explored in effective teaching representations.

Conclusion

The significant contribution made in this study was to synthesis 15 studies addressing the same problem and analysing the study as an entity. The study also addresses the impact of MI on Organic Chemistry curriculum. The study revealed that MI has a moderate effect on teaching Organic Chemistry. Further, the average effect size explains the heterogeneity of the effect sizes of the various studies reviewed. What this heterogeneity means is that data of this nature should be interpreted with caution.

Recommendations

It is recommended that a study of this nature should be opened the inclusion criteria so wide to accommodate several subject areas in science such as Physics and Biology. This will enable the study to make informed decisions by practitioners in terms of the effective approached to teaching.

Implications for classroom teaching

Primarily, teachers' instructional approach has direct effects on the learners' understanding and it correlates with students' achievement (Tatto, 2001). The findings of this study suggest that Multimodal Instructions (MI) had a direct impact on teaching and students' performance. This approach when adopted is likely to improve the students' knowledge in concepts in science courses. These modes of instructional catered for students' learning styles, arouse, and sustain their interest in the classroom. The method of instruction used in the study also motivated and challenged the students to think critically about concepts in the teaching process. The study therefore suggests that students should be taught using MIA in lesson delivery of concepts.
In conclusion, Organic Chemistry as a subject that is best taught through visualisation. Visualisation is a multimodal approach.

Acknowledgements

The study would not have been possible without University of Cape Coast (UCC) Library, granting the researcher access to access several databases in its online library service during this period of Covid-19 pandemic. Also grateful to Prof. Douglas D Agyei of the Department of Mathematics and Statistics, University of Cape Coast, Ghana, for taking me through academic writing.

p-ISSN: 2672-5371
e-ISSN: 2735-9808

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