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Trends in Chemistry Education Research on Student Transformation in the Philippines: A Meta-analytic Review

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Creating innovative methodologies and interventions in chemistry education is essential to promote positive student transformation outcomes. Although chemistry educators are key in utilizing its potential in the classroom, very little is known about its efficacy in teaching and learning. This study aims to determine the current research trends in chemistry education. It examines the effect of chemistry education research findings included in the meta-analysis on using varied teaching methodologies on student transformation outcomes. A systematic review and meta-analysis of a pool of studies related to chemistry instruction in the Philippines and through on site or online browsing were conducted. Results show that the country's pedagogical trend in chemistry education centers mainly on cooperative and inquiry-based learning, which aligns with and supports the framework and goals of 21st-century teaching. Results suggested that chemistry teachers can consider employing one of the various pedagogies and methods that effectively improve students' cognitive and affective outcomes. Heterogeneity test warrants that significant differences exist between the grouped features. The effect size data are directly influenced by the significance of the test derived from each study. Studies with significant results tend to have a larger effect size and significantly affect the study variables.

Keywords: trends, chemistry education, student transformation outcomes, meta-analysis, teaching methodologies, effect size

INTRODUCTION

Chemistry has become one of the most crucial science disciplines in the secondary school curriculum and has gained worldwide recognition (Hofstein & Naaman, 2011). Chemistry is considered one of the cornerstones in various sciences, technology, engineering, and industry fields. Teaching and learning chemistry have laid down the benefits that can be intrinsic and extrinsic. With the significant value and increasing importance of such discipline, the performance of Filipino students at secondary schools remains a disappointment. Students' performance in chemistry at international and national examinations remained considerably poor despite its relevance. The government implements the K-12 program to address the primary concern to improve the quality of education attributed to the low achievement performance of students and

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attain its goal of being more globally competent (Department of Education 2014). In this manner, we need to establish an excellent science education, particularly in chemistry, to participate in a world that is increasingly becoming more science and technology oriented.

Several reforms in chemistry education were addressed that brought rapid change from the standard of education. Technology integration in classroom instruction, scientific innovation, increased globalization, and the evolution of the students being dealt with have provided a new perspective on the chemistry teaching-learning process. Applying principles and processes that will lead to effective educational experiences is important in this changing educational environment. There are several factors identified that have much impact on students' poor academic performance. These are the quality of teachers, the teaching-learning process, the school curriculum, instructional materials, and administrative support (SEI-DOST & UPNISMED, 2011). The whole issue of teacher quality, including teacher strategies and practices, and improving teacher effectiveness in classrooms, is at the heart of efforts to improve the quality and performance of our secondary schools.

Changes in societal structures, technological advances, and the knowledge explosion demand a more literate and critical-thinking population of all ages (Prickel, 2000). It presents a greater challenge to educators and would require them to be sufficiently updated with the current knowledge and innovative driven in adapting new and suitable teaching approaches and practices to meet students' needs. To provide the status of chemistry education in the Philippines, it is important to examine the methods/strategies used and how they effectively fit into the student's needs and characteristics. Several studies investigated the impact of various teaching strategies towards academic performance (Nasr & Soltani, 2011; Sahin, 2012; Waxman, et al, 2003; Thoron & Meyers, 2011; Wanner, 2015), attitude (Roster, 2006; Rybczynsk & Schussler, 2012; Nars & Soltani, 2011; Johnsen, 2009; Capar & Tarim, 2015) and motivation (Chow & Yong, 2013; Caliskan, 2004; Dindar, 2016).

Decisions about an intervention's efficacy cannot depend only on the results of a single study because the findings vary from one study to another. Meta-analysis is a mechanism needed to synthesize data across studies. It is a systematic method that integrates data and summarizes the results of research studies to give a more precise estimate of the effect of a treatment approach. Meta-analysis can also show changes in the treatment effect over time (Israel & Ritcher, 2017). A Meta-analysis was conducted to investigate the effects of teaching methodologies on students' academic performance (Sugano & Nabua, 2020), attitude, and motivation (Sugano & Mamolo, 2021) in chemistry. As emphasized by Sugano and Nabua (2020), the conducted meta-analytic review on chemistry educational research was a pioneer across science education research in the Philippines. It reported various teaching interventions to promote academic gain, attitude, and motivation. This research provides reliable findings to inform better the current state of chemistry education research in the country.

The main goal of this study was to determine the current research trends in chemistry education studies on teaching methodologies. This study gives an informative overview of what has been done and needs to be done in recent time times in the research area of chemistry education. Also, to examine the effect of chemistry education studies included in the meta-analysis upon using varied teaching methodologies towards student transformation.

Aims of the Study:

1. What is the frequency distribution of included studies in the meta-analysis based on the following study features; Publication Form; Source of Study; Locale of Study; Study Rating; Duration of Exposure; Significance of Test; and Student Outcomes?

2. What teaching methodologies were studied in chemistry education research on student transformation from 2005 - 2015?

3. Does the effect of teaching methods on student transformation show a significant difference in every study feature?

METHOD

Search, Retrieval and Selection of Studies

A systematic review and meta-analysis of a pool of studies related to chemistry instruction throughout the Philippines and through on site or online browsing were conducted. A total of over 149 empirical studies from theses, dissertations, and journal articles in the field of chemistry education were identified. This method examined and combined all pertinent studies, both published and unpublished, so that a weighted mean effect size would be derived. This was executed by perusing the titles and abstracts of the research. In cases where the essential study characteristics were not evident from the titles and abstracts of the research, the full texts were consulted. After an extensive literature review, a total of 67 studies, which fit the inclusion criteria and the required source of data for the meta-analysis were identified. Some of the studies that did not meet the conditions set in the inclusion criteria were eliminated. Certain types of studies were excluded from the synthesis because of several reasons. Many studies were eliminated because they did not investigate the effects of different teaching methodologies on the identified student transformation outcomes. Some collected studies were not conducted in the inclusive year 2005 – 2016. Other reasons for the exclusion of studies include insufficient quantitative data for effect size computation, failure to focus on secondary students, failure to focus on chemistry discipline, and studies were correlational.

Selection Criteria

Out of this number, 67 studies qualified in the meta-analysis based on the framework of the established inclusion criteria. Surface level screening was performed in each of the gathered chemistry education research to efficiently exclude a substantial part of studies that did not meet the requirements set in the inclusion criteria. Rigorous criteria were used that limit the inclusion of studies in this synthesis. The following criteria include: 1. Studies should focus on student attitude, self-efficacy, learning style, motivation, multicultural and academic performance as resulting from the use of chemistry education innovative methodologies and interventions. 2. The study should be completed within 2005-2016. 3. The study should be conducted in the Philippines. 4. The study should be involved only in the chemistry curriculum academic domain of secondary schools. 5. The study should utilize the experimental or quasi-experimental research design. 6. The study reported effect size (ES) or contained statistical details necessary to calculate effect size (ES) such as mean, standard deviations, sample size, t, f and p values, ANOVA tables, degree of freedom (df), etc.

Calculating Effect Sizes

This study used the hyper-analysis mapping of research results wherein studies of impact were quantitatively synthesized using the meta-analysis technique to produce a big picture of influence among variables. The gathered findings of investigations were converted into the standard measurement unit called effect size. To make comparisons among studies, the outcomes of each study have been transformed into a general effect measure (Jacobse & Harskamp, 2012). The effect size is based on standardized mean difference; Cohen's d was utilized in this study. It is a pure number in standard deviation units, free of original measurement units used to index the size of the difference from the null condition. The study results were converted to an effect size estimate to allow different measures to be compared.

The effect size is the difference between the means of the two groups (treatment and control) divided by the within-groups pooled standard deviation. It is considered a standardized estimate of where the treatment group stands in comparison with the control group distribution (Waxman, 2003). This is the standard metric used to estimate, compare, describe, and indicate the effectiveness of a teaching methodology. The extensive review of pertinent literature to obtain the data for calculating the effect size produced 67 independent effect sizes from the studies that were subjected to meta-analysis. To meet the meta-analytical assumption of the independence of effect sizes, one effect size indicator per outcome variable presented in the study is represented in the analysis. The researcher used all 67 effects to explore the influence of teaching methods on the different dependent variables as these are also affected by the different study features. Effect size provides information by assessing how much difference there is between groups or how strong the relationship is between variables (Becker, 2000). Moreover, it assesses the magnitude of the findings that occur in research studies (Durlak, 2009).

A test of homogeneity of the weighted mean effect size (SE) was conducted to determine if the results of several experiments sufficiently warranty the combination in an overall result by using Q statistics (Kulinskaya et al, 2011). Cochran's Q refers to the weighted sum of squared differences between individual study effects and the pooled effect across studies (Jacobse & Harskamp, 2012). If Q were found to be statistically insignificant, a fixed-effects model would be adopted for data analysis. However, if Q were statistically significant, a random effects model would be used. A significant value of Q statistics signifies large variation between studies because in such cases the studies showed more variation than would be expected by the standard errors (Hedges & Olkin, 1985). In this meta-analysis, a large Q value ($Q = 831.741$, $p = 0.00$) was computed from all the studies included and revealed to be statistically significant in terms of variability. Hence, the heterogeneity exhibited across studies was resolved by fitting a random-effects model, which provides an estimate of the average true effects reported in different studies. Moreover, a heterogeneity-group heterogeneity statistic (Q Between) was also computed to test for statistical differences in the weighted mean effect sizes for various subsets (e.g., study features) of the effects.

FINDINGS AND DISCUSSION

Descriptive Results of Included Studies

The disaggregation of the features of each chemistry study included in the meta-analysis is presented. This descriptive analysis provides information on the studies' frequencies and characteristics based on the classified features, including publication year and form, source, locale, study rating, duration of exposure, the significance of the test, student outcome, and teaching methods.

Table 1
Frequency distribution of included studies by publication year and form

Study Feature	No. of Studies	Percentage (%)
1. Publication Year		
2005-2008	13	19.40
2009-2012	27	40.30
2013-2016	27	40.30
Total Studies	67	100
2. Publication Form		
Published	15	22.39
Unpublished	52	77.61
Total Studies	67	100

Based on Table 1, Results revealed that out of the 67 qualified studies, 27 (40%) studies were conducted within the inclusive years 2009-2012 and 2013-2016. It can be inferred that there was no increase in research conducted in the Philippines from 2009 to 2016. The findings support that there was an increase in the pursuit of research in chemistry education as compared to the earlier years from 2005 – 2008. Most of the research studies conducted all over the Philippines were up-to-date and believed that they addressed the present educational status describing the instructional scenario of the 21st century. This is a realization in one of the primary research agendas of the Commission of Higher Education – Higher Education Institutions (CHED-HEI), to enhance the research productivity of HEI's in distinctive competence areas. However, this does not limit producing more research in relevant fields and priority disciplines, particularly in education. There is still more to strive to establish a strong research capability in HEI's for international competitiveness (CHED, 2009).

Publishing scientific studies is essential in contributing to a discipline's knowledge and sharing the findings among researchers/scientists (Pho & Tran, 2016). It can be stated, based on Table 1 that the majority (n = 52, (77.61%) of the qualified studies were unpublished, and only 15 (22.39%) of the studies were published in referred scientific journals.

Several reasons may be identified to justify the result of this study. First, very few quantitative studies published in the last 11 years (2005 – 2016) included relevant data to permit a meta-analysis and calculation of effect size. Second, this is most likely due to the lack of confidence of graduate educators and researchers to submit their studies for further evaluation and publication, knowing that submitting scholarly research for publication requires a tedious task before it can be accepted. Finally, the lack of financial resources is also one of the primary obstacles that restrict researchers from publishing their studies.

Furthermore, the research capacity or performance of a university or a country can be evaluated based on the quantity and quality of publications (Pho & Tran, 2016). The low number of published research in the field of chemistry education signifies those Filipino educators and researchers do not give a premium on research and publication. The findings of this study call for encouragement to chemistry educators to become an active part of the scientific community making research accessible for many. To address the issue of the low number of published research, higher education institutions can set a new pace in driving research and publication as an obligatory duty for graduate students and university faculties in addition to teaching, even if the requirement must start at local publication (Pho & Tran, 2016). In this manner, it fulfills the institution's teaching and research missions. Moreover, training programs workshops, and other forms of assistance can also be provided by the government to both university faculty and researchers to properly disseminate knowledge, helping and motivating the students and other faculty to engage more in research and publication. Perhaps more international linkages can be established with higher educational and research institutions as this will open greater funding opportunities and make research more vibrant.

Table 2
Frequency distribution of included studies by source of study and locale of the study

Study Feature	No. of Studies	Percentage (%)
Source of Study		
Thesis	51	76.12
Dissertation	8	11.94
Journal Article	8	11.94
Total Studies	67	100
Locale of the Study		
Luzon	32	47.76
Visayas	17	25.37
Mindanao	18	26.87
Total Studies	67	100

In Table 2, the meta-analytic review based on the source and locale of the study, it was found that the most frequent source of studies was the thesis (n = 51, 76.12%), followed by the same number of studies in the dissertation (n = 8, 11.94%) and journals (n = 8, 11.94%). A more significant number of the qualified studies were conducted in Luzon (n = 32, 47.76%), while an almost equal number of studies were gathered from Visayas (n = 17, 25.37%) and Mindanao (n = 18, 26.87%). It can be observed that the universities in Luzon are dominant as compared to those in Visayas and Mindanao in terms of producing chemistry education research and offering graduate thesis degree programs. Most of the institutions in Luzon that offer chemistry education programs belong to the top-performing universities in the Philippines. Hence, it attracts more graduate students for admission because of quality and prestige. Moreover, these universities provide more significant opportunities, like facilities and specialized programs, for graduate students to be more equipped and exposed to research.

It can be stated from the data presented that establishing more local study centers in the southern Philippines is necessary to help universities and colleges develop their programs to strengthen research capabilities. Graduate education plays a significant role in producing experts needing to revitalize research endeavors in the country and the bulk of research outputs required for development, education, and policy formulation (CHED, 2009). Thus, there is a need to strengthen graduate programs in chemistry education in all promising higher education institutions of the Philippines with the capacity or reputation to undertake research (CHED, 2009).

Table 3
Frequency distribution of included studies by study rating, duration of exposure and significance of test

Study Feature	No. of Studies	Percentage (%)
Study Rating		
Experimental treatment vs control	14	20.90
Quasi-experimental, single group (pre-post)	23	34.33
Quasi-experimental, treat. vs control (pre-post)	23	34.33
Quasi-experimental, two or more groups	7	10.45
Total Studies	67	100
Duration of Exposure		
1-3 weeks	25	37.31
4-7 weeks	20	29.85
8-11 weeks	7	10.45
Not indicated	15	22.39
Total Studies	67	100
Significance of Test		
Significant	50	74.63
Not Significant	17	25.37
Total Studies	67	100

Out of 67 studies included in the meta-analysis, a total of 46 (68.66%) studies used quasi-experimental research utilizing the single group (pretest-posttest) and the two groups (pretest-posttest) design. In contrast, 14 (20.90%) of the qualified studies were experimental. Only 7 (10.45%) eligible studies used quasi-experimental design in more than two groups.

The findings presented in the study are supported by the results of the studies conducted by Waxman et al. (2003) and Schroeder et al. (2007). A more significant number of studies were obtained for quasi-experimental that used either a single pre-posttest design or a two-group pre-posttest design than experimental. The dominant use of quasi-experiments in most studies is possibly due to the difficulty of conducting randomized experimental studies with students and teachers in a school setting (Schroeder et, 2007).

The most common duration of exposure to interventions presented in the studies was between 1 to 3 weeks, followed by 4 to 7 weeks, and about 22.39% of the studies did not clearly emphasize the duration of the intervention. Approximately 74.63% of the studies indicated a significant result, as shown in Table 3. The result of the study shows that most of the studies were conducted short term and very few were long-term.

The leading occurrence of short-term studies in chemistry education research is due to some of the identified limitations in conducting experimental/quasi-experimental studies, including cost, ethics, external validity, the feasibility of implementing an experiment, time, and timing (Schanzenbach, 2012). With these considerations, researchers usually conduct short-term rather than following the ideal duration of educational experiments, which covers 6-10 weeks (Schanzenbach, 2012).

Table 4
Frequency distribution of included studies on student transformation outcomes

Study Feature	N (No. of Studies)	Percentage (%)
Student Transformation Outcomes		
Achievement	51	76.12
Attitude	12	17.91
Learning Styles	1	1.49
Motivation	2	2.99
Self-efficacy	1	1.49
Multicultural	0	0
Total Studies (for each feature)	67	100

In this meta-analysis, the dependent variable presented is student transformation outcomes. The six different parameters of student outcome used in the studies and their corresponding frequency distribution are shown in Table 4. These include achievement, attitude, learning styles, motivation, and self-efficacy, as studied in empirical educational research, which was scrutinized. The Table reveals that most (n = 51, 76.12%) of the qualified studies focused on studying the effectiveness of teaching methods on students' academic performance, while 12 (17.91%) qualified studies dealt with students' attitudes. However, few research studies were gathered and reviewed on learning styles, motivation, and self-efficacy—none of the primary studies in this review qualified for student multicultural characteristics.

The findings revealed that students' academic performance, comprised of different outcome measures, was intensively studied, and emphasized by chemistry educators and researchers in the teaching-learning process. Many qualified studies on academic performance connote that the primary focus of education centers only on increasing the cognitive aspect of performance and not on the affective and total capacity of the students. It implies that the student characteristics that are less studied could be given further consideration for future pedagogical investigations. The data entails those applications used in the educational system tend to neglect affective domains such as attitude and motivation compared to cognitive and psychomotor domains (Demirel & Dagyar, 2016).

In the case of student multicultural characteristics, as being zero in number, it can be implied that the cultural diversity of students is being neglected and is given less importance in terms of pursuing research. Multiculturalism is not highlighted as one of the priority research areas in education as reviewed in the National Higher Education Research Agenda 2 (NHERA 2) of 2009 – 2018. This is one of the primary reasons why it is given less attention by graduate educators and researchers. If this aspect is largely left out in the educational research priority, teachers who do not know anything about the everyday lived experiences of his/her students – the cultural backgrounds, the dialect, the family, the home, the community, teachers tend to pull the examples for teaching from his/her own experiences. Hence, connections established are not made for students. Aside from that, teachers in general lack sufficient knowledge and skills to teach in multicultural classrooms (Tosic, 2012). Multiculturalism may be given much attention and be properly addressed in the educational field to explore certain possibilities to address such emerging needs. It is like bringing culture to life in the classroom knowing the fact that the Philippines is known to be one of the countries that hold such great cultural diversity - cultural norms and language (dialects) backgrounds.

Finally, the study feature accounted as the independent variable for this meta-review is the teaching methodology evaluated from each of the qualified studies. These teaching methods were then classified into different treatment categories. The 67 studies described the effects of different treatment categories on student transformation. Nine (9) teaching methodology categories were modified and employed in this study. The list of treatment categories is presented in Table 5.

Table 5
Frequency distribution of qualified studies by teaching methods

Study Feature	n (No. of Studies)	Percentage (%)
Treatment Categories		
Combination Learning	2	2.99
Cooperative Learning	14	20.90
Individualized Instruction	7	10.45
Inquiry-based Learning	14	20.90
Manipulative, Models and Multiple Representations	11	16.42
Multicultural Education	2	2.99
Problem-based Learning	5	7.46
Project-based Learning	5	7.46
Technology-aided Instruction	7	10.45
Total Studies (for each feature)	67	100

A perusal of the above Table 5 shows that out of 67 studies, cooperative learning (n = 14, 20.90%) and inquiry-based (n = 14, 20.90%) were comparable. Manipulative, models, and multiple representations follow it (n = 11, 16.42%); then technology-aided and individualized instruction of the same number (n = 7, 10.45%). The other 20.90% of the qualified studies (14 studies) were equally classified under problem-based and project-based learning, and very few studies fell under combination learning and multicultural education.

The result of this meta-analytic review indicates that various teaching methods/strategies have been evaluated and implemented in chemistry classrooms for a decade. Cooperative and inquiry-based learning were the commonly studied methods/strategies used as an intervention in forging the different transformations of students in general. As mentioned, these two methods were considered the most widespread research and practice in science education (Duran et al., 2016; Ugwuanyi, 2015). It can be stated that the pedagogical trends in chemistry education center mainly on cooperative and inquiry-based learning, which align and support the framework and goals of 21st-century teaching.

Moreover, the findings (Table 5) prove that technology integration in classroom instruction has never lost its appeal to the Filipino scientific community. This may be due to the challenges currently addressed regarding rapid technological advancement among learners and society in this modern age (Sugano & Mamolo, 2021; Sugano & Nabua, 2020; Capar & Tarim, 2015; Schroeder, 2007). Individualized instruction is also becoming popular nowadays. Educators and researchers commonly pursued it because of the concrete application of the principle of individual differences in which students can proceed with their learning at their own pace.

On the other hand, combination learning, and multicultural education were among the pedagogies that call for further investigation and implementation in chemistry curricula for secondary schools (Sugano & Nabua, 2020). The limited number of studies included in this meta-review is affected by the established inclusion criteria.

Research on Teaching Methodologies

Several qualified studies in this meta-review dealt with two or three student transformation outcome variables like academic performance and attitude or attitude and motivation in a single study. The studies of Almerino (2012), Dangan (2008), Danipog (2008), Enrile (2012), Fajardo (2007), Fernan (2010), Gonzales (2012), Indad (2013), Manubag (2016), Mañus (2010), Nabua (2013), Reyes and Salise (2014) reported findings for two distinct outcome variables while Ferrer (2012) dealt three different outcome variables. These studies were accounted for and coded several times, including the study features exhibited, because multiple effect sizes were extracted from the same research. Hence, the obtained independent effect size was related to a single study.

In the study of Haas (2002), six teaching methodology types were used. For this meta-analysis, this area is expanded to nine (9) to include the recent trends in chemistry education. The treatment categories and the detailed description of the teaching methods obtained from the qualified studies with the corresponding authors are presented below.

Combination Learning

It is a recently adapted teaching and learning strategy for the 21st century viewed to foster and enhance learning. It is where students learn through the flexible combination of two or more learning/teaching components. The teaching methods most strongly associated with combination learning, the process described by the authors of the meta-analyzed research, are presented in Table 6.

Table 6
Teaching methods strongly associated with combination learning

Description of Teaching Method	Author/s	Year
Students were allowed to work together on in-class work by exposing them to exploration activities that raise causal questions and generate and test multiple hypotheses.	De Asis, C.P.	2012
Let students work in cooperative learning teams through interactive multimedia learning.	Berro, L.A.	2010

Cooperative Learning

Cooperative learning is viewed as a teaching-learning method where students work together on various tasks to achieve a common goal. Teachers arrange students in flexible groups to work on multiple tasks. As cited by Haas (2005), cooperative learning includes five elements to enhance student learning: positive interdependence, effective face-to-face interaction; individual and group accountability; interpersonal and small-group skills, and group processing. Table 7 offers several examples of teaching methods derived from studies under the broader category of cooperative learning.

Table 7
Teaching methods most strongly associated with cooperative learning

Description of Teaching Method	Author/s	Year
Involves the use of the Modified Student Teams Achievement Division (STAD) Technique where students are assigned to heterogeneous subgroups and work collaboratively.	Espinosa, R.S.	2016
The use of Peer-Assisted Learning Strategy.	Hernandez	2016
Involved in the use of the Peer-Assisted Learning Strategy (PALS) technique. Pair students as diads to work as tutor – tutee.	Belleza, E.V.	2016
It assessed students' achievement and problem-solving skills in chemistry topics by grouping them into three differing abilities.	Salise, J.G.	2014
Used a student-centered approach to learning aided by do-it-yourself equipment and manual	Reyes, F.P.	2012
Members of the group learn from one another through structured interactions and group analysis of a given task, which assesses students' motivation towards the lesson.	Reyes, F.P.	2012
Students were exposed to the peer-tutoring strategy which had student-centered interaction. Tutors and tutees were determined based on their grade performance.	Toborada, J.C.	2012
Involves the use of flexible groupings where students can work with a variety of peers of the same or different strengths or interests. Used to evaluate the attitude of students.	Gonzales, M.T.	2012
Students work as part of many groups depending on the tasks and content of the lesson. It used to assess the performance of the students.	Gonzales, M.T.	2012
Students were grouped to help one another identify their mistakes. It assessed the self-efficacy of students.	Mañus, L.M.	2010
It assessed students' achievement and retention scores by letting the students identify and make corrections of their mistakes from an activity. Students were working in groups.	Mañus, L.M.	2010
Students worked collaboratively in doing research on radioactivity and radiation to come up a required output. Students' attitudes toward the lesson were assessed through this method.	Fernan, M.C.	2008
Students were working together in doing the given web-quest. Students' achievement was assessed through this method.	Fernan, M.C.	2008

Individualized Instruction

A method of teaching in which content, instructional material (including technology) and pace of learning are based upon the abilities and interests of each learner. This includes the use of modules or any material that is self-contained and self-learning which enable the students to work independently with minimum teacher assistance. Teaching methods most strongly associated with individualized instruction are shown in Table 8. These were identified from the qualified studies.

Table 8
Teaching methods most strongly associated with individualized instruction

Description of Teaching Method	Author/s	Year
Use of programmed instruction materials that involved a bidirectional spiral pattern that permits students to read the material several times for mastery.	Arce, M.M.	2009
An instructional unit that is dependent and based on a single concept or area is used. Students were able to practice independence in dealing with the lesson and in solving problems from the given topic.	Enrile, C.R.	2012
The use of the Learning Activity Package (LAP) Approach in teaching stoichiometry and gas laws. It was used to determine its effectiveness on students' attitudes toward the lesson and the subject.	Enrile, C.R.	2012
Used computer-based instruction. It was carried out using the developed module to develop a positive attitude toward chemistry.	Dangan, L.R.	2013
Use of computer-based instruction. It was carried out using the developed module. It was used to assess students' academic performance on the given topic.	Dangan, L.R.	2013
Use of Strategic Intervention Material. A developed module was presented to the students with the aim of becoming self-directed and active during the learning process. It was designed for teaching remediation for low achieving students.	Rizada, J.B.	2012
Use of Vee Diagram that let the students direct and explore the lessons on their own. Teacher acts as facilitator.	Polancos, D.T.	2012

Inquiry-based Learning

It is an active learning approach that focuses on questioning, critical thinking and problem-solving. Using guided or facilitated inquiry activities, guided discoveries, inductive laboratory exercises, and indirect instruction. This is done by teaching students to acquire knowledge from direct observation by using questions.

As emphasized by Aktamis et al (2016), the National Science Education Standards established five main characteristics of inquiry-based science teaching without any classification. This includes the following: 1) Learners are engaged by scientifically oriented questions; 2) Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions. 3) Learners formulate explanations from evidence to address scientifically oriented questions. 4) Learners evaluate their explanations by considering alternative explanations, reflecting scientific understanding. 5) Learners communicate and justify their proposed explanations. Table 9 presents the teaching methods identified from the qualified studies that are associated with inquiry-based learning.

Table 9
Teaching methods most strongly associated with inquiry-based learning

Description of Teaching Method	Author/s	Year
Have students predict the outcomes, explain reasons for predictions and observe the given situation in a laboratory setting.	Avial, C.C.	2016
Students were exposed to activities that enabled them to predict, investigate, make observations, draw generalizations, and answer scientific questions to make conclusions.	Laureano, et al	2015
Students engage in guided inquiry using designed materials that direct them to establish their chemistry knowledge.	Villagonzalo, E.C.	2014
Involves learning activities using the Process Oriented Guide Inquiry Learning (POGIL). It assessed students' conceptual understanding of the topic.	Ferrer, A.P.	2012
Allow students to organize their own thoughts make observations and generate scientific information from the series of questions and activities presented.	Leonor, J.P.	2007
Presented activities of instruction into five phases; Engage, Explore, Explain, Elaborate and Evaluate.	Yap, M.C.	2005
Involve learning activities using the Process Oriented Guide Inquiry Learning (POGIL). It assessed students' learning styles.	Ferrer, A.P.	2012
Engage students in the thinking process promoting authentic inquiry. Have students analyze and revise their constructed ideas in light of experimental evidence presented in the lesson.	Matreo, E.B.	2013
Use learning activities by means of the Process Oriented Guide Inquiry Learning (POGIL). It assessed students' motivation.	Ferrer, A.P.	2012
Students make predictions for events, explain reasons for prediction and observe certain demonstrations or conduct experiments to compare the observation with their predictions.	Sales, et al	2015
It used the 7E model that consists of several phases of instruction: Elicit, Engage, Explore, Explain, Elaborate, Evaluate and Extend.	Taguiam, A.O.	2011
Encourage students to be involved in the given activities and explore concepts from a given series of questions.	Maurac, H.M.	2014
Expose students to hands-on and laboratory activities that require reflective thinking, discovery and inquiry learning and small group discussion.	Marasigan & Espinosa	2013
Students were trained to use their ideas and obtained knowledge utilizing open-ended questions. It assessed students' attitudes.	Marasigan & Espinosa	2005

Manipulative, Models and Multiple Representations

This engages the teacher to teach students techniques for generating or manipulating the representation of science content or processes, whether concrete, symbolic, or abstract. Multiple representations include graphs and diagrams, tables and grids, formulas, symbols, words, gestures, concrete models, physical and virtual manipulatives, pictures, videos, and sounds. Examples include operating apparatus, developing skills using manipulatives, drawing, or constructing something. A series of specific teaching methods most strongly associated with this category is presented.

Table 10
Teaching methods most strongly associated with manipulative, models and multiple representations

Description of Teaching Method	Author/s	Year
Use of multiple schematic and symbolic representations such as diagrams, illustrations, drawings, etc. to discuss the three-leveled nature of chemistry.	Sanchez, J.M.P.	2016
In-depth explorations and discussions of concepts are performed with images, tables, graphics, diagrams, conceptual change tests, concept maps, concept networks, data meaning tables and charts.	Mordeno, M.A.	2013
Involved in the use of standardized do-it-yourself (DIY) chemistry equipment in teaching selected topics in chemistry.	Alefante, I.C.	2012
Involved the use of problem solution map.	Benitez, E.F.	2011
Use of arts in teaching the mole concept in chemistry.	Danipog, D.L.	2008
Students' exposure to the use of music, games, and art-based techniques in learning selected topics in chemistry.	Anarcon, J.V.	2013
Several laboratory activities and experiments were carried out using commercially available and expensive spices and toys.	Ramos, M.	2007
Utilization of varied materials such as computers, objects (models), audio-aids (videotapes, cartridges), projected pictures (slides), graphic materials (charts, graphs) and still pictures (illustrations) as teaching tools.	Nagasangan, E.G.	2005
Application of block model, particulate diagram and reflective writing in teaching and learning stoichiometry. This approach used strips, bars, or rectangular regions called models to make problem-solvers visualize or even manipulate problem situations.	Tolosa, R.J.M.	2014
Using three-by-three grid of a tic-tac-toe board allow the students to participate in multiple tasks and demonstrate their understanding of the concepts in class.	Perez and Dolotallas	2016
Used of arts in teaching chemistry concepts (Mole). It assessed students' achievement.	Danipog, D.L.	2008

Problem-based Learning

A deductive method of teaching students that allows them to do research, combine theory and practice, find practical solutions to defined problem, and use their knowledge and skills. It is based on maximizing learning with investigations, explanations, and resolution by starting from real and meaningful problems. It allows students to investigate and solve real-world problems. The teaching methods most strongly associated with problem-based learning are shown in the Table below (Table 11).

Table 11
Teaching methods most strongly associated with problem-based learning

Description of Teaching Method	Author/s	Year
Involved students in applying the basic science processes like identifying, observing, predicting, differentiating, inferring, manipulating, measuring, comparing, and evaluating including verifying concepts and principles in chemistry.	Galvez, M.B.	2016
Allow students to investigate through observation and manipulation to find the answer to the given problem.	Villarta, Y.M.	2012
Elicit chemical/ scientific concepts based on actual events (real-life situations) and real-world problems. It assessed students' achievement and retentive scores towards chemistry.	Fajardo, M.T.	2007
Draw chemical/ scientific concepts based on actual events (real-life situations) and real-world problems. It assessed students' attitudes toward chemistry.	Fajardo, M.T.	2007
Use of improvised scientific materials that include the following conditions: 1) problem-solving within realistic situations, 2) learning in multiple contexts, 3) content derived from diverse work and life situations and 4) authentic assessment.	Rivera, G.M.	2016

Project-based Learning

Project-based learning is a systematic teaching method that engages students in learning knowledge and skills through an extended inquiry process structured around complex, authentic questions and carefully designed products and tasks. The list of teaching methods that are strongly associated with project-based learning is evealed in Table 12 below.

Table 12
Teaching methods most strongly associated with project-based learning

Description of Teaching Method	Author/s	Year
Students gain knowledge and skills in chemistry by working on an extended time to investigate and engage in complex given tasks.	Manubag, R.B.	2016
Challenge students to plan design, create and evaluate their product. It evaluated students' attitudes toward the subject.	Almerino, J.A.	2012
Engage students to do certain tasks; challenges them to hone their decision-making skills and promote higher order thinking skills.	Villacruz, E.	2011
Exposed students to plan design, create and evaluate their product. It evaluated students' academic performance.	Almerino, J.A.	2012
Working on an extended time to investigate and engage in complex given tasks, students gain chemistry knowledge and skills. It assesses the attitude of students.	Manubag, R.B.	2016

Technology-aided Instruction

Using electronic technological equipment to enhance instruction, computers are for simulations, modeling abstract concepts and collecting data, showing videos, photographs or diagrams are used to emphasize a concept and to practice scientific skills through software applications. Table 13 displays the qualified methods for using technology in chemistry instruction.

Table 13
Teaching methods most strongly associated with technology-aided instruction

Description of Teaching Method	Author/s	Year
Web-enhanced lessons were developed through the selection of topics and identification of standards, formulations of learning objectives, and designing of online Treasure Hunt and WebQuest which underwent summative and formative evaluation. It assessed students' attitudes.	Indad, S.B.	2013
The use of Youtube links in presenting the lessons on topics like chemical bonding, gas laws, balancing equations, electronic configuration, and atomic structure.	Palma, E.U.	2011
Instructional multimedia presentation was designed, developed, and formatted in a system that incorporates the use of text/words, animations and narration in conveying information or concepts in chemistry.	Nabor, D.	2010
The use of multimedia in introducing chemistry lessons (atoms and elements).	Urabo, R.C.	2005
Incorporated the use of technology in chemistry lessons and to promote collaboration among students in solving real world problems.	Rodriguez, C.A.	2009
Used software applications, specialized software for interactive learning, simulations, communication tools such as email and using the internet as a resource in teaching chemistry topics.	Lorenzana, M.A.	2008

Teaching methods presented in this meta-analysis study cannot be considered mutually exclusive for a certain category because one method may overlap with another method (Haas, 2005). A cooperative learning method may include the use of technology such as computers and calculators to enhance student understanding. Hence, this is to provide a general classification so that mean effect size may be inclusive of teaching methods related to one another.

Meta-Analysis Result of Included Studies by Study Features

In the results of analysis of the study feature, publication year and form shown in Table 14, significant effect sizes were detected.

Table 14
Meta-analysis result of included studies by publication year and form

Study Feature	Mean Effect Size (Cohen's d)	Lower Limit (95% CI)	Upper Limit (95% CI)	Z Value
1. Publication Year				
2005-2008	0.733	0.387	1.080	4.151
2009-2012	1.01	0.695	1.325	6.281
2013-2016	1.078	0.810	1.347	7.864
Heterogeneity Test	Q value = 2.790		P value = 0.967	
2. Publication Form				
Published	1.135	0.580	1.690	4.008
UnPublished	0.944	0.763	1.124	10.236
Heterogeneity Test	Q value = 0.412		P value = 0.521	

The highest effect size values are found in studies conducted from 2013 to 2016 (Cohen's d = 1.078) and on studies that are published (d = 1.135). Effect sizes above Cohen's 0.80 cut off value as "large" were found in the inclusive years of 2009 – 2012 (Cohen's d = 1.01) and unpublished studies (Cohen's d = 0.944). The effect size value that appeared to have medium effects is on the studies conducted from 2005 to 2008. The mean size effect of 0.733 signifies a moderate impact of the use of teaching methods on student transformation. All the mean effect sizes reflected in table 14 for the two study features are significant which denotes that teaching methods have significantly improved students' transformation characteristics.

Heterogeneity Test was also performed on the average effect sizes of the two parameters, publication year and publication form. As a result, it was found that there is no significant difference ($Q = 2.790$, $p > 0.05$) between the average effect sizes of studies based on publication year. Likewise, the $Q = 0.412$ for the parameter publication form is not significant. Among the selected studies subjected to meta-analysis, the mean effect sizes of published and unpublished studies are homogeneously distributed. This means that the effects of these treatment categories on student transformation were comparable for both published and unpublished studies. In the same way, the insignificant Q value of the mean effect size according to publication year denotes the same effect of the treatment categories observed throughout the given period (2005 – 2016). Findings imply that the quality of teaching methodologies used in the classroom did not change over time. It remains to be effective and useful in promoting learning and in developing the holistic being of the students.

Meta-analysis was also carried out in studies grouped according to source and locale of study. It can be deduced in Table 15 that the sources of the studies, master's theses ($d = 1.041$) and doctoral dissertations ($d = 0.879$) have large significant effect sizes. Journals, however, posed a $d = 0.745$ which is below the 0.80 cut off in Cohen's d qualitatively described to have contributed medium size effect. Similar results were found for the study feature, and locale of the study, where the studies that were conducted in Luzon posed a $d = 1.268$. However, medium effect sizes were observed on studies from the Visayas which posted a $d= 0.777$ and those which were taken from Mindanao with a $d = 0.736$. The data obtained shows that these study features have positive effects on the treatment categories in chemistry classes in secondary schools.

Table 15
Meta-analysis result of included studies by source and locale of study

Study Feature	Mean Effect Size (Cohen's d)	Lower Limit (95% CI)	Upper Limit (95% CI)	Z Value
1. Source of Study				
Thesis	1.041	0.820	1.262	9.232
Dissertation	0.879	0.520	1.237	4.800
Journals	0.745	0.249	1.242	2.943
Heterogeneity Test	Q value = 1.156		P value = 0.561	
2. Locale of Study				
Luzon	1.268	0.917	1.618	7.086
Visayas	0.777	0.491	1.000	5.597
Mindanao	0.736	0.513	0.959	6.470
Heterogeneity Test	Q value = 6.301*		P value = 0.043	

*significant @ 0.05 level.

The heterogeneity test was also performed to determine whether there is a significant difference between the effect sizes of studies according to the two study features. The results indicate that there is no significant difference ($Q = 1.156$, $p = 0.561$) among the studies grouped according to source. On the other hand, a significant difference (Q =

6.301, $p < 0.05$) was observed between the effect sizes of studies grouped according to the locale of study.

Findings imply that the observed effect of the treatment categories on student transformation is comparably effective and does not vary based on the study feature, or source of the study. The significant Q value in terms of the locale of the study could be attributed to the large positive influence of the parameter teaching methods on student characteristics and performance. It is to be noted that the mean effect size of the studies conducted in the Luzon institutions is much higher than those of the studies conducted in the Visayas and Mindanao. The studies posting lower than 0.80 Cohen's d in the latter category, however, still have a positive moderate effect on student transformation with respect to the use of teaching methods.

Table 16 below presents the meta-analysis result of qualified studies grouped according to study rating, duration of exposure and significance of test.

Table 16
Meta-analysis result of qualified studies by study rating, duration of exposure and significance of test

Study Feature		Mean Effect Size (Cohen's d)	Lower Limit (95% CI)	Upper Limit (95% CI)	Z Value
1. Study Rating					
Experimental, treatment vs control		0.555	0.348	0.763	5.243
Quasi-experimental, single group (pre-post)		1.916	1.543	2.289	10.07
Quasi-experimental, treatment vs control (pre-post)		0.54	0.329	0.751	5.020
Quasi-experimental, more than two groups		0.28	0.099	0.462	3.024
Heterogeneity Test	Q value = 60.007*	P value = 0.000			
2. Duration of Exposure					
1-3 weeks		0.992	0.705	1.278	6.791
4-7 weeks		1.243	0.812	1.674	5.651
8-11 weeks		0.784	0.417	1.150	4.191
Not indicated		0.731	0.475	0.987	5.591
Heterogeneity Test	Q value = 4.557	P value = 0.207			
3. Significance of Test					
Significant		1.328	1.107	1.550	11.751
Not Significant		0.10	0.002	0.197	2.003
Heterogeneity Test	Q value = 98.761*	P value = 0.000			

*significant @ 0.05 level.

The result of the analysis on the study feature, study rating, and high effect size (Cohen's d = 1.916) value was found in the quasi-experimental single group (pretest-posttest) design. This high value posted has a strong and important effect on students' transformation. Other study rating groups posted Cohen's d values which are categorized as medium effect size obtained for experimental, treatment vs control and quasi-experimental, treatment vs control (pre-posttest). A small effect size was obtained for quasi-experimental, more than two groups. The heterogeneity test result for the study rating feature shows $Q = 60.007$ at $p = 0.000$. This value indicates a significant difference between the mean effect sizes obtained for the different study ratings.

On the other hand, as shown in Table 16, on the study feature, duration of exposure, the highest effect size posted is Cohen's d of 1.243, for a 4–7-week duration of exposure, followed by 1-3 weeks duration of exposure with Cohen's d = 0.992. Both exposure durations have effect sizes which are categorized as "large" according to Cohen's Standardized Mean Difference Effect Size. The exposure duration of 8-11 weeks and that which is not indicated in the qualified studies have mean effect size which is categorized as "medium effect." The heterogeneity test performed shows a computed Q = 4.557 which indicates that the mean effect sizes do not differ significantly from each other.

The significance of the test is a study feature that is related to decisions researchers make when research hypotheses are either rejected or not rejected (accepted) at a certain confidence level. A cursory look at the effect size of each as expressed in Cohen's d values, it could be inferred that the effect sizes are significantly different from each other, for which this contention could be verified through the Q value of 98.761 (significant @ $\alpha = 0.05$).

The meta-analysis result done on the study feature, and study rating supports the findings of Kanadli (2016) conducted in Turkey, which presented the large common effect size of studies that used quasi-experimental procedure to establish the effect on academic performance, but a moderate effect size was detected on true-experimental design. It has been shown that studies utilizing quasi-experimental designs significantly augment students' characteristics and performance in chemistry. Simply, quasi-experimental studies have larger effect sizes than the experimental designed studies.

On the other hand, it is obvious to say that studies with significant results based on their individual outcomes have a significant influence on students learning than those reported as having no significant result. It can also be inferred that the studied teaching methods can be applied effectively in different implementation periods as they have comparable large effects on student characteristics and performance based on the variance test (Q = 4.557, p = 0.207) as reflected in Table 16.

Studies that qualified for meta-analysis were also grouped according to the study feature, dependent variable which refers to student transformation that includes academic performance, attitude, learning styles, motivation, self-efficacy and multiculturality. Table 17 presents the meta-analysis of qualified studies on the study feature, and dependent variable. It is also referred to as outcome variables. The dependent variables include academic performance, attitude, learning styles, motivation, and self-efficacy.

Table 17
Meta-analysis of qualified studies by student transformation outcomes

Study Feature	Mean Effect Size (Cohen's d)	Lower Limit (95% CI)	Upper Limit (95% CI)	Z Value
1. Student Transformation Outcomes				
Academic Performance	1.208	0.984	1.433	10.534
Attitude	0.379	0.171	0.586	3.579
Learning Styles	0.199	-0.024	0.422	1.745
Motivation	0.453	-0.311	1.217	1.163
Self-efficacy	0.041	-0.356	0.438	0.202
Multicultural	0	0	0	0
Heterogeneity Test	Q value = 52.004*		P value = 0.000	

*significant @ 0.05 level.

To investigate the results of the conducted meta-analysis, a significant effect ($p < 0.05$) has been identified on academic performance and attitude. The large effect size was observed on academic performance (d = 1.208) while a significant small effect size value was observed on attitude (d = 0.379). Motivation (d = 0.453), learning styles (d = 0.199) and self-efficacy (d = 0.041) were insignificant because of the confidence interval that includes zero (0) surrounding the effect size and reaches the negative limit.

It can be inferred that the number of studies included in the analysis can be one of the reasons why the variables, learning styles and self-efficacy have small effect size as compared to academic performance, attitude, and motivation. As claimed by Kalaian & Kasim (2014), the limited number of primary studies on the outcome variables, leads to low statistical power of the statistical test.

A test for heterogeneity was carried out to determine whether there is a significant difference between effect sizes of the meta-analysed studies according to dependent (outcomes) variables. The test (Table 5.5) revealed that there is a significant difference between the effect sizes of the studies (Q = 52.004, $p < 0.05$). The effects of teaching methods on the different outcome variables changed significantly in favor of academic performance.

As emphasized by Umer and Siddiqui (2013), several previous research have already proved the significant contribution of teaching methods on the academic performance of students. Schroeder et.al., (2007) claimed that alternative teaching methods/strategies were more effective than traditional methods/strategies in improving student achievement Students who were given instructions using modern teaching methods significantly secured higher marks in their subject tests as compared to those who were taught in conventional way.

This concurs with the findings in the meta-analysis of the qualified studies where teaching interventions showed a more meaningful effect on the academic performance of the students than on the use of traditional learning. It augments the cognitive achievement of the students and promotes conceptual understanding and thinking skills. Findings of previous research also revealed that academic achievement or performance should not only be of main concern in educational research but also give intensive focus on students' characteristics; attitude, learning styles, motivation, and self-efficacy.

These characteristics served as the primary factors that affect the overall performance of the learner. Thus, the teaching-learning process ought to be regulated in such a manner to cover the cognitive, affective, and psychomotor development of students (Demirel & Dagyar, 2016).

CONCLUSION AND IMPLICATIONS

In this present time where standard-based education has given much emphasis and has taken on a greater real-world, it is important that educators should provide students with authentic learning experiences and connections toward a learning environment that is beyond the traditional boundaries of teaching. The pedagogical trend in chemistry education in the country centers mainly on inquiry-based and cooperative learning which clearly aligns and supports the framework and goals of 21st-century teaching. The heterogeneity test warrants the conclusion that a significant difference exists between the grouped study features; locale of the study, study rating, significance of test and dependent variable, hence, the null hypothesis was rejected based on the Q values obtained. Likewise, the effect size data are directly influenced by the significance of tests derived from each study. The null hypothesis was rejected based on the computed r value. Studies with significant results tend to have larger effect sizes and are thought to have a significant influence on the study variables. Academic performance, attitude and motivation can be greatly enhanced if students are placed in an environment in which they can actively connect chemistry instruction to previously learned scientific and chemical concepts and materials through constructivist (inquiry-based and problem-based) and cooperative learning methods.

This meta-analysis calls for more empirical research studies in chemistry education particularly those that investigates the effectiveness of an instructional intervention towards student characteristics on learning styles, self-efficacy, and cultural diversity. Moreover, Science educators and researchers are encouraged to do research in less trodden areas such as those related to scientific literacy in relation to science/chemistry teaching, multicultural education, use of continuous assessment strategies in relation to instructional strategies and students' total development, role of parents and community in science/chemistry education, evaluating behaviors illustrative of knowledge and creativity among students, of chemistry, to mention a few. More chemistry education research may be published in scholarly journals and teaching interventions (methods/approaches) could be conducted in class with a longer duration of exposure to students. Research productivity concerning chemistry education may be enhanced in the higher education institutions of the Philippines, particularly Visayas and Mindanao.

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