CONTEXT-BASED APPROACH IN CHEMISTRY EDUCATION: A SYSTEMATIC REVIEW

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ABSTRACT

The implementation of context-based chemistry programs has been started before 40 years ago since 1980's in an attempt to make the learning of chemistry more meaningful for students. Consequent to its lengthy, there has been a steady increase in the number of interventional context-based (ICB) approach chemistry studies investigating the effect of various instructional strategies on students' learning outcomes from primary to post-secondary levels. However, there is a limitation of literature review conducted on interventional context-based chemistry studies. Hence, the present review was carried out to evaluate interventional context-based chemistry studies using six research questions based on the following categories (main headings): (1) countries or continents in which ICB chemistry studies were conducted in; (2) research methodologies implemented in ICB studies; (3) topics in which ICB chemistry studies used; (4) learning variables measured by ICB studies; (5) teaching methods and instructional strategies adopted by ICB studies; and (6) the effectiveness of context-based instructions on students' learning outcomes. Moreover, some sub-headings also followed the main headings. To achieve this objective, a rigorous systematic literature review has been executed using 25 selected ICB chemistry studies published between the years 2009 and 2022 based on the specific inclusion and exclusion criteria. These studies were accessed in internationally well-known databases (Google Scholar, ERIC, Semantic Scholar, and Mendeley); and the studies were organized and reviewed thematically. To summarize and present the findings of the studies, matrices, constructed by the researcher, were used. The review analysis results revealed and shed light on the critical appraisal of interventional context-based chemistry studies, missing parts of the context-based approach, and implications and suggestions for future studies. *[African Journal of Chemical Education—AJCE 13(3), July 2023]*

INTRODUCTION

The word context, literally, is derived from the Latin words ‘contexere’, ‘con’- meaning together and ‘texere’- meaning to weave [B17]. Its meaning is then weaving together. A context is also related to a noun ‘*contextus*’ which expresses ‘coherence’, ‘connection’, or ‘relationship’ [B3]. It might be also an authentic situation in daily life involving chemistry like industrial, social, economic, environmental, technological and/or a research setting [B1, B19]. Mahaffy, likewise, termed the word context as ‘human element’ when he modified a two-dimensional ‘triangular’ chemistry education into a three-dimensional ‘tetrahedral’ chemistry education [B8]. In general sense, for younger students, contexts are those having direct applications to students’ lives, whereas more advanced students, contexts are ‘what scientists do’ may be more common [B19].

Instructional Approach

An instructional approach refers to a view of looking at things, a set of principles, beliefs, or ideas about the nature of instructional activities [B6]. An instructional approach provides philosophy to the whole process of instruction and gives the overall wisdom, general principle, and direction to the entire spectrum of the teaching process to make learning possible [B6]. The authors also stated that instructional approach provides a basis for the development of teaching methods, and strategies and to define their components as well. That is, a teaching approach is a universal set from which we get teaching methods. Teaching methods also give teaching strategies. The concepts of teaching methods and instructional strategies are discussed in the next paragraphs.

A teaching (or an instructional) approach can be broadly classified into deductive and inductive, direct and indirect, or teacher-centered and learner-centered. In the learner-centered or constructivist approach students participate actively in learning and the teacher has facilitator role while in the teacher-centered instruction students are passive learners and the teacher has mainly authoritative role. Constructivist approach is an example of learner-centered approach in which students build their learning in the context [B3]. In this approach, the teaching-learning process begins at the context, and it is called as context-based approach.

Context-Based Approach

A context-based approach is an instructional approach starts with a context and gives equal emphasis to both content and context of chemistry [B3]. Metaphorically, context-based instructional approach can be viewed as the two sides of the chemical coin [B2]. Philosophically, a context-based approach is founded on a pragmatic philosophy. That is, education should be applied to the real-world environment making the process of teaching-learning more meaningful and effective [B11]. It believes that no truth is absolute and permanent as it is ever changing from time to time and place to place and from circumstance to circumstance. Thus, philosophers and educators believe that since life is dynamic the aims of education should also need to be dynamic.

Context-based approach is aligned with a social constructivist perspective. Social constructivism is a learning theory propounded by Lev Vygotsky in 1968 [B6], however, it emerged as the leading view of human learning in the 1980s. Social constructivism is a popular idea that is

being used to guide teaching, learning, and research in science education. It stresses the importance of what is already in the students' minds as a place to initiate instruction. In its perspective, learning does not limit only to the school compounds but rather any social interaction, outside the compounds, with anybody may also well lead to learning. This implies that learning occurs in the interaction between the learner and others. Social constructivism is based on the assumption that learners do not discover existing knowledge rather they actively construct it [B10]. They are not empty vessels to be filled by their teachers rather they come to the class with preconceived ideas, and prior knowledge [B10]. Therefore, every learner has prior knowledge on which the teacher builds a bridge to connect it with the new knowledge.

Teaching Methods and Instructional Strategies

Teaching methods and strategies are the two different concepts used by teachers during classroom instructions. The term teaching method refers to the general pedagogy used for classroom instruction [B4]. A teaching method could be *participatory* (e.g., hands-on activities, group discussions, questioning and answering, problem-based learning, and so on) or *non-participatory* (e.g., lecturing, and demonstration) method. It is a scientific way of teaching of a subject matter based on a selected approach and method [B4] in accordance with a defined plan of actions (strategy).

An instructional strategy is a careful plan of action designed to achieve a specific or series of goal(s) of instruction [B5]. It was also stated that an instructional strategy is a pattern of teaching-

learning activities that helps students to a better understanding of the material, and attains the learning objectives of the course under the teaching method. For every lesson, at the planning stage of instructional strategy, the teacher decides what method of teaching to adopt, whether participatory or non- participatory. Upon deciding which method to adopt for a specific topic, the teacher begins to carefully plan teaching activities (strategies) which can help to achieve learning objectives. Hence, a teaching method is a wider term covers a teaching strategy and helps for the practical realization of an approach.

Context-Based Instructional Strategies

A context-based approach (CBA) should have a clear instructional strategy and has to be explicitly reported by researchers. Such instructional strategy adopted in a context-based approach under the selected teaching method is a context-based instructional strategy. There are various context-based instructional strategies to be employed in CBA. These are REACT [A15], storyline [A7], 7E learning cycle [A16], 5E learning cycle [A6], ARCS [A17], EEKPST [A12], and scrum methodology [A24]. Amongst these, REACT is the first and the most frequently used instructional strategy in many CBA studies while scrum methodology has been used in CBA research in recent years.

Review Questions

In this review, the following review questions were addressed:

- Which continent and/or country dominate in conducting interventional context-based chemistry studies?
- What kinds of experimental designs and data analysis methods have been adopted in the interventional context-based chemistry studies?
- In what topics of chemistry is context-based approach used?
- What are the research variables investigated in interventional context-based chemistry studies?
- What are the teaching methods and instructional strategies adopted in interventional context-based approach of chemistry studies?
- What is the effectiveness of context-based instructional strategies in chemistry education with respect to chemistry topics and measured variables?

Significance of the Review Study

A review and synthesis of the interventional context-based approach studies has much to offer policy makers, curriculum developers, chemistry educators, education researchers, and teachers. A reviewing of the overall research methodologies being adopted and the effects of interventional context-based approach on students' learning outcomes will not only reveal the motives of the researchers who undertook it, but also guide future research towards poorly researched issues. As the interventional context-based approach leads students towards making links

between real life and chemistry, teachers will be able to harness methods used for research into classroom practice to achieve a better level of students' engagement in chemistry.

Limitation of the Review Study

The review has the following two main limitations:

- There was a scarcity of interventional context-based approach chemistry studies that conducted on different countries across the world; especially in developed countries (such as USA, UK, and South Africa) those started context-based programs earlier in 1980s, 1990s or 2000s. Hence, the review study was limited to only seven countries.
- The search strategy was limited only to the open access Journals, and English literature.

REVIEW METHODS AND MATERIALS

Search Sources

The methods of systematic literature review for the current paper were mainly adopted from the two sources, [B8] and [B10]. The paper consists of articles published in the last fourteen years on the use of context-based approach instruction in chemistry education. Papers published between January 2009 and October 2022 was searched in four electronic databases: Google Scholar, ERIC, Semantic Scholar, and Mendeley. To be included in the review, each article had to present a study in which context-based instructional approach had been implemented in action, which has to be an

interventional study, and involving student participants in any grade level in which chemistry is offered as a separated subject matter including post-secondary level students.

Exclusion/Inclusion Criteria

The exclusion criteria— a study must not fall into any one of the following categories: *Exclusion 1*: exclusion on approach (not context-based approach and not studying the effect of context-based approach on students' learning); *Exclusion 2*: exclusion on design (not experimental/ interventional studies); *Exclusion 3*: exclusion on participant types (not student participants, and not in primary, secondary and ternary levels); *Exclusion 4*: exclusion on study type (not empirical study). That is, original empirical studies, including unpublished doctoral theses, were included. In other hand, centre or government reports, policy documents, other systematic reviews, meta-analyses, commentaries, technical/methodological notes, short notes, and books or book chapters, master theses, were not included. *Exclusion 5*: exclusion on text (i.e., if full-text of the study is not available); *Exclusion 6*: exclusion on contexts/settings in which the study was carried out (i.e., the study is written in a language other than English); and *Exclusion 7*: exclusion on publication date (not published in the period of 2009–2022).

Limits and Methodology of the Search

The search strategy was carried out using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). The PRISMA statement was very helpful to the researchers

to the critical appraisal of published articles and improves the reporting of the current systematic review.

Procedures

The review was carried out between March and April 2022 and being updated in September and October 2022. Initially, the criteria for selecting the studies that could be part of the review were drawn up, as well as the selection of inclusions/exclusions and the databases. Afterwards, the selection of the databases for the bibliographic search was carried out. Four digital databases were selected for the following reasons. These databases were chosen because they are online databases with vital articles in the field of education. They are also the most important citation databases in the world and are highly regarded by the scientific community, so the researchers the current review considered them essential to include in the review.

All study articles were identified from the four databases using the following search strings [B8]. The search string was encompassing the following keywords:

1. (The effect of or impact of or influence of)
2. (Context-based or context-led or context-oriented)
3. (Contextualized or contextualized)
4. (Real life or everyday life or daily life or authentic life)
5. (Chemistry education or chemistry instruction or chemistry program or chemistry curricula, chemistry material or chemistry project or chemistry learning or chemical education or

chemical instruction)

6. #1 and #2 or #3 or #4 and #5 and (student's learning or pupils' learning or learner's learning outcomes or student's learning outcomes or pupils' learning outcomes)
7. #2 or #3 or #4 and #5
8. #7 and (on student's learning or pupils' learning or learner's learning outcomes or students' learning outcomes or pupils' learning outcomes)
9. Limit #7 and #8 to (English language and (lower elementary education or upper elementary education or lower secondary education or upper secondary education) and (Journal articles, conference proceedings or dissertations) and yr=2009-2022)

With these inclusion/exclusion criteria, primarily, 190 studies were obtained. Amongst these, 109 studies were from Google scholar, 41 studies from ERIC, 26 studies from Semantic scholar, and 14 studies from Mendeley. The process of analysis of the studies was carried out by three researchers. They worked independently and shared the results at the end of the work. On the second level of exclusion, 32 studies were excluded and only 25 studies accepted (Figure 1).

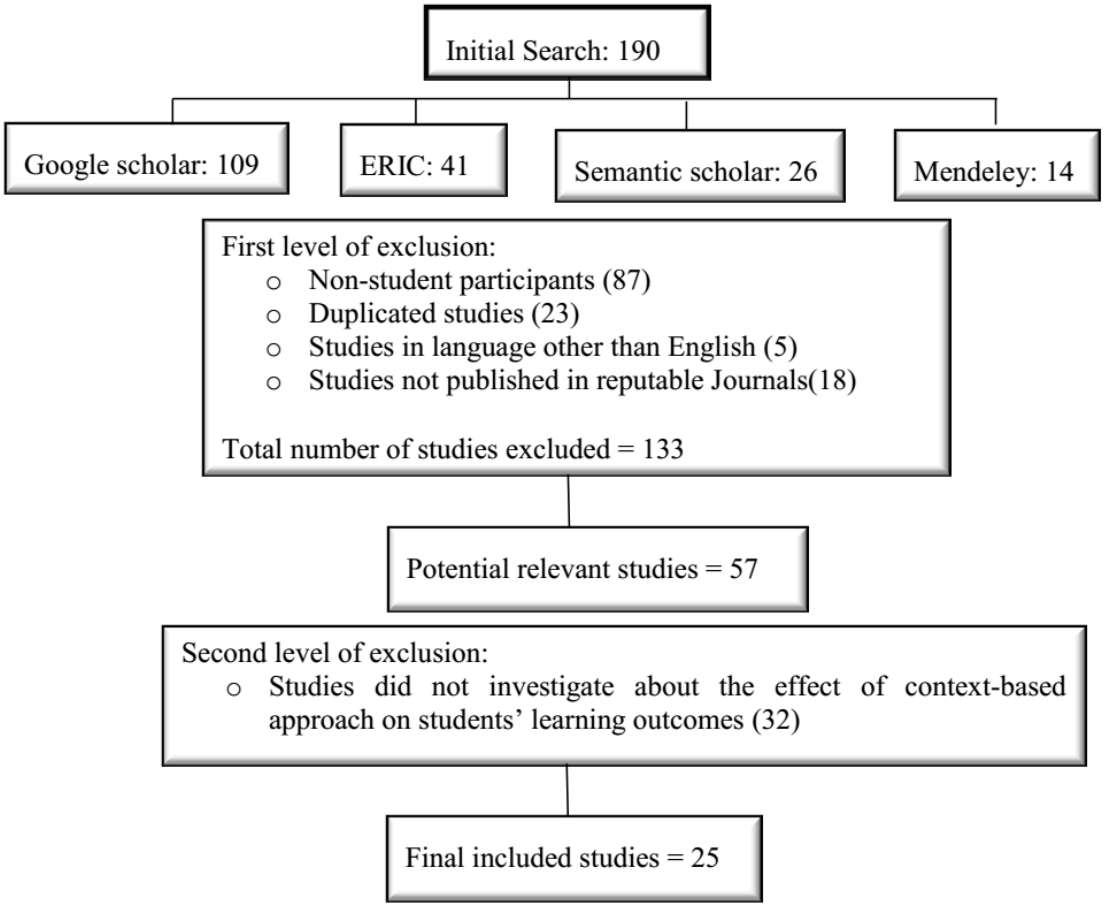

Figure 1. Flow Chart of Systematic Literature Review

With the final 25 study articles selected (Figure 2), following a systematic and thorough review process, each study was categorized, in relation to participant type, on the basis of the following categories: primary, secondary, and post-secondary levels. As it can be shown in the figure, 72 percent (18 out of 25) of the studies were undertaken with secondary school students, 24 percent (6 out of 25) using post-secondary level students, and 4 percent (1 out of 25) with primary

school students. This implies that significant numbers of the studies were carried out in secondary schools, and few in primary schools. Hence, it can be stated that most of the studies were carried out in secondary school students, next in post-secondary students and, lastly, in primary school students.

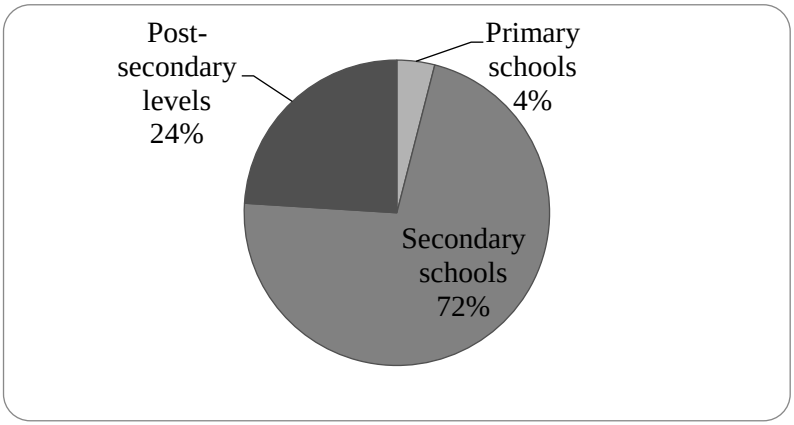

Figure 2. Percentage of ICB Chemistry Studies Conducted in Primary, Secondary, and Post-Secondary Level Student Participants

Quality Assurance Process

To assure the quality of studies, Journals were initially identified whether they are reputable. In addition, quality assurance procedures were also implemented by decisions on key-wording, title screening, abstract reviewing, full text examination, and in-depth data extraction. Furthermore, the PRISMA guidelines were essentially used as its guidelines include an evidence-based set of items to assess the quality of systematic reviews and meta-analysis.

RESULTS AND DISCUSSIONS

ICB Chemistry Studies per Continents/Countries

The first part of this section focuses on the countries and continents in which interventional context-based (ICB) chemistry studies were conducted. As illustrated in Figure 3, seven countries and three continents where such studies were being undertaken are identified. A total of twenty-five ICB studies were identified in these countries for the purpose of review. Except one of the studies [A13], the country of each study, where it was conducted in, is apparently stated by authors. The number and percentage of ICB chemistry studies of each country and continent is demonstrated in the figure. More than half (56) percent (14 out of 25) of the studies were undertaken in Turkey, and Nigeria (15.4) is next to Turkey. The other countries such as Indonesia (7.7 percent), Israel (3.8 percent), Netherland (3.8 percent), and Serbia (3.8 percent) are following to Nigeria.

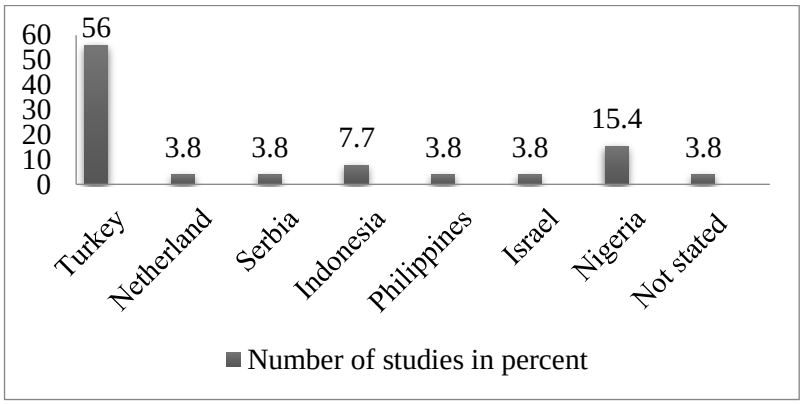

Figure 3. Percentage of ICB Chemistry Studies per Continents/Countries in Which They Were Conducted In

These indicate that the ICB chemistry studies, searched for this review, were exclusively found in three continents, namely, Africa (N = 4, 16 percent), Europe (N = 16, 64 percent), and Asia (N = 4, 16 percent). The three countries in Europe, where 16 studies were carried out, are Turkey, Netherland, and Serbia. Similarly, in Asia, there are also three countries (Indonesia, Philippines, and Israel) in which 4 studies were conducted in. But, the only country in Africa in which four ICB chemistry studies were conducted was Nigeria. Here, more than half percent (56, N = 14) of the total ICB chemistry studies was carried out in Turkey while the minimum, 4 percent (N =1), was conducted in each of the five countries (Netherland, Serbia, Philippines, Israel, and another country where its name was not mentioned). Generally, it can be suggested that Europe and Asia dominate the interventional context-based chemistry studies regarding to the number of countries, while Africa is poorly represented with only one country, Nigeria.

Research Methodologies Adopted in the ICB Approach of Chemistry Studies

Kinds of Experimental Design and Research Methods Adopted in ICB Chemistry Studies

Table 1 below shows the nature of experimental design and research methods adopted by ICB chemistry studies (N = 25). Amongst these, 76 percent (19 out of 25), 20 percent (5 out of 25), and zero percent of the studies had quasi-experimental, pre-experimental, and true-experimental designs respectively. But one of the studies, [A22], didn't explicitly state the nature of experimental design whether it was quasi-, pre-, or true-experimental. The table indicates that no study was conducted with true-experimental design as random sampling of human subjects is not generally

possible in experimental studies [A6, A12, A23]. But most of the review studies (76.0 percent, 19 out of 25) adopted quasi-experimental designs. Among the total number of studies (N = 25), only few (32 percent, N = 8) of them selected mixed-method research procedures, though all didn't state the priority/weighting and sequence/timing of the methods.

Table 10. The Nature of Experimental Design and Research Method (N = 25)

Design	Total N(%)	Mixed Method N(%)	Priority/weight		Sequence/timing	
			Stated N(%)	Not stated N(%)	Stated N(%)	Not stated N(%)
Pre-experimental	5(20.0)	3(60)	0(0)	3(100)	0(0)	3(100)
True-experimental	0(0)					
Quasi-experimental	19(76.0)	5(26.3)	0(0)	5(100)	0(0)	5(100)
Not stated	1(4.0)	0				
Total	25	8(32.0)	0(0)	8(100)	0(0)	8(100)

Data Analysis Methods Adopted in ICB Studies

Table 2 provides an overview of the types and frequencies of analysis methods adopted by the 25 studies. Majority of the chemistry studies adopted inferential statistics, except two studies [A3, A21] that used exclusively descriptive statistics. Besides, some kinds of qualitative data analysis methods such as NVivo [A4, A17], content analysis [A4], and thematically [A25] had been employed by those studies having mixed method reasearch procedures.

Amongst the inferential statistical analysis, t-tests [A1, A7, A10, A13, A14, A16, A17, A18, A22] and ANOVA/ANCOVA [A3, A5, A7, A8, A9, A11, A14, A19, A24, A25] are the most frequently used (F = 12 and 11 respectively) amongst the tests. In the case of t-tests, most studies

clearly specified whether the test was dependent or independent, while three [A1, A7, A22] of them didn't mention at all. For the case of ANOVA/ANCOVA, many of the studies (10 out of 11) used one-way ANOVA, while one of them [A11] had used two-way ANOVA.

Table 11. Data Analysis Methods of ICB Chemistry Studies (N = 25)

Data Analysis Method	Specific Type of DAM	CB study	N	N total
t-test	Dependent t-test	A10, A13, A16, A17	4	12
	Independent t-test	A10, A13, A14, A16, A18	5	
	Not stated	A1, A7, A22	3	
ANOVA or ANCOVA	One-way	A3, A5, A7, A8, A9, A14, A11, A19, A24, A25	10	11
	Two-way	A11	1	
MANOVA or MANCOVA	One-way	A6, A19, A23	3	4
	Two-way	A12	1	
Mann-Whitney U-Test		A15	1	1
Wilcoxon		A4, A15	2	2
Chi-square		A11	1	1
Descriptive statistics	M, SD, F	A2, A21	2	2
Qualitative method	NVivo	A14, A17	2	4
	Content analysis	A4	1	
	Thematically	A25	1	

Note: M- mean; SD- standard deviation; F- frequency; DAM- Data Analysis Method

Besides, four other studies [A6, A12, A19, A23] used MANOVA to analyze their quantitative data. Three of them [A6, A19, A23) used one-way MANOVA while one of the studies [A12] used two-way MANOVA. Furthermore, non-parametric tests such as Mann-Whitney U-Test [A15], Wilcoxon [A4, A15], and Chi-square [A11] were also used by five studies. However, these non-

parametric tests were applied less frequently (5 out of 25) than parametric tests. It seems reasonable to conclude from this review that t-tests and ANOVA are the most frequently used inferential statistical (or parametric) tests in interventional context-based approach studies in chemistry education.

Methods of Data Analysis per Numbers of Variables

The table presented below (Table 3) indicates the inferential statistics used in relation to the number of groups and variables (dependent and independent) in ICB chemistry studies. Most studies (23 out of 25) had two study groups (one intervention and one comparison); while the other two studies [A5, A11] had three study groups (two interventions and one comparison). [A5] and A11] had employed ANOVA analysis instead of t-tests which seemed to correspond to the number of groups. Regarding to the number of independent variables, there are three studies [A6, A7, A23] that had two independent variables (groups and other one variable). Amongst these three studies, only [A6] had clearly stated that he used two-way MANOVA, while [A7], and [A23] didn't obviously explained whether they applied one- or two-way ANOVA/MANOVA in their studies.

Table 12. Number of Groups, Dependent Variables, and Independent Variables in Relation to Inferential Statistics

CB study	N of Gp	N of IV	N of DV	Method of Data Analysis
A1	2	1	3	t-test
A15	2	1	1	Mann-Whitney U-Test, Wilcoxon
A5	3	1	2	ANCOVA
A7	2	2	1	t-test and ANCOVA
A9	2	1	2	Independent t-test and ANCOVA
A10	2	1	1	Paired-samples t-test
A11	3	1	2	One-way ANOVA, Scheffé Post-hoc test, chi-square tests and two-way ANOVA
A12	2	1	2	Two-way MANCOVA
A13	2	1	1	Dependent- and independent t-test
A14	2	1	3	Independent sample t-test, ANCOVA and NVivo
A16	2	1	1	Independent sample t-test, paired sample t-test
A17	2	1	4	Dependent t-test and NVivo
A18	2	1	3	Independent samples t-test
A19	2	1	2	MANOVA and ANOVA
A20	2	1	3	ANCOVA
A21	2	1	1	Descriptive statistics
A22	2	1	1	t-test
A23	2	2	3	MANCOVA
A2	2	1	1	Descriptive analysis
A4	2	1	5	Wilcoxon signed-rank test and content analysis
A24	2	1	2	ANCOVA and ANOVA
A3	2	1	3	ANCOVA
A6	2	2	4	Two-way MANCOVA
A8	2	1	3	One-way ANOVA
A25	2	1	1	One-way ANOVA and thematically

Note: N: Number; IV: Independent variable; DV: Dependent variable; Gp: Group

Concerning to the number of dependent variables, as can be seen in Table 3, there are nine studies [A2, A7, A10, A13, A15, A16, A21, A22, A25] that measured only one dependent variable. But, the remaining studies measured two or more variables. Most of the nine studies had selected t-tests for their inferential statistics, except [A25] which applied one-way ANOVA. In addition, two of these studies [A2, A21], didn't use inferential statistics to make inferences from the samples about the populations from which they have been drawn; rather they used descriptive statistics. Descriptive statistics are used only to describe, summarize, or explain a given set of data [B15], not to infer.

The rest of sixteen studies, those having two or more dependent variables, had employed different inferential statistics such as t-tests, ANOVA, ANCOVA, MANOVA, Wilcoxon signed-rank test, Mann-Whitney U-Test, and other qualitative data analysis techniques like NVivo, thematically, and content analysis. For example, [A1] used exclusively t-tests for his study with many dependent variables though MANOVA is used when there are multiple dependent variables [B14]. Moreover, [A5] adopted ANCOVA; [A12] used two-way MANCOVA; [A7], and [A9] employed t-test and ANCOVA; [A11] adopted one-way ANOVA, Scheffé Post-hoc test, chi-square tests and two-way ANOVA. Similarly, [A14] used independent sample t-test, ANCOVA and NVivo; [A19] adopted MANOVA and ANOVA, and [A20] used ANCOVA.

Chemistry Topics Used in ICB Chemistry Studies

In Table 4, the topics of general chemistry used by ICB studies are summarized. In the 25 studies, 20 chemistry topics, used by these studies, are identified. These are hydrocarbons; alkanes;

chemical kinetics; thermodynamics; periodic table; physical and chemical changes; cleaning agents; acids, bases and salts; precipitation titration; matter and chemical reactions; acid-base chemistry; inorganic chemistry; separating mixtures; states of matter; chemistry experiments; green chemistry; chemical changes; chemical reactions and energy; and petroleum and polymer. Amongst these, Alkanes [A15, A22], thermodynamics [A4, A7], and states of matter [A8, A23] were the three chemistry topics applied for teaching and learning each by two studies.

Table 13. Chemistry Topics Investigated By Interventional CB Chemistry Studies (N = 25)

Chemistry topic	CB study	No. of study	Total study N(%)
Hydrocarbon	A1	1	
Alkane	A15, A22	2	
Chemical kinetics	A5	1	23(92)
Thermodynamics	A4, A7	2	
Chemical equilibrium	A14	1	
Periodic Table	A9	1	
Physical & chemical changes	A10	1	
Cleaning agent	A12	1	
Acids, Bases & Salts	A13	1	
Precipitation titration	A16	1	
Matter & chemical rxn	A18	1	
Acid-base chemistry	A19	1	
Inorganic chemistry	A20	1	
Separating mixtures	A21	1	
States of matter	A23, A8	2	
Chemistry experiment	A2	1	
Green Chemistry	A24	1	
Chemical changes	A3	1	
Chemical rxn & energy	A6	1	
Petroleum and polymer	A25	1	
Not stated	A11, A17	2	2(8)

Note: N: number; CB: context-based; rxn: reaction

The remaining chemistry topics such as hydrocarbons [A1], chemical kinetics [A5], periodic tables [A9], and so on were covred by single study. But two of the studies [A11, A17] didn't clearly specify the topic of chemistry for intervention. Generally, 92 percent (23 out of 25) ICB chemistry studies clearly reported the topics used for teaching-learning intervention, while 8 percent, 2 out of 25, [A11, A17] didn't obviously state the topic of chemistry to their readers. Thus, this review signifies those chemistry topics used by ICB studies. This implies that there are still several chemistry topics that will be used by future ICB chemistry researchers. But it doesn't mean that the aforementioned 20 chemistry topics will not be used in the future researches. One can use these topics using different instructional strategies and learning variables.

Research Variables Investigated by ICB Chemistry Studies

16 various learning (dependent) variables are illustrated in Table 5. From these variables, some of them (gender score, achievement, motivation, attitude, understanding, chemical literacy and retention) were studied by more than one studies, while most variables were investigated only by one study. Students' academic achievement is the prominent variable which was investigated by more than half percent (52 percent, 13 out of 25) of the studies [A1, A3, A4, A5, A6, A13, A14, A16, A17, A18, A19, A20, A23]. This shows that majority of the studies concentrated on measuring students' academic achievement. Next to achievement, conceptual understanding (36 percent, 9 of 25) and attitude (36 percent, 9 of 25) are the variables investigated by numerous studies.

Table 14. Types of Variables in Relation to Chemistry Topics

Dependent Variable	Chemistry Topic	N of Topic	CB Study	Study N(%)
Gender scores	Hydrocarbons; chemical kinetics; inorganic chemistry	3	A1, A5, A20	3(12)
Achievement	Hydrocarbons; chemical kinetics; acids, bases and salts; states of matter; thermodynamics; precipitation titration; matter and chemical reactions; acid-base chemistry; inorganic chemistry; chemical changes; chemical reactions and energy	11	A1, A3, A4, A5, A6, A13, A14, A16, A17, A18, A19, A20, A23	13(52)
Understanding	Alkane; periodic table; physical and chemical changes; cleaning agent; green chemistry; chemical reactions and energy; states of matter	7	A8, A9; A10, A11; A12, A15, A24, A6	9(36)
Attitude	Periodic table; cleaning agent; matter and chemical reactions; acid-base chemistry; states of matter; chemistry experiment; thermodynamics	7	A9, A12, A17, A18, A19, A23, A2, A4, A8	9(36)
Motivation	Hydrocarbons; periodic table; thermodynamics; states of matter	4	A4, A6, A14, A17, A18	5(20)
Retention	Thermodynamics; matter and chemical reactions; chemical reactions and energy	3	A1, A4, A8, A9, A17, A23	6(24)

Dependent Variable	Chemistry Topic	N of Topic	CB Study	Study N(%)
Chemical literacy	Thermodynamics; alkane; chemical reactions and energy	3	A6, A7, A22	3(12)
Interest	Thermodynamics	1	A4	1(4)
Critical sc. Literacy	Green chemistry	1	A24	1(4)
Procedural knowledge	Not stated	1	A11	1(4)
Cons. l/envir.	Thermodynamics	1	A14	1(4)
Metacognition	Chemical changes	1	A3	1(4)
Multiple-intelligence	Chemical changes	1	A3	1(4)
Problem solving skills	Petroleum and polymer	1	A25	1(4)
Integrated sc. process skill	Separating mixtures	1	A21	1(4)
Residence	Inorganic chemistry	1	A20	1(4)
Total				25(100)

Note: N: Number; CB: context-based; sc.: science/scientific; ; Cons. l/envir.: constructivist learning environment

Subsequently, retention (24 percent), motivation (20 percent), gender scores (12 percent), and chemical literacy (12 percent) are investigated by more than one studies. But the rest of dependent variables (56.25 percent, 9 out of 16) such as students' interest, critical scientific literacy, procedural knowledge, constructivist learning environment, metacognition, multiple-intelligence, problem solving skills, integrated science process skill, and students' residence (rural/urban) are each studied by only one study. In general, many studies in this review focused on either students' achievement, conceptual understanding, attitude, motivation, or knowledge retention. From this review one can find out that there are still several variables yet not investigated by previous ICB chemistry studies. Moreover, amongst the 16 learning variables, future research can also carry out investigations using different chemistry topics and instructional strategies that were not used by past studies.

Table 5 also presents several dependent variables (students' learning outcomes, measured variables) that were investigated in correspondence to the various topics of chemistry. Except for one variable (i.e., procedural knowledge), the chemistry topics were obviously stated for most of the variables for which they were measured. But for procedural knowledge, the topic of intervention was not explicitly specified by the authors [A11]. Amongst the variables, the academic achievement of students was investigated by 52 percent (13 out of 25) of the studies using 11 chemistry topics (55 percent). These imply that the academic achievement is the most frequently studied learning outcome of students.

The two learning outcomes, conceptual understanding, and attitude of students are frequently investigated variables next to achievement. Each of them was studied with 7 chemistry topics (Table 5) and 8 studies (Table 5). Subsequently, understanding and attitude, retention, motivation, and chemical literacy were studied using 4, 3 and 3 chemistry topics, and 6, 5 and 3 empirical studies (Table 5) respectively. At last, interest, critical scientific literacy, procedural knowledge, constructivist learning environment, metacognition, multiple-intelligence, problem solving skills, integrated science process skill, and residence were the least frequently measured variables in ICB chemistry studies. Each variable was measured through 1 chemistry topic (out of 20).

In this review, it seems that there are variables and chemistry topics that are not still investigated by ICB chemistry studies. For example, student engagement, inquiry skills, decision-making skills, argumentation, and science process skills are some of the variables which are not yet studied. Atomic theory, chemistry of solutions, polarity and shapes of molecules, bonding theory, separation of mixtures, chemical calculations, and many are some of the chemistry topics that need attentions by future CB chemistry researchers. Thus, in general, it becomes clear for context-based chemistry researchers that which learning variables are not yet well studied in relation to chemistry topics, and which topics, in relation to variables, are not investigated by the twenty-five ICB chemistry studies.

Teaching Methods and Instructional Strategies Adopted in ICB Chemistry Studies

Teaching Methods and Interventional Strategies

In Table 6, the different participatory teaching methods under the umbrella of CB approach are presented in relation to the nature of instructional strategies adopted by 25 ICB chemistry studies. A teaching method is an effective scientific way of presentation of a subject matter based on a selected approach [B4]. It is then the practical realization of an approach. It is a wider term covers a strategy of teaching. It can be generally categorized into *participatory* (e.g., hands-on activities, group discussions, questioning and answering, problem-based learning, and so on), and *non-participatory* (e.g., lecturing, and demonstration) teaching method. Thus, since context-based approach follows constructivist's principles, ICB chemistry studies are expected to adopt participatory teaching methods.

Table 6. Types of Instructional Strategies and Teaching Methods

Instructional Strategy	Teaching Method [Study]
Reading & analyzing of articles	Metacognitive prompts [A11]
REACT	Worksheets, animation, molecule model [A15]
	Not stated [A15]
7E cycle	Computer-assisted instruction [A16]
ARCS	Experiments [A17]
PBL	Worksheet [A4]
Scrum methodology	Assignments, exercises [A24]
4Ex2 model	Experiments, worksheet [A2]
5E learning cycle	Spider web metaphor, demonstration [A6]
	Not stated [A23]
Storyline	Images, lab works, worksheet, discussion [A7]
	Not stated [A9, A10]
EEKPST	Not stated [A12]
5E+REACT	Not stated [A13]
Procedures without specific names	Spider web metaphor, simulation [A7]
	Not stated [A21]
	Group discussion, presentation [A25]
	Experiments [A18]
Not stated	Worksheet [A3]
	Problem-solving [A5]
	Not stated [A1, A14, A19, A20, A22]

Note: PPT: PowerPoint

Based on the above table, fourteen studies (56 percent, 14 out of 25) used certain kinds of participatory teaching methods with openly stated CB instructional strategies, otherwise lists of procedures. However, amongst the remaining studies (44 percent, 11 out of 25), some of them specified either the teaching methods [A3, A5, A18], or instructional strategies [A2, A4, A6, A7, A9, A10, A11, A12, A13, A15, A16, A17, A23, A24]; while the rest of the studies [A1, A14, A19, A20, A22] stated neither teaching methods nor instructional strategies under their context-based

instructional approach. For instance, [A7] used spider web metaphor and computer simulations using storylines. One study [A15] also adopted REACT strategy under the four teaching methods: worksheets, animation, molecular model, and experiments. But, amongst the fourteen studies two of them [A7, A25] didn't obviously state the name of the instructional strategy rather the authors revealed the procedures of the teaching methods. Thus, this indicates that only 36 percent (9 out of 25) of the total studies (N = 25) were conducted with undoubtedly named teaching methods and instructional strategies.

This review identified 10 context-based instructional strategies adopted (with specific names) by ICB chemistry studies (Table 6). These are REACT, PBL, 4Ex2, 5E, 5E+REACT, 7E, storyline, EEKPST, ARCS, and scrum methodology. The other strategies like reading and analyzing of science articles [A11], procedure without specific names [A7, A21, A25] were not included in the total number of strategies as their specific names were not identified by the authors. 17 studies were undertaken with specified type of CB strategies whereas; 8 studies were conducted without obviously stated strategies. For example, [A9], [A10], and [A8] adopted similar strategy (i.e., storyline) when [A6], and [A23] employed 5E learning cycle in their context-based approach. But [A1, A3, A5, A14, A18, A19, A20, A22] didn't mention the names of the CB strategies or procedures they employed.

On the other hand, different from the two types of studies, mentioned above, there are three studies [A7, A21, A25] that had properly written the detail CB procedures though the appropriate

names of the strategies were not noticeably reported. That is, in these reviewed studies, the procedures for the selected teaching methods under the CB approach were described well but the the names of the procedures were not stated to their readers. Thus, generally, 32 percent (8 out of 25) of the studies didn't not state the proper name of the strategy adopted in the context-based approach of instruction.

The Effectiveness of Context-Based Instructional Strategies per Chemistry Topics and Research Variables

Table 7 shows the various topics of chemistry corresponding to the adopted context-based instructional strategy and the number of studies using this strategy. As it can be seen in the table, different chemistry topics, by different studies, were investigated by the same instructional strategy, or the same chemistry topic was studied by using different strategies. For example, *alkane* was studied with the same strategy, REACT, by two different studies [A15, A22] (Table 6), while, a *state of matter* was studied using different strategies (viz., 5E learning cycle and storyline) by two different studies [A8, A23] (Table 6) at different time.

In addition, thermodynamics [A4, A7] was studied using PBL strategy and lists of procedures (unnamed strategy), periodic table [A9], and physical and chemical changes [A10] were investigated using storylines. Cleaning agents [A12] were also addressed by employing EEKPST (need-to-engage, need-to-explore, need-to-share, need-to-know, need- to-transfer and need-to-proceed) strategy. Acids, bases and salts were investigated with 5E+REACT strategy. Moreover, other studies

[such as A3, A6, A16, A21, A24], and investigated precipitation titration, separating mixtures, green chemistry, chemical changes, and chemical reaction & energy by adopting 7E cycle, unnamed procedures, scrum methodology, 4Ex2 model, and 5E learning cycle respectively.

However, 7 extra chemistry topics such as hydrocarbon, chemical kinetics, chemistry experiments, chemical equilibrium, matter and chemical reactions, acid-base chemistry, and inorganic chemistry were not studied by using explicitly stated context-based instructional strategies. For instance, hydrocarbon was studied by [A1] with no clearly named strategy or properly listed procedures. Some studies didn't mention either the specific names of the strategies or lists of procedural activites during studying of the aforementioned chemistry topics [A1]. Therefore, this review makes clear, for readers, that which chemistry topic was studied by what instructional strategy and which one was with unclear (not stated) strategy.

Conventional science programs have focused on the idle forms of teaching of theoretical facts and concepts in a fixed, direct, and logical order [B16, B17]. Several secondary school science/chemistry education problems were associated with such kinds of courses that lack of the linking of concepts to the everyday life of students which ultimately leads to a decline of students' achievement, motivation, interest, and attitude towards science subjects. When science educators and researchers attempted to introduce contexts into science and chemistry courses, their focuses were to address these problems by connecting concepts with contexts and engaging students more in their own learning activities. Thus, theme 5 focuses on the effectiveness of context-based

instructional strategies with respect to chemistry topics used and research variables measured in the studies.

Table 8 provides 22 ICB chemistry studies from the total of 25 studies as the remaining 3 studies did not clearly specify either the instructional strategies or chemistry topics. According to this table, most studies (81.8 percent, 18 out of 22) reported the effectiveness of context-based approach education using different instructional strategies in several chemistry topics (e.g., precipitation titration, separating mixtures, thermodynamics, states of matter, etc.). These studies have found that context-based chemistry instruction brought significant changes on students' learning outcomes. For example, two studies [A9, A10] were carried out on periodic table, and physical and chemical changes by employing the same strategy (i.e., storyline) on students' understanding, attitude, and retention. Both studies confirmed that a storyline is an effective context-based instructional strategy in both topics of chemistry (periodic table, and physical and chemical changes). Likewise, other 16 studies (out of 18) also approved that context-based approach, using a diverse instructional strategy, is an effective way of instructional approach over the conventional instructional approach.

Table 8. The Effectiveness of CB Instructional Strategy in Relation to Chemistry Topic and Measured Variables in ICB Studies

Strategy	Chemistry topic	Dependent variable	Effectiveness	Number of studies
REACT	Alkane	Understanding	Significant	2
		Achievements	Significant	
PBL	Thermodynamics	Retention	Significant	1
		Attitudes	Not significant	
		Motivation	Not significant	
		Interest	Significant	
	Petroleum and polymer	Problem solving skills	Significant	1
Storyline	Periodic table	Understanding	Significant	1
		Attitude	Significant	
		Retention	Significant	
	Physical & chemical changes	Understanding	Significant	1
EEKPST	Cleaning agent	Understanding	Significant	1
		Attitude	Not significant	
5E+REACT	Acids, Bases and Salts	Achievement	Significant	1
7E cycle	Precipitation titration	Achievement	Significant	1
List of procedure	Separating mixtures	Integrated science process skill	Effective	1
	Thermodynamics	Chemical literacy	Significant	1
5E learning cycle	Chemical reactions & energy	Understanding	Significant	1
		Achievement	Significant	
		Chem. literacy	Significant	
		Motivation	Not-significant	
		Gender scores	Not-significant	
	Hydrocarbon	Achievement	Significant	1
Not stated		Retention	Significant	
		Gender score	Not-significant	
	chemical kinetics	Achievement	Significant	1
		Gender score	Not-significant	
	Chemistry experiment	Attitude	Positive	1
	Chemical equilibrium	Achievement	Significant	1
		Motivation	Significant	
		Con. l/ envir.	Significant	
	Matter & chem. reactions	Achievement	Significant	1
		Motivation	Significant	
		Attitude	Significant	
	Acid-base chemistry	Achievement	Significant	1
		Attitude	Significant	
	Inorganic chemistry	Gender score	Not significant	1
		Residence score	Significant	
		Achievement	Significant	

Note: Cri. sc. lit: critical scientific literacy; multi. -intell.: multiple-intelligence; con. l/ envir.: constructivist learning environment

Moreover, there are four studies [A1, A5, A6, A20] reported on gender difference regarding to the mean scores of students' achievement. As stated by these studies, student scores have been appeared to have non-significant mean difference regardless of their gender in hydrocarbons, chemical kinetics, chemical reaction and energy, and inorganic chemistry achievement tests.

In contrast, four studies reported contradicting results with respect to students' motivation, attitude, and multiple intelligences in certain topics of chemistry. Three of the four studies [A3, A4, A12] argued that context-based approach using 4Ex2, PBL, and EEKPST strategies do not cause significant changes on students' multiple-intelligence, motivation, and attitude towards chemical changes, thermodynamics, and cleaning agents respectively. [A4], and [A6] also reported that teaching of thermodynamics, and chemical reactions and energy with PBL, and 5E learning cycle have no significant effects on students' attitude, and motivation in that order. Thus, studies on the context-based approach provided inconsistency and conflicting reports on certain learning outcomes of students like motivation, attitude, and multiple-intelligence. Hence, there is a need to conduct further studies and to resolve these contradictions.

SUMMARY, IMPLICATIONS AND RECOMMENDATIONS

This systematic review of studies on interventional context-based approach in chemistry education is timely as this approach has gained popularity amongst chemistry and science

researchers. It is essential to understand the current practices in the field to shed light on coming implementations. A total of twenty-five articles (64 percent in Europe, 16 percent in Africa, and 16 percent in Asia) were deeply analyzed and framed around six major research questions.

According to this in-depth analysis, it has been known that most ICB chemistry studies (76 percent) preferred to adopt quasi-experimental designs over the true- and pre-experimental design options. No true-experimental studies were identified, except few pre-experimental (20 percent, 5 out of 25) studies. Though most quasi-experimental studies employed quantitative approach, there were few studies (32 percent) selected mixed-method procedures. However, these mixed-method studies didn't clearly state the weight and timing of the quantitative and qualitative approaches. Thus, it can be said that the interventional context-based chemistry studies need to have explicitly stated research methods and designs to make more understandable by the readers.

When chemistry topics are considered, 20 topics are used by the interventional context-based studies. Although most of the studies (92 percent) reported the topics of study used, two of them [A11, A17] didn't noticeably state the kind of topics to their readers. This implies that there is a need to make clear the type of topics applied by studies, and there is also a need to carry out investigations by using other topics of chemistry which are still not yet addressed by interventional context-based chemistry studies. Not only this, but researchers can also conduct their studies using those identified chemistry topics with other dependent variables.

Regarding to research variables, the review identified 16 dependent variables measured by the 25 interventional context-based chemistry studies. This suggests that there are still other variables to be investigated by future studies. There is also a possibility to conduct studies amongst the 16 variables by varying chemistry topics in different matches. In relation to the data analysis techniques, most studies adopted t-tests and ANOVA for one and more than one dependent variables, except few studies those employ MANOVA [A6, A12, A19, A23]. Running MANOVA can help to reduce the occurrence of Type I error rather than conducting individual t-tests [B15].

Choosing appropriate teaching methods and instructional strategies under a particular approach is very crucial for a successful implementation of the approach. In context-based approach, it has been agreed that the adopted teaching methods should be participatory, and the instructional strategies should be context-based with descriptive procedures. Most ICB studies adopted proper teaching methods and instructional strategies. In this review, 11 context-based strategies were identified in the 25 studies. However, in some cases, the adopted teaching methods and instructional strategies were not explicitly stated by 44 and 32 percent of the studies respectively. Therefore, it is very helpful for researchers to identify what kinds of teaching methods are adopted with which instructional strategies and which are not.

The effectiveness of the context-based approach on students' learning is also an important issue that chemistry educators and researchers seek to know. It has been stated that the context-based approach is usually accompanied with specific teaching methods and instructional strategies adopted

through it. In this regard, it seems that the effectiveness of the context-based approach may depend on the types of teaching methods and instructional strategies selected and used by researchers. Even though, in this review, more than 80 percent [e.g., A5, A6, A20] of the studies have claimed the effectiveness of context-based approach over the conventional instructional approach, there are some studies reported contradictory results.

For example, a context-based approach didn't bring a significant change in medical laboratory students' motivation and attitude towards thermodynamic chemistry using a specific instructional strategy (PBL) and teaching method (worksheet) [A4]. Similarly, [A3] argued that pre-service chemistry students did not show a statistically significance difference in their multiple-intelligence during learning of chemical changes using a context-based approach by adopting 4Ex2 model as instructional strategy, and experiments and worksheets as teaching methods. Thus, these indicate that there is a need of conducting research on such inconsistent findings by varying teaching methods, instructional strategies, chemistry topics, and contexts.

In sum, this systematic review is unique and has great importance in identifying research gaps and inconsistencies in a body of knowledge. According to the outcomes of this review, worldwide countries where interventional context-based approach studies are concentrated, chemistry topics used by context-based approach studies, dependent variables frequently measured, the appropriate instructional strategies used through context-based approach, and the teaching methods used under context-based approach are identified. In addition, inconsistency reports

regarding to the effectiveness of the context-based approach on students' learning outcomes are also assessed in this review study. Generally, the findings from this systematic review provide a roadmap for future studies in context-based approach chemistry education.

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