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CONTEXT-BASED LESSONS WITH 5E MODEL TO PROMOTE CONCEPTUAL UNDERSTANDING OF CHEMICAL REACTIONS AND ENERGY CONCEPTS

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Abstract. *This study explores whether the context-based approach with 5E model (CBA-5E) can lead to better understanding of chemical reactions and energy concepts when compared to conventional instruction (CI). Additionally, the study delves into the effect of treatment with regards to gender. Eleventh grade science-major classes with 175 students from two public high schools were enrolled. The experimental groups were treated with CBA-5E, the control groups as CI, the treatments were randomly assigned to the groups. The chemical reactions and energy concepts test, including the common alternative conceptions, was administered as pre- and post-test. The chemical reactions and energy achievement test, including conceptual and algorithmic problems, was administered as a post-test to the groups. Multivariate Analysis of Covariance (MANCOVA) was used for the analysis of the data, and the results revealed that CBA-5E was superior to CI on the students' conceptual understanding regarding these concepts regardless of gender difference.*

Key words: *chemical reactions and energy, conceptual understanding, context-based lessons, gender, 5E model.*

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Introduction

Context-based approach has attracted national and international attention in science education field for the last decades. A considerable number of studies have investigated its impact on different concepts (Bennett & Holman, 2002; Campbell & Lubben, 2000; Fensham, 2009; Schwartz, 2006). Although CBA has become more prevalent, the existing literature is usually, and much more, focused on students' interests rather than conceptual understanding in chemistry. Belt, Leisvik, Hyde and Overton (2005) studied thermodynamics, kinetics, and electrochemistry for undergraduate physical chemistry. They concluded that students enjoyed studying chemistry within a context and, consequently, their knowledge of school subject developed. Barker and Millar (1999) investigated students' reasoning of chemical reactions in a context-based post-16 chemistry course, and revealed that their understanding had improved permanently as the course progressed. Kortland (2007) developed a contextual lesson on traffic situations and stated that studies on developing didactical structures for enhancement of teaching learning of concepts uses sequences in designing lessons.

In addition, the existing research on CBA has deficiencies related to a clear description of the instructional models and the methodology (such as, experimental-control group designs) used in the design of CBA. Taasoobshirazi and Carr, (2008) have made critical remarks related to this issue in physics education. They state that it is not easy to draw conclusions about the effectiveness of context-based instruction, since significant methodological problems exist in the majority of the studies they reviewed. Some of these problems include; no comparison group designs, no assessment of achievement, and no pre-test or post-test designs, thus making it impossible to know whether any change occurred in learning. In a majority of CBA studies, the instructional method, strategy or the model used during the implementation is not described in detail either.

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Exploring whether the treatment has an effect across gender in science related fields has been concern of research studies for a long time. Nieswandt (2005) revealed that males and females were differently affected from implementations; females usually work better when they are engaged in social activities, and small group works, contrarily, males usually prefer to work individually. Specifically related to contextual learning, Taasoob-shirazi (2007) stated that gender differences in achievement as well as the motivation to learn physics may be minimized by context-based instruction by making the lesson more relevant to students. De Jong (2006) states that a context is required to be well-known and relevant for both boys and girls in order to avoid situations or contexts which will favour males or females. That is, the selection of context in context-based approach becomes also critical in order to avoid causing superiority for males or females. According to Gilbert (2006) a context should be designed in a way to engage all students, the collection of contexts should have better to make chemistry more relevant to all students. Therefore, this study found it necessary to explore the effect of treatments on gender too.

When it comes to fundamental topics in chemistry, CBA integrated with any specific instructional model has not been incorporated into concepts of chemical reactions and energy (CRE). In this respect, only a few studies have reported students' understanding of CRE concepts such as, Barker and Millar, (1999; 2000), De Vos and Verdonk, (1985a) and Goedhart and Kaper, (2002). Because of its abstractness, difficulty, and popularity in society, the concepts of chemical reactions and energy (CRE) deserve far more scrutiny. The rationale for conceptual understanding of these concepts is described by Goedhart and Kaper (2002) as follows. First, these concepts are experienced in the classroom or outside the school frequently. Second, the comprehension of reaction energy and relevant concepts enables students to predict some parameters regarding chemical processes that students will learn later. The third reason is related with scientific literacy; because energy is a societal issue, students as educated citizens are expected to have a certain understanding of these concepts. The concepts of heat and temperature, endothermic-exothermic changes constitute the base for understanding of the concepts. The unit is entitled as *Chemical Reactions and Energy* in the national eleventh grade chemistry curricula in Turkey. Considerable number of studies reported students' problems related to these concepts. Table 1 has some common problems reported in the literature.

Table 1. Common problems related to CRE concepts.

Concepts	Problems with concepts	Studies
Heat and temperature	Distinguishing between heat and temperature	Goedhart & Kaper (2002), Yeo & Zadnik (2001)
Endothermic and exothermic changes	Identifying reaction as endothermic or exothermic. Difficulties in understanding exothermic /endothermic reactions and spontaneity.	De Vos & Verdonk (1986a); De Vos & Verdonk (1986b); Boo &Watson (2001)
Bond formation-dissociation energies	Bond breaking is an energy release process Energy is required for bond making. Bond making is endothermic process	Barker & Millar (2000); Boo & Watson (2001); Goedhart & Kaper (2002)
Chemical reactions and calorimeter	System and surrounding are the same	Greenbowe &Meltzer (2003)
Entropy & disorder	Entropy and disorder are the same, Entropy is cause of disorder in the system	Sözbilir & Bennett (2007)

These issues justify the need for promoting students' conceptual understanding. The designed lessons based on CBA integrated with the 5E model can be implemented in the teaching and learning of CRE concepts in a way to overcome the above-mentioned problems. The implementation of CBA through this strategy requires a specific design, in which the critical effort is put for meaningful learning. The present study will reveal whether the integration of CBA with 5E model will lead to better understanding by remedying existing misconceptions of students in CRE concepts. The authors' hypothesis is "design can resolve the learning difficulties experienced with CRE concepts by allowing students to construct their own knowledge". Recognizable contexts attract students and provide a "need-to-know" basis (Westbroek, 2005) for chemistry concepts to be learned. The present study describes the design of contextualized instruction using the context of a 4-stroke car engine through the 5E model addressing the concepts of CRE. Thus, the paper aims to investigate the effectiveness of CBA through 5E over the conventional instruction (CI) on conceptual understanding of eleventh grade high school students, whilst avoiding differences in the effect of treatment with regards to gender.

Theoretical Background

Context-Based Approach; the Use of "Context" in Chemistry Education: Gilbert (2006) describes "context" as a tool to provide a rational structural comprehension of a topic newly introduced in a broader perspective. Some clues are provided regarding the term, referring to it as a "focal event", which is embedded in the cultural settings of a society with four attributes: (a) a context requires a platform, on which a social-spatial framework is established for mental encounters to be settled with focal events. For this specific study, within the framework of Gilbert's (2006) description, historical development of cars, from steam to 4 stroke engines was established. (b) It is a behavioural environment for encounters, and the way in which the concepts are associated with the addressed focal event. In this study, production of more efficient cars, more efficient fuels, bio-fuels, high octane ratings, reduction of environmental hazards was talked. (c) It is the use of language, since conversation takes place with regard to the focal event. About this, the efficiency of car engines, 1.4, – 1.6 or 2.0 capacity; different energy types; energy related discussion in the society were discussed. (d) It is the relationship to the extra-situational knowledge attained. Chemical reactions and energy terms in car engines; system, surrounding, heat, work, internal energy were explored as background for those who act. According to Gilbert, how attributes a-d are connected to context-based education are explained by ideas of situated learning. First, idea is participation in a group of activities which means students and teachers must accept themselves as engaging together in "community of learners". Next, idea is the effective involvement of students and teachers to develop their identities by means of constructive interactions. Participation of students in productive interactions could be assisted by teachers and students to improve students' identities as learners.

In addition to Gilbert (2006) context description, Westbroek (2005) proposed three key features for meaningful chemistry learning. These are: use of (a) *context* (b) *need-to-know* and (c) *attention for students' input.* Briefly, the collection of contexts utilized should bring about the likelihood of transferring concepts to other contexts to develop students' ability in relating knowledge they have learnt to other situations. *Context* for concepts provides the use of concepts with a distinct function, and thereby makes students' use of the concepts meaningful and motivating. Then, addressing students' questions on a *need to know basis* "which also implies properly building on their existing knowledge, provides for an increasing involvement of students in the teaching-learning process, as they will see the point of what they learn every step of the way" (Westbroek, 2005, p.18). The third characteristic is closely related to the second characteristic: if one aims at *really* incorporating a need-to-know approach in the design of a teaching-learning process, then 'real attention for student input' is inevitable. In a successful *need-to-know* approach students have more insight into and experience the functionality of 'what comes next'. Thus, the teacher has more opportunity to pay real attention to their input, which now could become a driving force of the content-related progression. Within this respect, this study utilizes both Gilbert (2006)' educational context framework and Westbroek (2005)'s framework to address the concepts of chemical reactions and energy.

CBA has potential to be integrated with a variety of instructional models to reach specific purposes for implementations in which contexts are critical components in the teaching-learning environment. Since the specific purpose of learning under the study concerns the conceptual understanding of CRE, the authors choose the 5E model because it supports the remediation of the alternative conceptions held by students. The reason to integrate CBA with 5E model is they have some common characteristics for improvement of teaching and learning to deepen the discussion related to the concepts of chemical reactions and energy on real-world issues and to make flow of the lessons more explicit. As designed in the sample lesson plans provided by current Turkish National Physics curriculum, CBA was integrated into 5E model through each phase. Figure 1 shows the intersections and differences of them and it indicates the main theoretical framework utilized in this study.

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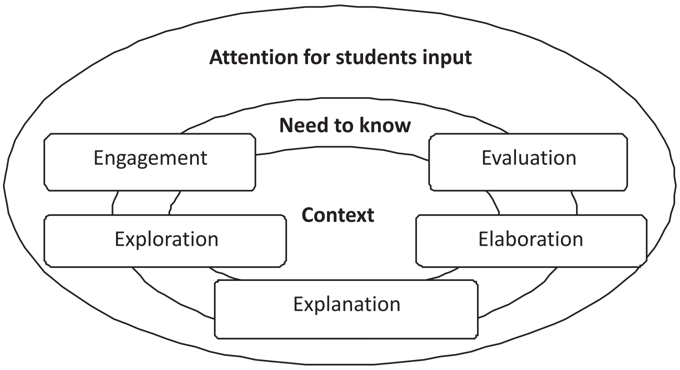

Figure 1: Theoretical framework.

Learning *Cycle* (LC) *Strategy; The 5E Instructional Model,* LC is accepted as an instructional strategy that improves students' understanding of science concepts and supports their affective factors while remediation the alternative conceptions students pose (Bybee et al., 2006; Ceylan & Geban, 2009; Marek et al., 2003). According to Bybee et al. (2006), the 5E instructional model takes its roots from the constructivist philosophy of education and supports inquiry-based science learning. The strategy has five phases, which are engagement, exploration, explanation, elaboration, and evaluation. Based on the Bybee et al. (2006) description, the each 'E' is a phase which functions differently to support teachers' instructions and students' understanding, attitudes, and skills.

Abraham (1997) describes LC as an appropriate strategy for developing well-designed curriculum materials and instructional strategies in the field of science education. Additionally, Bybee et al. (2006) pursued research further on LC strategy which implies positive impacts on attaining subject matter and scientific reasoning in science concepts. Similarly, Marek refers to LC as "move students through a scientific investigation by encouraging them first to explore materials, then construct a concept, and finally apply or extend the concept to other situations" (p. 63, 2008). Substantial literature on LC strategy proved it to be an effective way for conceptual understanding (Bybee et al., 2006; Ceylan & Geban, 2009). The literature on CBA lacks satisfactory evidences to conclude that it is powerful on conceptual understanding. On this basis, designing materials incorporating LC strategy and CBA have the potential to play a significant role in relating theoretical knowledge to real life applications in developing conceptual understanding.

In this study, CBA is defined as "a way of instruction adopted in science teaching, in which contexts and applications of science are used as the *starting point* for the development of scientific ideas which contrasts with more traditional approaches covering scientific ideas first and conclude with a brief mention of applications" (Bennett et al., 2006, p.348). CBA with 5E model is defined as an instruction in which each "E" of 5E is provided over the context chosen and inquiry-based activities are provided. On the other hand, we describe conventional instruction as a teacher-centred instruction in which the teacher introduces the concepts, makes algorithmic problems solving and calculations on the board and rarely demonstrates experiments during those students listen, take notes and occasionally ask questions or make comments. The *research questions* are; (1) Does CBA integrated with 5E model lead to better learning results compared to CI in the conceptual understanding of chemical reactions and energy concepts? (2) What, if any, is the effect of interaction between gender and treatment with respect to the students' mean scores obtained from chemical reactions and energy tests?

Methodology of Research

The quasi-experimental design was utilized as a type of experimental research for the study. In order to compare the effect of CBA-5E with CI on students' understanding in CRE concepts, the treatments were randomly assigned to the intact classes which were already formed. The CBA-5E classes were experimental groups (EGs), the CI were control groups (CGs). The study was carried out with eleventh grade students aged 15-17 at two schools with three teachers in 2011.

Table 2. Research design of the study.

Groups	Pre-tests	Treatments	Post-tests
EG	CRECT, SPST	CBA-5E	CRECT, CREAT
CG	CRECT, SPST	CI	CRECT, CREAT

Note. EG: Experimental group, CG: Control group, CRECT: Chemical reactions energy concept test, SPST: Science process skill test, CBA-5E: Context-based approach with 5E model, CI: Conventional instruction, CREAT: Chemical reactions energy achievement test.

Sample

Eleventh-grade science major students in two public high schools from the same distinct were conveniently selected as the sample of the study. The scores of students obtained from high school entrance examination for these two schools were close to each other. From school A teacher X (female) and teacher Y (male), and from school B, teacher Z (male) were volunteers for participating in the study. Teachers had experience of at least 10 years. Each teacher had an experimental group (EG) and a control group (CG); that is, there were three EGs and three CGs for implementations. The subjects consisted of 175 eleventh grade science major students. Of these, 94 were females and 81 were males. 91 of the participants (39 male, 52 females) were in EGs and 84 of them (42 males 42 females) were in CGs. The details are given in Table 3.

Table 3. The distribution of the sample.

	School-A				School-B		
	Teacher X		Teacher Y		Teacher Z		Total
	CG-1	EG-1	CG-2	EG-2	CG-3	EG-3	
Male	8	10	18	13	16	16	81
Female	20	20	12	17	10	15	94
Total	28	30	30	30	26	31	175

Instruments

The instruments used in this study are Chemical Reactions and Energy Concept Test (CRECT), Chemical Reactions and Energy Achievement Test (CREAT), and Science Process Skill Test (SPST). Both CRECT and CREAT were set as traditional questions, as Bennett and Holman (2002) claimed that if the scope of a context-based lesson design is to develop conceptual understanding, then students could be assessed in de-contextualized ways about their understanding of chemical ideas.

Chemical Reactions and Energy Conceptions Test (CRECT): It included common misconceptions to reveal both students' pre-conceptions about chemical reactions and energy and their conceptions after the implementations. The instrument was originally developed by Yeo and Zadnik (2001) and translated to Turkish by Ceylan (2004). In its original form, CRECT had 20 multiple-choice items, five of which were assigned to students' pre-conceptions, and the rest to learning outcomes of the current 11th grade chemistry curriculum. Seven items were taken from Ceylan (2004) and 13 were developed by authors. The test was piloted with 12th grade science major students, resulting in some item revisions. Based on the pilot study scores, the item difficulties and item discrimination indexes were checked with ITEMAN, item analysis program, and they were found within the acceptable ranges. The questions were classified into categories of, heat-temperature and energy, energy of bond dissociation and bond formation, endothermic and exothermic changes, heat of reactions, enthalpy, spontaneous changes, systems and energy, entropy changes, and Gibbs free energy. The validity of the test was established by three experts in chemistry education field and a chemistry teacher. Also, feedback by one Turkish language expert and another chemistry teacher was used for both understandability and face validity of the instrument. Once again, the final version of

CRECT had 20 items, the maximum score is 20, the minimum is 0.The Cronbach alpha reliability of the test scores was found to be .72. Final version of the test was administered to experimental and control groups both as a pre-test and as post-test.

Chemical Reactions and Energy Achievement Test (CREAT): The authors developed CREAT to assess students' understanding of conceptual and algorithmic problems about chemical reactions and energy. Based on the learning outcomes, researchers constructed them by utilizing textbooks and National university entrance exam tests. There were 25 multiple-choice questions in CREAT, the maximum score is 25, and the minimum is 0. The appropriateness and content validity of the test was established by chemistry teachers, chemistry education experts. The first version of the test was piloted with 85 12th grade students before the treatment. According to item analysis, item difficulty and discrimination indexes were checked, some of the questions were revised, some were dropped, and instead new ones were constructed. The Cronbach alpha reliability of the final version of the test scores was found to be .74. The test was administered to both EGs and CGs after the treatment in regular class hours as a post-test to determine the effect of treatments on students' understanding.

Science Process Skill Test (SPST): It was originally developed in 1982 by Okey, Wise and Burns. Later, Geban, Askar, and Ozkan translated and adopted this test into Turkish in 1992. The instrument was constructed to measure the intellectual abilities of students in identifying variables, stating and identifying hypotheses, defining and designing investigations operationally, graphing and interpreting data. Since the treatment included experiments and hypothesis testing, the researchers utilized the test to reveal equality of groups before implementation. There are 36 items in this test and each question is in multiple-choice form with four alternatives, the maximum score is 36, the minimum is 0. The Cronbach alpha reliability of the test scores was found to be .88. Both EGs and CGs took this test before the instruction.

Treatments

Context-Based Approach with5E Learning Cycle Model: Based on the descriptions of Gilbert (2006), Westbroek (2005), and Bybee et al. (2006) lesson plans integrating 5E model were designed. Initially, in the *engagement* phase students' curiosity was stimulated by asking questions related to the context of "Cars". At the beginning of the lesson, the context was presented to students as a form of discussion; teachers took students' responses and asked further questions to deepen the discussion as much as possible. For example, in the first lesson plan (see table 4 for all lesson plans), the teacher asked about handout distributed; and further inquired about the applications of chemistry in cars. The simulation video of "how car engines work" was displayed and additional questions were asked. Related to systems and energy types, students guessed a 4-stroke engine cylinder to be an open system and further discussion was carried on other system types. For, energy transformations in a cylinder, the teacher asked more questions and students made some guesses. The discussion was taken to matter-energy transformations, heat-mechanical and energy-internal energy changes as well as the first law of thermodynamics using context-related questions. Here, the teacher assured to elicit students' prior knowledge as starting point to engage students in construction of new knowledge and get them to come into disequilibrium. This process was progressed over the context.

Then, from the contextual questions, discussions, and experimental activities the teacher continued with creating a need-to-know base for new knowledge construction. The next step, *exploration* phase, an experiment was conducted by the teacher in class asking questions related with the experiment so as to stimulate students' curiosity. Related to that experiment, the teacher asked students how the reaction of zinc with hydrochloric acid would move the piston, why the motion was upward and whether the work was done by the system or the surroundings. Later, the students are asked to write their hypothesis regarding the questions, and then the students performed the experiment and tested their hypothesis by working in groups. At this step the disequilibrium was created.

The next step was *explanation* phase, where the students were required to answer the questions given in the previous phases. The teacher constantly guided, posed additional questions to students to make them explain their ideas and observations in their own words in order to help them to resolve the disequilibrium. For example, it is asked which parameters were important in terms of work, heat and internal energy. While anticipating the responses, the teacher provided additional explanations whenever needed, as well as briefly explaining and clarifying students' ideas and observation related to work-heat-energy transitions. The formula related to internal energy and parameters that contribute internal energy were also explained in this step. In the next phase, *elaboration*, students watched another video (a closed system) and the teacher asked even more questions for purpose of elaborateness. For example, it was asked how the heat of the system changed (enthalpy change), and how this change is related to the internal energy of the system. The teacher elicited from students more examples from daily life so as to further explain those type of systems such as open, closed, isolated, isothermal along with energy transformations and heat-work- energy relation in systems. Production of more efficient cars, more efficient fuels, bio-fuels, high octane ratings, reduction of environmental hazards was discussed here. Thus, at the end of this step, the need-to-know base which provided more insight into and experience the functionality of 'what comes next' was satisfied.

The final step of the CBA with 5E model is *evaluation* where the context-related questions were directed to students and the main concepts were clarified in detail. The knowledge constructed was transferred to other contexts or problem situations. In this step, students' evaluated their own understanding. Together with satisfaction of need-to-know base and attention for the students' input were established all lesson plans. Thus, the teacher has more opportunity to pay real attention to their input, which could become a driving force of the content-related progression.

Table 4. Lesson plans implemented in experimental groups.

The context for chemical reactions and energy unit: cars			
Lesson plan I: 4-stroke engines: how car engines work	Lesson plan II: Reaction of fossil fuels in engines Exp: Heat of Reaction	Lesson plan III: Air-conditioners in cars -How-refrigerators work? Exp: Liquid nitrogen	Lesson plan IV: Reading assignment: What is free about Gibbs free energy
RLO: Systems and energy types	RLO: Enthalpy change of a system	RLO: Spontaneity of changes	RLO: Entropy and Gibbs free energy

Note: RLO: Related learning outcomes of CRE unit, Exp: Experiment

Conventional Instruction; The basic framework for conventional classrooms was set as a teacher-centred instruction in which the teacher introduces the concepts, makes algorithmic problems solving and calculations on the board and rarely demonstrates experiments during which students listen, take notes and occasionally ask questions or make comments. Naturally, teacher started to briefly introduce basic concepts and later, solved some simple exemplary problems, gradually increasing the difficulty level of questions and expecting students to propose solutions. For example, just at the beginning of the lesson, the teacher wrote a title on the board and the types of systems, and clarified them in detail. Then s/he read from the textbook and students followed on to take notes to themselves. The definitions and the formulas related to heat, work, and internal energy were directly presented by the teacher and definitions were provided. In essence, the teachers were doing whatever they were doing in their routine class hours and the methods were mainly included in lecturing and questioning, with occasional discussions around the topic. Here, the difference was that real-life contexts were not introduced at the beginning, instead, after introducing main concepts the teacher generally focused on the problem solving. In control groups, the John Henry effect was reduced by movies and simulations displays same as those used in the experimental groups.

To verify the treatments, the researchers also carried out systematic classroom observations both in the experimental and control groups. After each class hour, the teacher and researcher evaluated the implementations, and the same procedure was fallowed with other teachers. Researcher necessary support was provided to teachers at any given time together with additional feedback and suggestions in order to make the intervention more in line with the purpose of the study. Additionally, the teachers were informed to teach in their control groups in the way that they were accustomed to. In all, the implementations took six weeks, in each of which, students had three chemistry lecture hours to study chemical reactions and energy concepts both for experimental and control groups. The post tests were distributed to the students at the end of the treatments.

Data Analysis

The obtained data was entered into Predictive Analytics Software (PASW) Statistics 18. The independent variables were groups (EGs & CGs) and gender (males vs. females), dependent variables were students' understanding scores measured by CREAT and post-CRECT.

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Results of Research

Prior to main analysis, whether pre-CRECT and SPST scores differ across schools and teachers was investigated, no significant difference was found.

Statistics of Pre-CRECT and SPST Score; One-way between groups multivariate analysis of variance (MANOVA) was performed to investigate if a statistically significant mean difference exists between the experimental and the control groups with respect to the pre-CRECT and SPST scores. The descriptive statistics appears in Table 5.

Table 5. Descriptive statistics for Pre-CRECT and SPST scores.

Test	N		Mean		Standard Deviations	
	CG	EG	CG	EG	CG	EG
Pre-CRECT	84	91	11.30	11.45	2.63	2.50
SPST	84	91	18.33	22.41	6.56	7.33

Before this computation, the assumptions of MANOVA; sample size, normality, outliers, linearity, homogeneity of regression, multi-co-linearity and singularity, and homogeneity of variance-covariance matrices were checked, they were not violated. When the results of the Pre-CRECT and SPST were examined, there was a statistically significant difference F (2, 172)=7.835, p=.001; Wilks' Lambda= .917 among EGs and the CGs. Then, follow up ANOVAs were examined.

Table 6. Follow-up ANOVAs for pairwise comparisons.

	Dependent Variable	Degree of freedom	F	Sig. (p)	Eta Squared	Power
Group (EG, CG)	Pre-CRECT	1	.147	.702	.001	.067
	SPST	1	14.987	.000	.080	.971

As seen from Table 5, for Pre-CRECT scores, the means are (M= 11.45, SD= 2.50) for EG and (M= 11.30, SD= 2.63) for CG. For the SPST scores, EG had (M= 22.41, SD= 7.33) and CG (M= 18.33, SD= 6.56). When the results of the Pre-CRECT and SPST were considered separately (Table 6), there was a statistically significant difference in the SPST scores, F (1, 173) =14.987, p=.000, partial eta squared=.080. A pre-existing difference in the SPST scores requires it to be controlled for statistical analysis of the post-CRECT, thus SPST scores were assigned as a covariate.

Statistical Analysis of Post-CRECT and CREAT Scores: At the end of the implementation, post-CRECT and CREAT were administered. The research questions were tested using MANCOVA (Multivariate Analysis of Covariance). In this analysis, the post-CRECT and the CREAT scores were dependent variables, the SPST score was covariate, and treatment and gender were independent variables with two categories. The descriptive are given in Table 7.

Table 7. Descriptive statistics for Post-CRECT and CREAT across the groups and gender.

	Mean			
	CG	EG	Male	Female
Post-CRECT	11.92	13.22	12.19	12.95
CREAT	14.88	18.34	16.20	17.10

EGs' mean scores on the post-CRECT and CREAT were higher than the CGs (Table 7). Whether these differences were significant were analyzed in the main analysis. 175 participants took the post-tests, of which 81 were male and 94 female. The mean scores of females on post-CRECT and CREAT were slightly higher than males (Table 7). Whether a statistical significant mean difference across males/females exists was analyzed in the main analysis. Before computing the MANCOVA, the assumptions - sample size, normality and outliers, linearity, multicollinearity and singularity, homogeneity of variances and covariance matrices, homogeneity of variance, and homogeneity of regression slopes - were controlled and no violation was observed. The results of MANCOVA were reported in Table 8.

Table 8. MANCOVA results regarding the collective dependent variables.

Source	Wilks' Lambda	Multivariate F	Hypothesis df	Error df	Sig. (p)	Eta-Squared	Observed Power
Treatment	.782	23.621	2	169	.000	.218	1.000
Gender	.971	2.558	2	169	.080	.029	.506
SPST	.943	5.081	2	169	.007	.057	.815
Treatment* Gender	.997	.254	2	169	.776	.003	.090

Based on the results given in Table 8, it is seen that the EGs and CGs had significant mean difference ($p = .000$) with respect to understanding of chemical reactions and energy concepts when their SPST scores were controlled ($F(2, 169) = 23.621$, Wilks' Lambda = .782, $p < 0.05$). This difference was obtained from the effect of treatment, and it is possible to state that the effect size was large since the value of eta-squared is found to be .218. An eta-squared value larger than .14 is said to be large, which means 21.8 % of the variance of dependent variables was aroused from the independent variables.

In addition to the effect size, the observed power (1.00) of the study indicated that the source of difference across the EGs and CGs was related to the effect of treatment. Furthermore, such a value indicated that this effect had a practical significance as well. The results revealed that there was no significant mean difference between males and females with respect to collective dependent variables of the study when their SPST scores were controlled ($F(2, 169) = 2.558$, Wilk's Lambda = .971, $p > 0.05$). The difference among the males and females was obtained as .029 from the eta-squared value. The value means 2.9 % of multivariate variance on the collective dependent variables was associated with gender. Table 8 also reveals the interaction values related to gender and treatment. Based on these values, it is clear to state that no interaction existed between treatment and gender ($F(2, 169) = .254$ Wilk's Lambda = .997, $p > 0.05$). To differentiate the effect of treatment and gender separately on each dependent variable, the univariate ANCOVAs were performed. The univariate or follow-up ANCOVA results are given in Table 9.

Table 9. Univariate ANCOVA results based on each dependent variable.

	Dependent Variable	df1	F	Sig. (p)	Eta Squared	Power
Treatment	Post-CRECT	1	13.269	.000	.072	.952
	CREAT	1	31.584	.000	.157	1.000
Gender	Post-CRECT	1	3.811	.053	.022	.493
	CREAT	1	1.069	.303	.006	.177
Treatment* Gender	Post-CRECT	1	.065	.799	.000	.057
	CREAT	1	.466	.496	.003	.104

According to Table 9, the research questions were answered. The results indicated a significant mean difference ($p= .000$) between the groups exposed to CBA and conventionally designed chemistry instruction. When students' SPST scores were controlled, EGs' understanding (Post-CRECT; $F(1, 169) = .13.269$, $p= .000$) and achievement (CREAT; $F(1, 169) = .31.584$, $p= .000$) of CRE concepts were more improved compared to CGs. The proportion of variance in the students' conceptual understanding of CRE concepts explained by the treatment is 7.2 % which means medium effect size. Additionally, the effect of the treatments was investigated across the gender, there was no significant mean difference between males and females with respect to Post-CRECT ($F(1, 169) = .3.811$, $p= .053$) and CREAT ($F(1, 169) = .1.069$, $p= .303$). The interaction cell of Table 9 showed that gender and treatment did not interact for post-CRECT and CREAT scores: that is, the treatment did not significantly changed among females or males.

Although there were items that CGs have higher correct response percentages than EGs, in the majority of the

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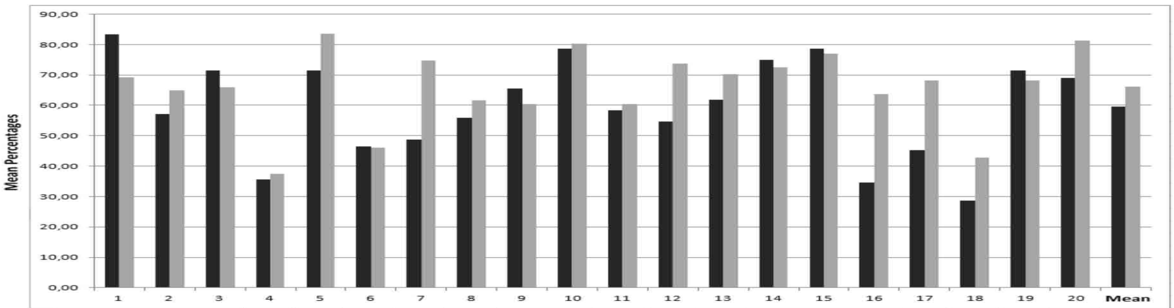
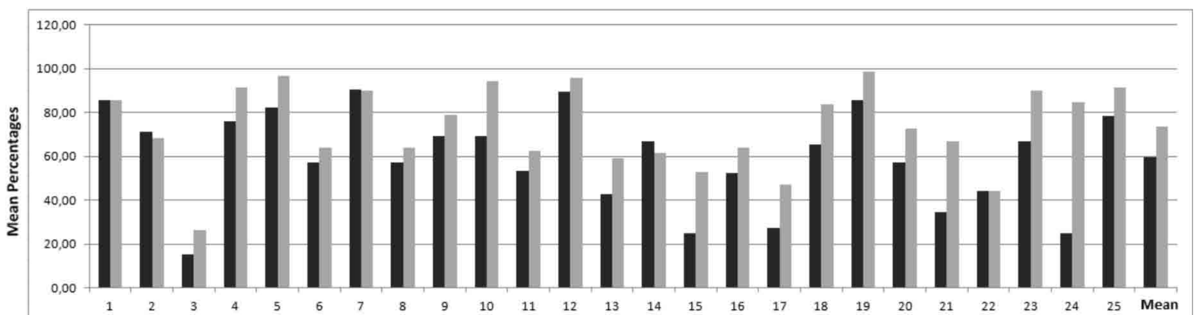
items of the post-CRECT EGs students had higher scores. Specifically, CGs had higher scores on the first and third items, which were assigned to students' pre-conceptions about heat flow and heat-temperature. EGs had higher percentages of correct responses especially on the items about endothermic-exothermic reactions (item7), spontaneity (item12), oxidation reactions (item 16), bond energies (item 17), and temperature (item 18) (see Figure 2).



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Mean
CG	83,33	57,14	71,43	35,71	71,43	46,43	48,81	55,95	65,48	78,57	58,33	54,76	61,90	75,00	78,57	34,52	45,24	28,57	71,43	69,05	59,58
EG	69,23	64,84	65,93	37,36	83,52	46,15	74,73	61,54	60,44	80,22	60,44	73,63	70,33	72,53	76,92	63,74	68,13	42,86	68,13	81,32	66,10

Figure 2: Mean percentages of correct responses for post-CRECT across the groups.

Similarly, students' percentages of correct responses on item regarding the 'entropy' of the substance (item 20) were significantly different for EGs and CGs. Additionally, there was a striking difference between the percentages of two groups on the item regarding the endothermic and exothermic properties of bond formation and bond dissociation (item 7).



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Mean
CG	85,71	71,43	15,48	76,19	82,14	57,14	90,48	57,14	69,05	69,05	53,57	89,29	42,86	66,67	25,00	52,38	27,38	65,48	85,71	57,14	34,52	44,05	66,67	25,00	78,57	59,52
EG	85,71	68,13	26,37	91,21	96,70	63,74	90,11	63,74	79,12	94,51	62,64	95,60	59,34	61,54	52,75	63,74	47,25	83,52	98,90	72,53	67,03	43,96	90,11	84,62	91,21	73,36

Figure 3: Mean percentages of correct responses for CREAT across the groups.

Students' percentages of correct responses for Chemical reactions and energy achievement test (CREAT) are shown in Figure 3. The EGs overwhelmingly had higher mean percentages than CGs when compared to post-CRECT percentages.

Discussion

From the findings it can be implied that context-based approach (CBA) with 5E model led to better learning results when compared to conventional instruction (CI) in the case of conceptual understanding of chemical reactions and energy (CRE) concepts regardless of gender difference. The groups had almost equal prior knowledge before the treatment however, at the end of the implementations the results indicated that EGs had higher percentages of correct responses than the CGs implying that the former group's alternative conceptions are more remedied. The design appears to be an effective way of instruction in overcoming students' misconceptions, along with increasing students' achievement. In CBA-5E lessons, through *context* students became familiar with applications of concepts, then; over the context engagement, exploration, explanation, elaboration, and evaluation steps were fallowed.

Through these steps the need-to-know base was satisfied, which later supports the attention for students' input. Similarly, Kortland (2007) designed lessons for enhancement of teaching learning of concepts that uses sequences in designing lessons. Their didactical structure has four subsequent phases; each with specific function requires satisfying the conditions to relate activities of students.

Although the CBA-5E implementation evoked students' prior-conceptualization, it was not successful on removing a few alternative conceptions related to heat-temperature (first five items of CRECT, which are assigned to pre-conceptions). According to Goedhart and Kaper (2002) the terms heat and temperature are used synonymy and, students have profound incorrect conceptualization about them. For that reason, students may still have misconceptions. However, the design was successful on the majority of the rest of the items as seen from Figure 2. Similarly, students' percentages of correct responses on item regarding the 'entropy' of the substance (item 20 of post-CRECT) were significantly different for EGs and CGs. As Sözbilir and Bennett (2007) revealed, students had difficulties in explaining the term 'entropy' as the probability and arrangement in microstates. Additionally, there was a striking difference between the percentages of two groups on the item regarding the endothermic and exothermic properties of bond formation and bond dissociation (item7 of post-CRECT). The design possibly contributed to students' correct conceptualization on these issues by creating a learning environment in which students mental activities are most devoted to learning progress. Students' incorrect conceptualization in classifying reactions as endothermic or exothermic which is also reported by De Vos and Verdonk (1985b) was reduced too.

Although EG have higher percentages in the majority of the items of post-CRECT and CREAT, CG students' mean percentages for items 2,7, and 14 of CREAT (see figure 3) was slightly different in favour of them. Similarly, Barker and Millar (1999) studied chemical reactions through CBA; they also revealed that many students begin post-16 studies with substantial misconceptions regarding the CRE concepts. When the inferential statistics results are examined, we can claim that the specific design of CBA-5E lead to better conceptualization of CRE concepts and better remedied students' misconception through inquiry-based activities. Comparing the percentages reported in Figure 2 and Figure 3, it is obvious to state that the design did affect the conceptual understanding (measured by post-CRECT) but not as much as an effect on students' understanding in both conceptual and algorithmic problems (measured by CREAT).

This design generally supported conceptual understanding regardless of gender difference. From the findings, it can be stated that the context used for the study is well-known and relevant for boys and girls. Additionally we can claim that context and 5E integration is appropriate to avoid gender difference in conceptual understanding. Our findings are consistent with the recommendation stated by Taasoobshirazi (2007) as gender difference can be minimized by contextual instruction. We can state that both boys and girls engaged in inquiry-based activities when they are presented over real-life applications.

Watching the videos and teacher-driven questions created disequilibrium to feed the need-to-know phase for knowledge inventory; students engaged in well-established activities, such as carrying out experiments as necessary means to comprehend the topic. Through these processes students could test their hypothesis, collect and analyze data, and interpret the results. They constructed their understanding of CRE concepts through the activities performed; they shared their ideas by asking questions and discussing with teachers and friends. In control groups, the conventional instruction was utilized. The expository teaching with questioning and discussion was carried with the same flow of instruction i.e., the same experiments but without hypothesis testing though contextual activities. In EGs, learning environment was more inquiry-based compared to CG, as Parchmann et al. (2006) stated, the use of context created learning environments to stimulate students' personal mental activities to enable progression of learning successfully.

Conclusions

Supporting conceptual understanding is a difficult endeavour, CBA-5E integration is more effective instruction to remedy misconceptions on CRE concepts compared to conventional methods. This study provided evidence that CBA-5E overcome learning difficulties of students through inquiry-based activities that created opportunities to students for active engagement in investigations. Incorporating a variety of non-traditional teaching activities into CBA may be considered as an intensive effort to improve students' understanding, however; as the aim was to improve conceptual understanding, the authors incorporated inquiry into the lessons. Moreover, there is usually a lack of definition of CBA on improving conceptual understanding, thus, 5E which supports opportunities to construct concepts, patterns, and to create meaning about concepts was integrated. Different from the studies

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reporting their findings as the sole effect of CBA, this study explicitly dictates that designing contextual lessons based on the definite phases has the ability to improve students' conceptual understanding.

We also conclude that when 5E was integrated to CBA, it is more a directive for teachers and researchers, since the flow of the lesson becomes quite explicit. Additionally, students more easily engage in inquiry-based activities when they are presented over real-life applications. Although, conclusions drawn from CBA studies have been shown as the effect of CBA itself, which could also be an effect of the specific instructional model, this study reported its results as the mutual effect of CBA and 5E. Further studies can investigate the effect of such a design on understanding of other chemistry topics relevant to their purposes, since the design suggests a clear way on how the course is carried out. Moreover, studies can investigate how the nature of teaching method influences the effect of CBA in detail through qualitative approaches. Such a design is recommended, since students are engaged in the learning environment that incorporates minds-on activities for supporting conceptual understanding. Thus, there will be a latent capacity available around the real-world problems in which students can construct knowledge with a more meaningful understanding and answer the very common question why one needs to learn a certain topic.

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