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An Application of Context- and Problem-Based Learning (C-PBL) into Teaching Thermodynamics

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Abstract This study aims to investigate the applicability of context- and problem-based learning (C-PBL) into teaching thermodynamics and to examine its influence on the students' achievements in chemistry, retention of knowledge, students' attitudes, motivation and interest towards chemistry. The embedded mixed method design was utilized with a group of 13 chemistry students in a 2-year program of "Medical Laboratory and Techniques" at a state university in an underdeveloped city at the southeastern region of Turkey. The research data were collected via questionnaires regarding the students' attitudes, motivation and interest in chemistry, an achievement test on "thermodynamics" and interviews utilized to find out the applicability of C-PBL into thermodynamics. The findings demonstrated that C-PBL led a statistically significant increase in the students' achievement in thermodynamics and their interest in chemistry, while no statistically significant difference was observed in the students' attitudes and motivation towards chemistry before and after the intervention. The interviews revealed that C-PBL developed not only the students' communication skills but also their skills in using time effectively, making presentations, reporting research results and using technology. It was also found to increase their self-confidence together with the positive attitudes towards C-PBL and being able to associate chemistry with daily life. In light of these findings, it could be stated that it will be beneficial to increase the use of C-PBL in teaching chemistry.

Keywords Chemistry · Context- and problem-based learning (C-PBL) · Thermodynamics · Mixed method design

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Introduction

Although people have long wondered how learning occurs, the first related scientific studies were carried out in the nineteenth century to satisfy this curiosity (Schunk 2012, p. 7). A number of theories were put forward regarding how learning occurs. Today, increasing knowledge, the changing student profile and rapid developments in technology have all increased the expectations of students about learning independently, managing their time, researching and having a high quality of knowledge. Due to the inefficiency of the traditional methods influenced by the positivist viewpoint, it is now a problem at schools that students fail to concretize their knowledge or to use their knowledge in daily life. Various methods have been developed and are still being developed for more effective and permanent learning. Therefore, in recent years, constructivist theories have been put forward which are based on the post-positivist and interpretive paradigm, which put students in the centre and which allow students to structure their background knowledge, their perceptions, their social environment, their language and their behaviour actively in their minds during the learning activity. The social constructivism perspective claims that meaning is not independent of an individual's social environment and that learning is influenced by the individual's culture and language (Merriam and Caffarella 1999; Vygotsky 1978). Social constructivism is applied at schools via various methods such as problem-based learning, cooperative learning, project-based learning, situated learning, cognitive apprenticeship and context-based learning.

A model of social constructivism is the method of context-based learning (CBL) which claims learning occurs via contexts in an individual's social environment. CBL includes learning in contexts or learning that occurs via real-life experiences. The CBL approach focusses on the application of science as a means of enhancing scientific understanding of the students' real worlds while developing the students' capacities to function as responsible participants in their everyday lives (Bennett 2005; King 2012). CBL uses a real-life context of a student as a teaching material, while in problem-based learning (PBL), a sub-category of the context-based learning approach, the context is used in the form of problem scenario that the student is likely to encounter in daily life (Overton et al. 2009). The process of CBL involves students being provided with a scenario and undertaking a student-led process of hypothesising, which ultimately results in the development of the students' own learning needs. The identified learning needs are explored by the student group, who use current research and resources to consolidate a position, and present these to their peers. As a teaching tool CBL, utilizes a group approach to learning—the process of working together creates discourse and leads students towards a solution focus (Trimmer et al. 2009).

On the other hand, PBL invites students to search, to think critical, to work in a team and to find solutions to the problems that are given in scenarios. In the science education literature, there are studies that investigate uses of PBL and its effects suggesting that learners prefer this method to the conventional, lecture-based method (Albanese and Mitchell 1993; Vernon and Blake 1993). Compared with conventional instruction, PBL, as suggested by the findings, is more nurturing and enjoyable (Albanese and Mitchell 1993). Furthermore, studies suggest that students in PBL are better at applying their skills but there are contradictory evidences that PBL improves

the knowledge base (Colliver 2000). Van den Bossche et al. (2000) concluded that PBL had a positive robust effect on the skills of students but a negative nonrobust effect on knowledge. Riberio and Mizukami (2005), after applying PBL to engineering students, found out that this approach improves the skill of studying in small groups, the skill of discussing and the skill of synthesizing the knowledge. On the other hand, there is evidence (Senocak et al. 2007; Tosun and Taşkesenligil 2013) that PBL improves students' academic achievement and knowledge base as well as other skills. However, there are studies (i.e. Kirschner et al. 2006) which criticize the effects of instructional approaches such as PBL and inquiry-based instruction. These approaches are considered minimally guided or unguided, and, therefore, it was argued that they are less effective and less efficient than instructional approaches which put more emphasis on guidance of a student's learning process. Therefore, PBL is found ineffective compared to instruction that provides direct, explicit information (Sweller et al. 2007). However, this view is criticized and arguments included that PBL allows for flexible adaptation of guidance, and its underlying principles are very well compatible with the manner in which our cognitive structures are organized (Schmidt et al. 2007).

CBL does not necessarily need a problem. The context could be any issue, such as a cultural issue, an event from newspaper, a story or an environmental problem from the learner's social environment. In contrary, PBL uses contextualized real-world problems and these are typically a set of descriptions of phenomena or situations in need of explanations and resolution (Schmidt 1983). For example, in CBL, the context can be a problem or other issues from the students' social environment, but PBL needs a problem which is from the students' social environment (such as poisoning, global warming, criminal event or any contextualized problems that need to be solved). Context- and problem-based learning (C-PBL), emphasizes the context side of PBL. Tiwari et al. (2001) define C-PBL as below:

> "The context-based PBL model is designed to retain the philosophy and key features of the 'typical' PBL approach while providing the transition to bridge the gap between traditional dependent didactic learning and self-directed independent learning".

If a problem is presented in a real-life context, the context-based problem is formed. Learning via context-based problem uses real-life contexts, and problems to support the students' control over their learning (Overton 2007). For students, this provides the opportunity to test theories through real-life examples. "The C/PBL approach works by setting students open ended problems with engaging scenarios which help illustrate the variety [sic] of ways in which the students' understanding of the subject may be applied as well as the importance of problem solving skills to professional" (Williams and McKenzie 2013). Therefore, as argued by Eilks and Byers (2010), it would be "highly desirable to embed the connection to everyday life, contemporary research, society, or chemical technology into our teaching by using context- and problem-based approaches to promote the meaningful learning of chemistry" (pp. 236–237). There is an abundance of evidences that C-PBL designs produce better learning. For example, Belt et al. (2002) and Summerfield et al. (2003) have trialled C-PBL resources for analytical chemistry, drawing on contexts in industrial, pharmaceutical, environmental and forensic chemistry. These resources deliver learning outcomes in analytical chemistry and also help the development of a range of transferable skills. In another study, sport was used as the context to meet learning outcomes in biochemistry, simple thermodynamics and materials chemistry (Potter and Overton 2006). C-PBL is mostly used in the Western world, while rare examples of

its vast use come from the University of Hong Kong. Tang et al. (1997) applied C-PBL to different cases, and it is showed that C-PBL allows students to learn deeper.

Previous Studies Conducted on Thermodynamics

Research into chemistry education shows that the majority of students have difficulty in understanding a variety of subjects in chemistry and that they learn them inadequately. As revealed in many studies so far, the thermodynamics of chemistry is considered to be a difficult subject to learn. The literature review points out that students find physical chemistry and the thermodynamics of chemistry challenging (Sozbilir 2004a, b; Sözbilir et al. 2010). Moreover, Castier and Amer (2011) state that classes in thermodynamics are difficult not only for a number of students to learn, but also for some educators to teach. Thomas and Schwenz (1998) found that senior chemistry students have common misconceptions about the basics of chemistry, including a large number in thermodynamics as well. A great deal of conceptual difficulty is experienced while teaching thermodynamics and balancing chemical equations in secondary and undergraduate courses (Sreenivasulu and Subramaniam 2013). Klimenko (2012) reports that engineering students do not have difficulty understanding the first law of energy and thermodynamics, but they do have trouble with the concepts of entropy and the second and third laws. Turanyi and Toth (2013) conducted a survey among environmental science, biology and chemistry students on thermodynamics and reaction kinetics and found that the students had thermodynamic misconceptions previously reported in related literature. These studies indicate that the problem continues to exist in further academic experiences unless the aforementioned misconceptions are cleared up. Thanks to their four-step diagnostic tests carried out on 106 students at the National University of Singapore, Sreenivasulu and Subramaniam (2013) identified a total of 34 misconceptions about thermodynamics, most of which included; energy transfer between the system and surroundings, internal energy, enthalpy, change of entropy, free energy, the third law of thermodynamics, endothermic and exothermic systems, using Celsius scale in thermodynamic formula, inaccurate information on thermodynamic equations, and so on. Furthermore, analysing related studies, Sozbilir (2004a) found that students have misconceptions about various thermodynamic subjects such as entropy, chemical bond energy, enthalpy and Gibbs free energy.

As seen from the above-mentioned studies conducted so far, the majority of students have difficulty in learning thermodynamics, as a result of which they develop scientific misconceptions. However, the underlying problem is why students have inaccurate or inadequate knowledge and have trouble understanding the subject, which has several determining factors: the fact that thermodynamics requires more math skills, the students' inefficient skills, the insufficiency of the students' prior knowledge and the lack of students' interest and logical thinking (Belt et al. 2005). In addition, Doige and Day (2012) state that differences between scientific and daily languages and mismatches in course books in particular, prevent students from learning physics and chemistry courses. Sozbilir (2003) points out that the practical meanings of scientific terms are dominant in students' theoretical interpretation, and teachers should check whether students have learned the accurate and scientific meanings of concepts so that they can put these not only into practice but also into theory. It is thought that developing opportunities and materials to attract the students' interest and encourage logical thinking is necessary to prevent students from coming with inadequate information. In accordance with this thought, it is also considered that real-life problems students are familiar with should be introduced to the learning environments of students, who are at the beginning of their academic life, so as to

promote their interest in thermodynamics of chemistry as well as their motivation for it. As a consequence of this, it could be stated that students are assured that not only is thermodynamics a matter of mathematical formulae but it is also the result of a series of events in various stages of their lives.

Research Questions

This study aims to investigate the applicability of C-PBL into practice in thermodynamics, in an undergraduate general chemistry course. Particularly, it investigates the effects of C-PBL on the students' academic achievement and retention of knowledge of chemistry together with its effects on the students' interest, motivation and attitudes towards chemistry. In order to fulfil this purpose, the following research questions were addressed in the present study.

1. What are the effects of C-PBL on the students' academic achievement and retention of chemistry knowledge?
2. What are the effects of C-PBL on the students' interest in chemistry?
3. What are the effects of C-PBL on the students' attitudes towards chemistry?
4. What are the effects of C-PBL on the students' motivation for chemistry?
5. What is the applicability of C-PBL to the undergraduate general chemistry course on thermodynamics?

Method

Research Design

This study has employed a mixed methods approach. Mixed methods research is an approach in which quantitative and qualitative data are brought together to provide more complete understanding of the research problem (Creswell 2014). Creswell classified mixed methods research as *basic* and *advanced* mixed methods designs in his recent book. The embedded mixed methods design is counted as an advanced mixed methods design. It is defined as a design which "nests one more forms of data (quantitative or qualitative or both) within a larger design (e.g. a narrative, an ethnography, an experiment)" (p. 228). Researchers use this design when they need qualitative or quantitative data to answer a research question within a largely quantitative or qualitative study (Creswell and Plano-Clark 2007). This study was designed as an intervention in teaching thermodynamics. However, instead of measuring the effect of the designated intervention only by means of quantitative measures, we wanted to see how applicable this intervention was in practical settings (e.g. vocational schools) together with its effect on the students' learning of thermodynamics and their motivation, interest and attitudes towards chemistry. The students' achievement in thermodynamics and their interest and motivation in chemistry and attitudes towards chemistry were measured through quantitative measures, while the applicability of C-PBL into teaching thermodynamics was determined through qualitative data. Therefore, in this intervention study (a pre-experimental study), qualitative data were embedded into an experimental setting to find out the participants' perspectives and impact of the intervention.

Data Collection Tools

Data were collected through various quantitative and qualitative tools. Among them were quantitative instruments such as achievement test, questionnaires for interest, attitudes and motivation towards chemistry and qualitative instruments such as individual and focus group interviews. The instruments are described below.

Thermodynamics Academic Achievement Test

The students' academic achievements in thermodynamics before and after teaching were measured by the Thermodynamics Academic Achievement Test (TAAT), which was developed by Baran (2013). It has 36 multiple choice items designed to cover all learning objectives. The validity and reliability studies were carried out with 233 students, and the reliability coefficient for the test was reported as 0.868. TAAT was applied as pre-test, as post-test and as retention test.

Interest in Chemistry Questionnaire

The students' interest in chemistry was measured by the Interest in Chemistry Questionnaire (ICQ). It was developed by Baran (2013) to measure the students' interest in basic chemistry and thermodynamics and has 34 items. It was applied before and after application of C-PBL intervention. The participating students were asked to rate their interest on a five-point scale (1 = never and 5 = very much). The reliability study was carried out with 217 students, and the reliability coefficient for the questionnaire was reported as 0.93.

Attitudes Towards Chemistry Questionnaire

The Attitudes towards Chemistry Questionnaire (ACQ) used in this study was developed by Geban et al. (1994), and its reliability was reported by the authors as 0.83. The ACQ has 15 positive and negative five-point Likert-type items ranging from strongly agree to strongly disagree.

Motivation in Chemistry Questionnaire

The original of Motivation in Chemistry Questionnaire (MCQ) was developed by Glynn and Koballa (2006). It has 22 five-point Likert-type items to measure the students' motivation in chemistry, and the reported reliability was 0.82.

Interviews

After the intervention, two types of interviews (focus group and individual) were carried out. The aim of the interviews is to find out the students' opinion about C-PBL and also whether C-PBL is a suitable method or not for them. In the first round, focus group interviews were carried out to find the effects of C-PBL. In the focus group interviews, the effectiveness of C-PBL together with the advantages and disadvantages of C-PBL were questioned. Through the second round, individual interviews were carried out after the analysis of TAAT result. The questions that the students had difficulty in answering were identified. In individual interviews,

each of the student's mistakes in TAAT and the reasons for them were questioned. During the development stage of interview protocols, in order to achieve the content validity, five university instructors were requested to read the interview protocols and provide feedback.

Participants

The participants of the study were 13 students (7 female and 6 male) taking the course of Chemistry in a 2-year program of "Medical Laboratory and Techniques" at a state university in an underdeveloped city at the southeastern region of Turkey in the academic year of 2012–2013. The group was taught by the first author. Prior to the study, permission was sought to take part in the study and the whole group volunteered participate. Considering the size of the group, it was not possible to set a control group. Therefore, instead of setting two groups, the whole group was taken as an intervention (i.e. experimental) group. Therefore, there was no control group to identify the effect of C-PBL intervention in comparison to the conventional instruction. This weakness resulted due to small sample size, and having no control group was overcome by embedding rich qualitative interview data into the quantitative data. However, the results should be evaluated with care due to the weak representativeness of the sample.

Intervention

Development of C-PBL Scenarios

Taking the learning outcomes and the content in thermodynamics (given in Appendixes 1 and 2) into account, two different problem scenarios were developed. The main challenge to develop these scenarios was identifying real-life problems that reflect the thermodynamic content also known by all students. Then, the problems were selected and the scenarios were written. With the help of five open-ended questions in the scenario titled "Stove and carbon monoxide poisoning", it was intended that the students would learn the concepts related to system, environment, internal energy, the first law of thermodynamics and enthalpy. With the help of the seventh open-ended question addressed in the second scenario entitled "The Top Miracle", the purpose was to help students learn about reversible/irreversible changes, entropy, Gibbs free energy and the second and third laws of thermodynamics. A sample scenario is given in Appendix 3. In order to establish the validity of the scenarios, expert help was sought. Five university instructors were requested to read the scenarios and provide feedback. Those feedbacks were generally about rationality of scenarios, such as the amount of substances, why certain amounts are used, criticisms about the language and some corrections about reactions. According to the comments, necessary modifications were made.

Implementation of the Scenarios

Prior to the intervention, quantitative instruments were applied as a pre-test. Participants were informed about the C-PBL and the procedures to be followed. In the first part of the study, the students were divided into three homogeneous groups, and each student in each group was provided with the worksheets of the first scenario. The students were encouraged to read the scenario and share their knowledge. In addition, working papers were given to the students. On the working papers, there were guiding statements like "What do we know about the scenario?", "What we need to know to answer the problem?" and "How and where to find

the necessary knowledge". Following this, the students were observed carefully by the instructor who tried to clarify the points where students failed to understand. The students were also informed about available sources from which they could benefit and about the way they should follow. As it can be seen above, the instructor's/teacher's role in this study are listed below:

- Dividing students into homogeneous groups.
- Explaining the teaching process about C-PBL.
- Encourage them to read the scenarios.
- Make them to think deeply.
- Observing the students during the C-PBL process.
- Activating passive students.
- Applying pre- and post-tests.

Assessing the report and presentation

In the second stage of the study, the students were requested to conduct investigations on the questions in the scenario for a week and to prepare a report and present it in front of the class. Besides, they were also requested to prepare a detailed written report. To sum up, the students' responsibilities are listed below:

- Reading and comprehending the scenarios.
- Deciding what to know.
- Try to find possible answers to the problems or ways to solve the problems through group discussions.
- Identifying what they need to know to solve the problems.
- Carry out the research.
- Analysing the data and information gathered and reach conclusions.
- Presenting the findings.
- Writing a report about the scenarios' questions.

The same method was also used for the second scenario. Upon completion of the intervention, all the quantitative instruments were applied as post-tests. At the end of the semester, the TAAT was applied as a delayed post-test again.

Data Analysis

Quantitative data were analysed statistically with SPSS© 18. In order to analyse the data collected via interviews, the content analysis technique was utilized. Content analysis is a research method for the subjective interpretation of the content of text data through the systematic classification process of coding and identifying themes or patterns (Hsieh and Shannon 2005). In analysing the interview data, codes, categories, themes, explanations and frequencies were identified. The findings were presented in tables, and descriptions were made where necessary.

The research questions investigated and the data collection tools and data analysis methods employed are summarized in Table 1.

Table 1 Research questions, data collection tools and data analysis methods

Research questions	Data collection tools	Data analysis methods
1. What are the effects of C-PBL on the students' academic achievement and retention of knowledge of chemistry?	•Thermodynamics Academic Achievement Test (TAAT) •Individual interviews in which each of the student's mistakes in TAAT and the reasons for them were questioned	•Inferential statistics •Content analysis
2. What are the effects of C-PBL on the students' interest in chemistry?	•Interest in Chemistry Questionnaire (ICQ) •Interviews	•Inferential statistics •Content analysis
3. What are the effects of C-PBL on the students' attitudes towards chemistry?	•Attitudes towards Chemistry Questionnaire (ACQ) •Interviews	•Inferential statistics •Content analysis
4. What are the effects of C-PBL on the students' motivation for chemistry?	•Motivation in Chemistry Questionnaire (MCQ) •Interviews	•Inferential statistics •Content analysis
5. What is the applicability of C-PBL to the undergraduate general chemistry course on thermodynamics?	•Interviews	•Content analysis

Findings

This section starts with the presentation of the findings gathered from quantitative measures and follows with the qualitative data. The conclusions reached are discussed together at the end.

The Effect of C-PBL on the Students' Achievements and the Retention of Knowledge

The findings obtained from the achievement test and the results of statistical analysis are given in Tables 2 and 3.

The minimum and the maximum of the TAAT were 0 and 36 respectively. In other words, a student who answered all the questions correctly collects 36 marks, and those who answered all the questions incorrectly receive 0. When the descriptive statistics are examined in Table 2, it is seen that the median and mean scores of the students in pre-test, post-test and delayed post-test were close to one another for each student and that there was a difference between the pre- and post-tests as well as

Table 2 Descriptive statistics for TAAT

Test type		Number	Median	X	SD	SE
Achievement test	Pre-test	13	12.00	11.77	2.52	0.70
	Post-test	13	23.00	23.77	1.96	0.54
	Delayed post-test	13	20.00	19.15	5.94	1.65

Table 3 Results of Wilcoxon signed-rank test for TAAT

		Number	Mean rank	Sum of rank	z	p value	r
TAAT post-test- pre-test	Negative ranks	0	0	0.00			
	Positive ranks	13	7.00	91.00	−3.19[a]	.001	−0.63
	Ties	0					
	Total	13					
TAAT delayed post-test-post-test	Negative ranks	10[a]	7.85	78.50			
	Positive ranks	3[b]	4.17	12.50	−2.31[a]	.02	−0.45
	Ties	0[c]					
	Total	13					

[a] Based on negative ranks

[b] Based on positive ranks

[c] Wilcoxon signed-rank test

pre-test and delayed post-test scores. In order to test if that difference was statistically significant, Wilcoxon signed-rank test, which is a nonparametric equivalent of paired sample t test, was used as the number of participants was small although the sample was homogeneous (Field 2009). The findings are given in Table 3.

Table 2 indicates that there was a statistically significant increase in the students' achievements ($z = -3.19$, $p < .05$) and that the effect size calculated indicates that the difference displays a large effect in practice ($r = -0.63$) (Field 2009). The margins for the effect sizes are $r = 0.10$ (small effect), $r = 0.30$ (medium effect) and $r = 0.50$ (large effect).

Similarly, when Table 2 is examined, it is clearly seen that the average student achievement was 23.77 following the application ($X = 23.77$, SD = 1.96) though the maximum test score to be received from the achievement test was 36. These values show that the students still had difficulty in understanding the thermodynamics. Careful analysis of the results helped to identify the topics which were not understood even after the intervention. The results showed that the topics which were least understood were as follows:

- Calculation of enthalpy, entropy and Gibbs free energy.
- Systems and its surroundings.
- Hess's law.
- Internal energy.
- Energy interaction between the system and the surrounding.

When the questions with these sub-headings are examined, it is seen that the students had difficulty in answering the algebraic questions that involve mathematics. To make this point clearer, further interviews were held with the students, and they solved the same questions by thinking aloud. The individual interviews demonstrated that the students had difficulty in answering the questions as they could not remember the necessary equations and also could not make sense of the mathematical equations. The following quotes taken from participants S4 and S11 indicates this difficulty:

> Miss, I don't remember anything about this question at all. Delta H is equal, Gibbs energy is something like that, there was a T but I do not remember. I don't remember Gibbs (S4).

> Delta system, was it Delta H- T. Delta… which of these formulas should be used, it is not that Delta not the products- Delta inputs, logically. I eliminate that, or was it that? was Delta H it surrounding system, Delta H equal to system, Delta H minus?, there was something like Delta surrounding. Well, no I don't remember. (S11).

In addition to a mathematical burden, the analysis revealed that students were mostly good at questions requiring first "remembering" (86%), then "comprehension" questions (63%), "application" questions (54%) and finally questions of analysis (31%).

As can be seen in Table 2, there was a four-point decrease between the means of the post-test and the retention test. Although there was a statistically significant difference between the post-test and the delayed post-test, there is four-point decrease in the mean scores. This reveals that the students could still remember most of what they had learned. As a result of studies carried out on the retention of knowledge, Ebbinghaus (1885) presented a curve of forgetting and suggested that within a month, individuals could remember 20% of the learned information. However, in the study, the retention test was performed 4 weeks after the intervention, but the fact that the participants could still remember most of the acquired knowledge after 4 weeks revealed that the C-PBL method had an effect on the retention of knowledge.

Effect of the C-PBL on the Students' Interest in Chemistry

A pre- and a post-test were administered before and after the intervention so as to measure the interests of students in chemistry. Descriptive values were examined through Wilcoxon signed-rank test to reveal any significant difference between the pre- and post-test interest questionnaires. The results of these tests are given in Tables 4 and 5.

When the figures in Table 4 are examined, it is seen that there were about 23-point mean difference between the results of pre- and post-tests in favour of the post-test. However, Wilcoxon signed-rank test was conducted to find out if the effect of this test on the students' interest was low, medium or high. The results of this test are given in Table 5.

When the results of Wilcoxon signed-rank test are investigated, it is seen that there is a statistically significant difference between the pre- and post-test scores in favour of the post-test indicating that C-PBL had significantly increased the students' interest in chemistry, and this difference had a medium size effect in practice ($r = -0.4$).

Effect of the C-PBL on the Students' Attitudes Towards Chemistry

The quantitative findings obtained via the ACQ are analysed. It showed that there was no difference between the students' scores in pre- and post-tests. This is also confirmed statistically via Wilcoxon signed-rank test ($z = -0.24$, $p > .05$).

Table 4 Descriptive statistics for ICQ

Test type		Number	Median	X	SD	SE
Interest	Pre-test	13	110	108.38	23.83	6.61
	Post-test	13	140	131.00	26.17	7.26

Table 5 Results of Wilcoxon signed-rank test for ICQ

		Number	Mean rank	Sum of rank	*z*	*p* value	*r*
Interest post Interest pre	Negative ranks	3	5.67	17.00	−2.00	.046	−0.4
	Positive ranks	10	7.40	74.00			
	Ties	0					
	Total	13					

Effect of the C-PBL on the Students' Motivation Towards Chemistry

The statistical data obtained via MCQ were conducted before and after the intervention to reveal the effect of C-PBL on the students' motivation towards the chemistry. When the findings are examined, it is found that the difference between the pre- and post-tests was 3.15 in favour of the post-test. However, Wilcoxon signed-rank test was conducted to check if the difference was statistically significant or not. The results show that there is no statistically significant difference.

Applicability of C-PBL to the Undergraduate General Chemistry Course on Thermodynamics

The findings gathered from the analysis of the interviews are presented. The findings were divided into codes, categories and themes, and their frequencies were given. The participants were given codes as S1, S2, S3, and so on, to reveal which student reported each view. Table 6 presents finding about the participant's views on applicability of C-PBL in chemistry class.

The analysis of the interviews revealed three categories related to the applicability of C-PBL: they are its effect on *learning*, *life skills* and *cognitive skills*.

The Effect of C-PBL on Learning

When we examined the students' views on the effect of C-PBL on learning, three codes were identified. The learning skills developed by the help of performing individual investigations and group works was the most common one with 12 out of 13 students. The following excerpt exemplifies the case.

> Well, I think in that way. I don't like to do investigations much, but thanks to that method, we could do investigations in many areas and we built communication. One of the most important things here is that I did that in public. I can say that I challenged my phobia (S7).

As can be understood from the comments, C-PBL encouraged students to do individual investigations, to build intragroup and intergroup communication skills and to make presentations to help them gain self-confidence. Another finding revealed via the effects of C-PBL method on learning was permanent learning. Eleven participants stated that C-PBL contributed to the retention of knowledge as seen below:

Table 6 The participants' views about the applicability of C-PBL

Theme	Category	Code	f[a]
The applicability of C-PBL	Effect of C-PBL on learning	Learning by investigation	12
		Permanent learning	11
		Application of knowledge into real life	10
	Effect of C-PBL on life skills	Communication skills	13
		Presentation skills	11
		Gaining self-confidence	8
		Time management skills	5
		Technology adaptation skills	5
	Effect of C-PBL on cognitive skills	Report writing skills	7
		Permanent learning	10
		Problem-solving skills	9
Shortcomings of C-PBL	Weak in/between group communication	Unequal task sharing between the group members	3
		Weak communication due to socio-cultural facts	4
	Unfair evaluation of student performance	Treating the passive group members equally with the others	3
		Out of classroom activities are not observed and evaluated	3
Teacher competency	Competency	Competent	6
		Not motivating	1
		No control or support out of the classroom	3

[a] Number of students

> When you read something new or when you have to memorize something, you cannot learn it; however, when you search for something, you learn it quite well as you wish to do it (S5)
>
> As you yourself learn or search for it, the learning is permanent. Once you learn, you like to learn about chemical issues more, & the subjects in this academic term are more enjoyable than those in previous term. In other words, such daily things were more attention-taking for me. For example, I would wonder why the snow on the summit of mountains would melt late and why the snow on the mountain skirts would melt immediately. Or does the snow we put in a bottle in the mountains melt when we come down the summit, and so on. Or what kind of gas is it which causes heat poisoning, what can be done when heat poisoning happens? As these are the things that we live within our daily lives, we wondered a lot and wanted to learn more. It was quite enjoyable (S1).

In relation to the contribution of C-PBL application of knowledge into real life, ten participants stated that the C-PBL method helped them apply the knowledge gained in this course into the real life. Some of the views are quoted below:

> As we had a team work, we had wonderful relations with friends. As we were searching for chemical issues, we realized that all chemical subjects are closely related to one another. Thus, as we were looking for a subject, we had knowledge of some other subjects (S11).

> Of course, we experienced many common points, chemical reactions, enthalpy, self-generated events, Gibbs, which were the things we should never forget, we all recalled them, but we realized that we had forgotten many other things that we should not (S4).

The Effect of C-PBL on Life Skills

On the other hand, the findings reached from the students' views indicate students gaining several life skills through C-PBL. They are listed in Table 6.

The analysis of the interviews held with the participants suggested that the students found the report writing very beneficial because they engaged intensively with the knowledge need to be acquired and, therefore, knowledge acquired become more permanent and also helped to improve more communication skills. The participants expressed their views as follows:

> We exchange information; we talk to one another, but it is a necessity to note it down to make it permanent knowledge (S1)
> Miss, do you remember what was mentioned in that text; as you go up to the summit of mountains, snow melts later. I mean I did not think never before on why snow melts in the skirts but remains longer on top. I used to wonder, and I was interested, as well. There is a saying, spoken words fly away but written words remain. Therefore, to make knowledge permanent, it needs to be written (S3)

The above quotations point out the importance of writing reports for effective learning. In addition to this, S11 expressed the need for writing the knowledge in reports in a more detailed way as in the following statement:

> Miss, when we expressed our thoughts in spoken language, we could not get into much detail. However, when it was time to prepare a report, we realized that we could get into the every detail of the subject. In other words, we could focus on the report with eyes open (S11).

As can be concluded from the statements of the participants, it was found out that C-PBL improved the participants' views on how important reporting in written format for learning was.

It was also revealed that C-PBL not only contributed to learning but also helped students to improve their self-confidence and control their feelings as seen in the below quotation:

> I consider it to be very useful for communication. I had prepared a slide. I think the slide was a little bit long. When my slide was interrupted, two friends laugh at me. So I got angry with them. But I tried to keep my anger considering that I was in public, and I did. Then, when I was telling about the subject, some other friends intended to interrupt, but I managed to keep going without any hesitation in a fluent manner (S12).

Besides, some of the participants suggested that group work increased motivation as reported below:

> But we achieved it together. Group work was very good. My motivation to learn chemistry has increased (S7).
> I think there was a good communication in our group. When one of us could not do it, another member was just there to make it up. Nobody escaped from the task to leave it on others, or nobody thought that they are always the one to do the task or it is time for

> others to do it now. Our communication was strong. Thanks to this communication, I much motivated to learn (S12).

We can conclude here that group works contributed to the students' interaction and increased their motivation to learn chemistry. It could also be stated that C-PBL had a positive impact on developing the interaction between the groups as well as in a group, and hence motivation to learn. This intergroup interactions have also enhanced the retention of acquired knowledge. The following quotes support this view:

> When I first saw that problem, I found it very confusing and I was not sure if I would solve it. However, when my friends could solve the problem, I realized how simple it was. Therefore, I tried to solve the problems after some preliminary studies, and I achieved it. This was the most positive effect on me (S9).
>
> For example, group members would come and ask some questions. What do you think? What will happen? What do you think about that? And so on. Under normal conditions, I would not take care about those questions, but thanks to group works, we met them out of school and worked on the questions as well (S7).

This finding was also one of the goals of C-PBL as a constructivist learning method. This finding ensures that this goal was achieved. On the other hand, the participants reported that one of the significant effects of C-PBL on communication was developed through the presentations made. They claimed that presentations increased their self-confidence and self-expression. They put their views into words as follows:

> Well, I didn't have any problem with self-confidence, but I realized that I didn't have a good level of dialogue with people at all. Thanks to this study, I developed self-confidence which allowed me to express myself clearly (S9).

> Firstly, it gave us a positive impact in expressing ourselves. For example, we tried to explain the concepts clearly in front of our classmates and you, miss. This indicates that both my friends and I could develop a fruitful communication with the society (S11).

Moreover, it is found out that communication skills also helped the student's ability to transfer scientific knowledge. The students expressed their views on their skills in transferring their scientific knowledge as follows:

> That's well done, I think. Because I prepared a long presentation, but I realized that a presentation shouldn't be that long; the audience could get bored. I understood that the information must be expressed more clearly and directly (S12).

The students who thought C-PBL helped acquire the skill in using time effectively expressed their feelings in the quote below:

> Yes, I also think that it contributes because I went on the stage first and summarized the scenario in five minutes. Then, S9 called us one by one to inform who would speak on which subject. S12 did the presentation. This increased efficiency in using the time (S6).

One of the skills targeted in C-PBL was related to effective use of time. Table 6 shows that 5 out of 13 students developed this skill. Besides this, the students who were not able to use technology for learning expressed accepted that they learned how to use technology effectively, thanks to C-PBL. The students' statement regarding this was as follows:

> In fact we didn't previously know how to use the Internet for our studies. Thanks to this, we accessed several research oriented websites, databases and therefore were able to read a lot of thesis, research reports and articles (S7).

The Effect of C-PBL on Cognitive Skills

The contribution of C-PBL to cognitive skills is also questioned through the interviews. The findings suggest that students were able to establish a connection between C-PBL's contribution to dealing with real-life problems and increasing their curiosity through problem solving. They found the problem scenarios interesting and motivating.

> The thing to explain here was lectured very joyfully. Chemistry can be boring for most of us. But these scenarios were interesting. Therefore, working on it was also interesting (S1).

> The scenarios were interesting and motivating. With the subjects told and the questions asked, it evoked curiosity in us (S12).

There were some beliefs that as one of the most efficient materials of C-PBL, the scenarios had a positive effect on the students' curiosity. One of the students stated that scenarios increased curiosity as quoted below.

> Being honest, I didn't like chemistry before, I like it now just because of my teachers. I attend classes only because I like teachers. But the example of stove poisoning was much more interesting because people can face it the real life. It was positive because of this (S6).

The Shortcomings of C-PBL

Although there were several advantages of using C-PBL as a teaching approach, there were also issues that arose during interviews, which need to be dealt with care. These issues are brought together under the theme called "Shortcomings of C-PBL". The shortcomings were generally related with the in/between group interactions and also evaluation as seen in Table 6.

Although all participants reported that C-PBL method increased communication among them, there were cases where students were complaining about the some problems that arose due to weak interaction between students in the same groups and some socio-cultural factors resulting in unequal task sharing and contribution to the group work among the group members. S13 reported his views as follows:

> In fact it is a good method, however, it seems it makes lazy some of the members, some of the students stay in comfort. I follow the groups, some of them are taking it seriously but others do not; 1–2 hours of work would be enough for them (S13).

Some of the students stated that one of the reasons for weak communication was due to socio-cultural beliefs. There were female students who were married, and for the local community, it was unacceptable for a married woman to come together out of school to work on the project with particular male group mates. This issue was evident in the following two quotes.

> If I hadn't been married and we had communicated better and I would have done my part (S5).
>
> If the other two group mates had been female it would have been better for the group communication (S2).

The unfair evaluation of student performance in C-PBL is seen as another shortcoming of C-PBL by the students. The students' opinion about this issue is given below.

> If it is implemented individually, it would be much better for me. Because we can't see each other often as I stay in a different dormitory, I could not do my part better. According to me, you must give the grades given to me to S2 and S7 as I could not displayed the same performance as they did (S5).

The Competency of Teacher in C-PBL

The opinions about the instructor's competency are categorized in three codes. Almost half of the students found the instructor competent, only one of the students thought that the instructor was not motivating. Three students felt themselves in a difficult case with no support of instructors during out-of-classroom activities (see Table 6).

Although half of the students found the instructor as competent, there were students arguing that the instructor was not motivating enough. Students stated that the instructor should motivate them as well as supervise outside the classroom. Their views are given below:

> My view is, beyond the education system in Turkey, for example, they newly started it… for example, I think, student and teacher interaction should be efficient and students should be able to contact the teacher anytime. It shouldn't be restricted within the school limits. For example, in case of a problem, we should be able to contact and interact, and have dialogues concerning the problems and improvements (S4).
>
> Teachers should promote the students more. Else, students should be free to choose whether they would like to work in a group or individually. When there are students who want to deal with a subject on his own, s/he should state that, I mean the students should say, "I want to work alone. I think that would be better." (S8).

As could be seen from the quotes above, the role of the instructor for out-of-school hours have been criticized. Since the instructor was not able to provide support during the students' out-of-school hours, it caused them to be alienated from the process. Therefore, it is thought that the instructor needs to be more supportive both in and outside the classroom.

Conclusions and Discussion

The Students' Achievement and Retention of Knowledge

The findings of the study indicate that C-PBL improves students' chemistry achievement based on the pre and post-test results. This result is in fact an expected outcome of any kind of teaching. However, if the possible maximum total score of 36 that could be taken from TAAT is considered, the average post-test TAAT score of 23.00 indicates that students still have significant difficulties in learning basic concepts and

the ideas of thermodynamics taught. Table 2 shows the descriptive statistics for the overall students' achievements in TAAT from pre-test to delayed post-test. As seen from the Table 2, increase in the students' level of achievement is not satisfactory. Students showed a moderate achievement through the implementation period. To be able to understand one of the major reasons for this moderate achievement increase, it is necessary to understand the particular cases for the participants. The participating group has never experienced a teaching approach like C-PBL before. This is the first time students came across this kind of a student-centred teaching approach. Therefore, it was difficult for them to familiarize the methods and get used to a self-directed learning environment. As students are familiar with lecturing, mostly, they rely on the provided knowledge in a structured manner by the instructor. They have difficulty finding the necessary information and comprehending basic concepts and ideas. As a result of this, they failed to crystallize the main ideas and develop a conceptual understanding. Therefore, they are mostly successful in questions requiring lower order cognitive skills such as remembering. On the other hand, there are serious difficulties with questions requiring mathematical knowledge and skills. The students who are in this particular group come from different types of high schools such as science, mathematics and social sciences backgrounds. In undeveloped cities, such as Hakkâri, even after C-PBL, social sciences background students still have difficulties solving mathematical problems. One of the main problems is that the study was undertaken in a short time and in that, short-term students who had difficulties in mathematics could not change their mind or could not improve their mathematical skills in that time. It can be showed as one of the limitations of our study. Therefore, mathematical knowledge and skills necessary to solve the problems were challenging for those students. As no extracurricular activities to remove the mathematical burden were provided during the intervention, it was thought that the students were less successful in solving problems requiring mathematical skills. Therefore, it would be advisable to provide extracurricular activities and apply C-PBL long term, to remove mathematical burden from the students in these kinds of activities to see the real effect of C-PBL.

The research literature indicates mixed results about the effect of problem-based teaching on the students' achievements. While there are studies in which academic achievement is evident (Nowak 2002; Overton 2001). Moreover, C-PBL is thought to be more effective in learning and as well as retention of what has been learned. Context-based materials are attracting the students' attention and helping them to see the relationship between subjects taught and its implication in everyday lives. Moreover, on one hand, it helps students to build self-confidence in small groups, on the other hand, it motivates them to work cooperatively on activities outside the classroom.

The Students' Interest, Motivation and Attitudes

Concerning the students' interest in science, C-PBL has a positive affect (Harland 2002). This is because students work on problems originating from their real lives. Improving student's interest in chemistry is important. There is mounting evidence that student's interest in science is declining (i.e. Osborne et al. 2003) and teachers complain about the lack of students' interest in chemistry subjects. However, teachers also admit that students like to relate chemical principles to everyday things.

According to Bennett et al. (2005), context-based approaches are approaches adopted in science teaching where contexts and applications of science are used as the starting point for the development of scientific ideas. One of the aims of these approaches is to enhance the students' interest in science subjects (Bennett and Lubben 2006; Summerfield et al. 2003). The increasing interest in chemistry from the results of this study (see Tables 3 and 4) also confirms this theoretical perspective. Improvement in interest studying chemistry is important as it affects the motivation of the students. Adversely, an individual with low interest has more problems in motivation. Therefore, it is important to develop teaching environments that students find interesting to secure the strong future of chemistry. In this sense, C-PBL is one of the best approaches in teaching chemistry.

In contrast to the students' increasing interest in chemistry, the students' attitudes towards chemistry and motivation to learn, stayed unchanged before and after the C-PBL intervention. This is understandable as both motivation and attitudes are affective behaviours requiring longtime treatment to see a significant lasting effect, although interest can be changed in a short time interval. This result is in parallel with the previous literature claiming that it is not easy to change attitude and motivation (Wijnia et al. 2011) through short time interventions, although there is contrasting evidence that C-PBL practices have positive effects on students' attitudes (Gutwill-Wise 2001; Overton 2001) and motivation (Klegeris and Hurren 2011).

Applicability of the C-PBL

Results about applicability of the C-PBL into practice are much more encouraging than the results for academic achievement and skills related to affective domain such as attitude and motivation. It is evident that group work improves the students' life skills such as communication, report writing, presentation, time management and adapting to contemporary technology. Also small-group learning activities have shown that they lead to positive outcomes such as higher achievement, increased positive attitudes towards the subject area studied, higher self-esteem, greater acceptance of differences among peers, greater persistence, greater retention and enhanced conceptual development across content areas and in a wide range of educational settings (Qin, Johnson & Johnson, 1995; Tobias, Chubin & Aylesworth, 1995; cited in Towns et al. 2000). C-PBL is a strategy that motivates the students to work cooperatively and improves communication skills and lifelong learning habits (Coca 2013). As argued by De Wet and Walker (2013), group work helps students to understand several difficult ideas easily, hence they prefer to work in groups rather than individually. However, there are shortcomings of group work that can be seen as barrier to create effective groups such as unequal sharing of the workload among the group members and also some socio-cultural barriers that arose in our findings (see Table 6).

Writing a report is an activity in which students need to work either individually or as a group. Report writing is a written communication skill of which students need throughout their lives. Besides being an effective assessment tool, it also provides objective reporting skills (Waters and McCracken 1997). While writing a report, students need to carry out analysis and synthesis to organize what to report in a meaningful way. Therefore, it develops higher order cognitive skills such as analysis and synthesis as well as evaluation. It has been noticed that with the help of C-PBL,

students have improved those skills. Similar findings also reported by King (2009) in which a context-based learning approach is implemented.

Developing problem solving skills and self-confidence is important in terms of today's society. C-PBL practices used in this study aimed to help students develop problem-solving skills and self-confidence. The interview data presented in the findings indicate that they develop problem-solving skills which also improve their self-confidence. Problem-based learning literature (i.e. Adnan et al. 2011) reports a similar finding that students who are exposed to the problem-based learning method have higher self-confidence levels when compared to students trained with conventional teaching methods.

Based on the qualitative data reported in the findings, it can be argued that participants had significant experiences in time management and this helped them a lot to improve their time management skills during investigations, presentations and report writing and working in groups that C-PBL necessitates. These results do not mean that they fully developed those skills: however, it is clear that C-PBL practices helped students to improve and/or gain time management skills. In similar studies, it has been put forth that implementing the problem-based learning method helped students gain time management skills (Chin and Chia 2004; Pinheiro et al. 2012).

Collaboration has a great impact in the C-PBL approach. It affects the performance of students seriously. However, the results indicate that some students do not collaborate enough during group work and this also creates discomfort among the students as the evaluation is made according to the whole group performance. This is an issue in other PBL studies reported in the literature. Weak communication channels and distribution of people in time and in space make it more difficult for PBL groups to carry out cognitive activities and communication activities when constructing shared knowledge in virtual environments (Miao and Haake 2001).

In this study, a noteworthy reason for weak communication in a group during out-of-school times was due to the socio-cultural facts. There were some married female students in some groups, and they were having difficulty coming together out of school times to work on the project as their families were not in favour of letting them to work together with male group mates out of the school premises. The university in which the study was performed is located in a small city at the southeastern part of Turkey. In small cities, there are fewer opportunities for students to come together and work out of school hours. Therefore, students mostly come together to work in their dormitories or their private houses. Particularly, if you are a married female, it is hardly accepted by the local community to come together with unmarried male group mates in a male-dominated environment. This problem was not thought about at the stages of group forming. In all group work studies, as suggested by the literature, heterogeneity was taken into account in terms of skills as well as gender. However, gender heterogeneity was found as a barrier in this particular case for an effective group work.

Since student-centred approaches put the students in the centre, throughout those approaches, students become active researchers, and the teachers act as facilitators. In PBL, teachers behave as facilitator and mentor. Compared to the teacher-centred approach, this is quite reversed, and therefore students have difficulty in getting used to these roles of teacher. Therefore, it is important to see how students perceive the new role of teacher in C-PBL.

Regarding the instructor role in the C-PBL approach, students found difficulty in finding support out of school times. In conventional lecturing approach, the

responsibility for learning rests mainly with the instructor; therefore, students are able to reach the information they needed directly. However, in a context-based approach, the responsibility for learning is shared by instructor and learner, requiring instructors to change their teaching activities into shared or loose control strategies (Putter-Smits et al. 2012): therefore, students had difficulty accepting the new role of the instructor. The instructor behaved as a guide rather than controlling the learning process of the students. But, students were expecting more direct help than guidance. Moreover, in some cases, this new role of instructor was perceived by the students as an inadequacy of the instructor.

Another shortcoming of C-PBL is the assessment of students in a collaborative group work, because it is difficult to say that every student's contribution is equal. So, the assessment is more difficult. It gives more workload to instructors. As Davies (2009) claimed, there are disadvantages and equity issues in terms of assessment. Students who are weaker can have their abilities effectively masked by more able members of the group, and capable students are left unstimulated. It would be helpful if the instructor defines responsibilities of group members, without losing control during the process, or require more assessment materials such as evaluating each other, which motivate an individual to think independently.

Brush and Saye (2000) claimed that successful implementation of PBL methods requires teachers to assume a guiding role and to simultaneously attend to many different aspects of the classroom. Chowdhury (2013) suggested that chemistry teachers must know and use their content knowledge in a variety of ways to motivate students in their learning and become interested in chemistry, to be responsive to the needs of students, to help facilitate the students' understanding and to provide a challenge for them. To solve the shortcomings of C-PBL, it can be suggested that instructor should be careful about social backgrounds of students and try to make the homogeny (about knowledge) groups related that background. Instructor should be careful about passive students and should motivate them to the lesson. For that aim, the instructor should try to know the students' social real life and create the context of problems close to that background.

Implications for Teaching

This is a small-scale study, and the results are based on a single intervention. We acknowledge that it is rather hard to reach generalizable conclusions out of such small-scale studies. However, this does not mean that the conclusions reached and the implications suggested are not useful for practice. The implications suggested are based on the data we gathered. Therefore, it would be helpful for those audiences who may have experienced similar cases. In the light of the findings, it could be argued that the C-PBL approach induces students to become autonomous learners and promotes investigation and life skills as well as helping to achieve the required knowledge, although it is not at an expected level. The achievement test results indicate that student only could reach the two thirds of the expected level of academic achievement. Based on this result, it could be suggested that in a C-PBL teaching approach, instructors need to be more helpful to the students to ensure that the required knowledge has been gained. Otherwise, students may go out with weak knowledge of the subject taught, although they may be in advantageous position in

terms of gaining some investigation and life skills. This brings the discussion to what role the teacher has to take in cases where students are not able to reach the accepted or expected scientific level of concepts taught? Whether to insist on a guidance role and allow students to grasp the ideas or switch to the traditional instructor role? This is not an easy question to answer. Based on the experiences that came out of this study, we believe that at the initial stages of the trial of a student-centred approach, teachers need to be more flexible and available to help students form their knowledge and then gradually let them investigate by themselves. If the instructor is not available out of school hours, particularly if they have to learn abstract concepts, as in this case, students feel themselves alienated and helpless. They do not know what to do particularly if they are coming from a long tradition of conventional teaching practices. Therefore, intensive student-instructor interaction at the initial stages is necessary. However, once the students get used to the method, they start to overcome this problem and start to organize questions to discuss with the instructor in the allocated times.

As in the case of this study, it is clear that C-PBL could be an alternative to lecturing, even to teach, difficult ideas like thermodynamics in chemistry if we can put it into a real-life context that students are familiar. However, this creates another difficulty. The context may vitiate from region to region, state to state and even between the cities. Therefore, it is not easy to create context for every student that makes sense. Using C-PBL requires contextualization of the concepts, and this requires new skills for the teachers. Therefore, in this process, the teacher and the researcher collaboration is essential.

After implementing C-PBL on thermodynamics in chemistry, an increase in the students' interest in both thermodynamics and chemistry, in general, has been witnessed. Based on this finding, it could be argued that subjects like thermodynamics could be effectively taught through a real-life context, with more concrete materials that could be developed to increase the students' interest in chemistry. Since there are insufficient resources (books, sample scenarios, videos etc.) in order to help C-PBL practices become common, materials need to be developed, piloted to establish the validity and made available to teachers and students.

In addition, the C-PBL approach encourages passive students to take part in group work and promote individual activities in order to have each member in the group participate in the study. However, teachers should be more careful about equal sharing of the responsibilities within the groups because less motivated students may experience problems in collaboration, task sharing and interaction within the group members, which would affect their achievement levels. One more issue with the group forming is the issue of taking the heterogeneity of gender into account in different environments in which there are some socio-cultural barriers as mentioned above. If there are some cultural barriers, they need to be taken into account. Insisting on heterogeneous groups in terms of gender may cause collaboration problems as it was the case in this study.

Finally, concerning the effect of C-PBL on the students' motivation to learn and attitudes towards chemistry, much longer interventions are needed. This study is implemented over 4 weeks' time only on one unit of chemistry. To be able to see a real effect on affective dimensions like motivation and attitudes, semester or year long practices are needed. Although context-based approaches are accepted as increasing the motivation to learn, this is also quite

related with how it is implemented. In the hands of inexperienced teachers, this effect may not be seen in a short while as teachers are learning and adapting themselves to this new method. Therefore, it is suggested that much longer implementation time is necessary.

Appendix 1 (Learning Outcomes)

Learning Outcomes

1. Realizes the importance of the relationship between system and surrounding
2. Classifies systems with the variables of heat exchange, temperature, pressure and volume
3. Explains the internal energy of a system on the basis of atoms/molecules
4. Associate the internal energy of the constant volume and constant pressure systems with the mechanical energy and heat exchange.
5. Describes the first law of thermodynamics
6. Gives examples to the field of thermodynamics applications in daily life
7. Explains the enthalpy change (dH) via reaction temperature (qp)
8. Relates the reaction enthalpy changes with "standard formation enthalpy changes"
9. Correlates the enthalpy change of a reaction with intermediate steps of enthalpy change
10. Establishes a relationship between the enthalpy changes in chemical reactions and the bond energies
11. Examines the concept of spontaneous/nonspontaneous change
12. Explains spontaneous processes tend to achieve a state of minimum energy and gives examples
13. Gives examples to spontaneous changes that do not meet the minimum energy
14. Explains the concept of entropy, on the basis to "thermal energy" and "probability"
15. Establishes a relationship between entropy changes (ΔS) and the spontaneity
16. Interprets the second and third laws of thermodynamics
17. Describes the total entropy change of the system and the universe via "Gibbs free energy"
18. Examines the spontaneity of chemical reactions via Gibbs free energy

Appendix 2 (The Content Covered in Thermodynamics)

The Curriculum in Thermodynamics

1. Systems and types of energy
    (a) System and surrounding
    (b) Internal energy
    (c) Heat and work
    (d) The first law of thermodynamics
2. Enthalpy and changes in the system
    (a) Enthalpy

(b) Standard formal energy
(c) Hess's law
(d) Bound energy

3. Spontaneity

(a) Spontaneous and nonspontaneous processes
(b) The second and third laws of thermodynamics
(c) Gibbs free energy
(d) The relation between the spontaneity of system and Gibbs free energy

Appendix 3 (Sample Scenario)

Stove and Carbon Monoxide Poisoning



On a cold winter day Mrs. Emine wants to make tea on a coal stove, so she puts 3 kilos of coal into the stove and ignites the coal. She puts the tea pot onto the heater.

After a while, her daughter Derya comes home from school and sits by the stove, stretches her hands towards it to warm up a little after a stormy snowy day. Seeing the boiling teapot on the stove, she thinks "how it is possible that a little heater like this can warm up the whole room and boil the water in the pot". She falls asleep by the hot stove. After a while she wakes up and feels the room and herself cold and thinks, "why nobody did invented a coal that burns out forever". She brings three more kilos of coal and fills up the stove and lies down on the cushion by the stove. After a while Mrs. Emine backs to home and sees her daughter sleeping by the stove, and calls on her. When her daughter does not respond, she goes to her and tries to wake her up. Despite all her efforts, she can't wake her up, and immediately calls emergency. When the health care team arrives and examines Derya, they diagnose that she suffers from carbon monoxide poisoning. They take Derya to a hospital for treatment.

Considering the story above, please answer the following questions. You can make use of the internet, course books and other recourses to make comprehensive and extensive explanations.

1. What is the reason for Derya's poisoning and how does this poisoning happen?
2. How the heating takes place? What kind of energy transfers and how this energy transfers take place between the stove and its surrounding?
3. Write the reaction that accompany to the coal burning and balance the reaction. Calculate enthalpy changes accompanying to the 3 kg of coal burning. Accept the formula and molecular weight of coal as C135H96O9NS, Ma= 1906 g.mole-1.
4. Other than coal what other alternative fossil energy sources can be used for heating, and what are the reactions that accompany during their burning? What is the enthalpy changes accompanying to the 1 kg of these fuels and compare them with the coal?
5. What do you think about the possibility of producing an ever burning coal? Discuss this question considering the first law of thermodynamics?

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