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Using Non-traditional Writing as a Tool in Learning Chemistry

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This study investigated the effect of using a non-traditional writing task and different audiences on 9th grade students' conceptual understanding of a chemistry unit on mixture. 524 students instructed by 3 chemistry teachers in 2 public high schools participated in this study. Upon completion of the mixture unit, 181 students engaged in traditional writing activities, 121 students wrote a letter to a younger audience, 92 students wrote a letter to their peers, and 130 students wrote a letter to their teacher. Mixture achievement test was administered as a pre- and posttest to all the groups to assess students' understanding of mixture concepts. Semi-structured interviews were conducted with 24 students from the non-traditional writing group at the end of the instruction to understand students' ideas about non-traditional writing task. Posttest analyses indicated that non-traditional writing group outperformed the traditional writing group, and the groups that wrote to peers and younger students performed better than those that wrote to the teacher, when the effects of the pretest scores were controlled. The results also showed that students' performance on the writing task significantly differed with respect to the audience. Moreover, interview results revealed that non-traditional writing tasks were very helpful in students' understanding of the mixture concepts.

Keywords: audience, chemistry education, mixture, non-traditional writing

INTRODUCTION

Development of scientific literacy can be achieved through the appropriate use of language (Yore, Bisanz, & Hand, 2003; Yore & Treagust, 2006). It is impossible to do science, to understand science, and to communicate about science without language (Hand, Norton-Meier, Staker, & Bintz, 2009). Reading, writing, speaking, and listening are the basic modes of communication for developing students' knowledge and understanding in science (Prain, 2007; Wellington & Osborne, 2001). Drawing and sketching are also forms of language and communicative tools that support the meaning-making process (Ainsworth, Prain, & Tytler, 2011); because drawing and sketching make student thinking visible, play a critical role in developing students' creative abilities (McGrath & Brown, 2005),

and facilitate students' construction of ideas and concepts (Dym, Agogino, Eris, Frey, & Leifer, 2005). Accordingly, drawing and sketching are considered as complementary to writing (Norris, Mokhtari, & Reichard, 1998). According to Emig (1977), writing is a unique form of learning in that it requires enactive (action-based), iconic (image-based), and symbolic (language-based) ways to represent the knowledge. Both left and right hemispheres of the brain, eyes, and hands work together when engaged in a writing activity. Because writing allows learners to use various learning strategies and results in a visible product, it assists learning.

Over the last three decades, there has been a great emphasis on using writing in science non-traditionally in addition to its traditional role (Keys, 1999). Traditional writing refers to using writing in science lessons for the purposes of communication and evaluation. This form of writing is compatible with the knowledge-telling model (Bereiter & Scardamalia, 1987). Communicating what a student knows to the teacher, giving short responses to teacher-generated questions, and taking notes from the board emphasize knowledge

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State of the literature

- Using writing-to-learn strategies in science education is a developing research area all over the world.
- Five elements that guide learning from writing in science are writing type, writing purpose, audience, topic and method of text production.
- Writing for authentic audiences in a variety of formats facilitates conceptual understanding.

Contribution of this paper to the literature

- Finding significant differences in students' conceptual understanding with respect to the audience factor encourages use of authentic audiences along with diversified types of writing in learning various science concepts at all levels of education.
- Demonstrating the value of non-traditional writing activities in learning chemistry suggests a shift from using traditional writing tasks to non-traditional writing tasks in line with the recent curricular revisions.

transmission and generally results in rote memorization rather than meaningful learning (Yore et al., 2003). On the other hand, non-traditional writing refers to using writing in science as a mode of learning through a number of diversified writing tasks, which align with the knowledge-transforming model (Bereiter & Scardamalia, 1987). When students engage in the knowledge-transforming model of writing, they consider their prior knowledge about the content; and they think about the meaning of the new concepts and the ways to communicate that meaning to the audience. This kind of writing occurs in an interactive-constructivist learning environment in which both individual and social construction of knowledge were emphasized in addition to the basic principles of constructivism, such as the influence of prior understandings on learning new concepts (Hand, Prain, Lawrence, & Yore, 1999). Individuals who are engaged in a social activity do not just internalize socially constructed meanings; they also negotiate those meanings with themselves (Prawat, 1996).

Prain and Hand (1996) proposed a framework of five elements to guide learning from writing in science: writing type, writing purpose, audience, topic, and method of text production. Writing type refers to using various kinds of writing (e.g., letter, newspaper, powerpoint presentation, and brochure) to support student learning. Writing purpose is related to a diverse range of purposes (e.g., reviewing, clarifying, and persuading) to encourage students in developing conceptual understanding. Audience is about writing for

a wide range of readers (e.g., peers, younger or older peers) to make students clarify their conceptual understanding considering the characteristics of the audience. Writing topic is the instructional content about which the writing is composed. It is important for a writing topic to demand that students analyze, represent, or manipulate their understanding in a new version. Students can be asked to write about key concepts of a topic or applications of those concepts and to link the major connecting ideas of that topic. Finally, method of text production refers to composing a text individually or as part of a group and writing a text by hand or on a computer. Variations in writing production methods are crucial in developing cognitive and metacognitive aspects of learning. Effective combinations of these elements can be used in a writing activity for an increased science understanding. When students are given opportunities to apply their understandings in a new context or to manipulate the content, they are likely to learn more (Langer & Applebee, 1987).

Of the five components suggested by Prain and Hand (1996), audience and writing type were frequently manipulated in writing-to-learn studies. The studies generally showed that writing for authentic audiences in a variety of formats increased student engagement and satisfaction in learning process (Hand, Yang, & Bruxwoort, 2007; McDermott & Kuhn, 2011; Wallace, 2007). For example, Gunel, Hand, and McDermott (2009) addressed teacher, peers, younger students, and parents as the audiences for high school students writing explanations about biology concepts; their results revealed that writing for peers or younger students was more beneficial than writing for the teacher or parents. McDermott and Kuhn (2011) examined the perceptions of college students engaged in two separate writing-to-learn activities for authentic audiences beyond the instructor. Based on student responses, writing-to-learn activities helped students learn better because of their consideration of audience during writing. When writing for audiences other than the instructor, students considered their own understandings and engaged in research when they realized gaps in their knowledge. In addition, students indicated that writing to a professor outside of the science area caused both considerations of their own understanding and of the rhetorical and professional qualities of the product.

In addition to the audience factor in a writing-to-learn activity, the relationships between student planning, writing and learning in science, and the influence of the number of writing tasks were investigated by Hand, Hohenshell, and Prain (2004). Their results indicated that either initially or delayed planning in a non-traditional writing activity was helpful in promoting students' conceptual understanding. They

found that students who engaged in more than one non-traditional writing task performed better on conceptual questions compared to those engaged in only one writing task. Some studies (Atila, Günel, & Büyükkasap, 2010; Gunel, Hand, & Gunduz, 2006; Hand, Gunel, & Ulu, 2009) used multimodal representations embedded within writing-to-learn activities in order to benefit more from writing. There were also some studies integrating writing-to-learn activities within argument-based inquiry classrooms using approaches such as the science writing heuristic (SWH; Hand & Choi, 2010; Hand, Wallace, & Yang, 2004; Hohenshell & Hand, 2006) and argument-driven inquiry (Sampson & Walker, 2012). For example, Hand, Wallace et al. (2004) investigated the contribution of using a second task of writing a textbook explanation in SWH classes to students' conceptual understanding. There were three groups: a control group, a treatment group exposed to the SWH approach, and a treatment group exposed to the SWH approach and writing a textbook explanation for their peers (SWH + textbook). The findings indicated that SWH and SWH + textbook group outperformed control group students on the multiple-choice test. However, only the SWH + textbook group performed better than the other two groups on essay-type questions. Student interviews revealed that textbook writing increased students' conceptual understanding and metacognition because students recognized their own knowledge gaps and translated technical knowledge into everyday knowledge during writing.

Reviewing a number of studies using non-traditional writing activities, Wallace (2007) pointed out a closer link between cognitive and metacognitive strategies and increased learning. A set of cognitive and metacognitive activities are used in the writing process, including planning, translating, reviewing, and monitoring (Flower & Hayes, 1981). In the planning stage, students generate ideas through the retrieval of relevant information from long-term memory. Then, they structure their ideas by ordering or grouping current ideas or by searching and forming new ideas in order to make meaning. Goal setting is an important aspect of the planning process because the goals influence the writer's generation and organization of ideas and vice versa. Those ideas are put into visible language during the translation process. Written ideas are reviewed based on two subprocesses, namely, evaluating and revising. Writing is a recursive process because reviewing may lead to new cycles of planning and translating. During the composition of the text, students can monitor the processes they engaged in as well as their own pace and progress.

Individuals have their own language structures in relation to their past understandings and experiences. When an individual's language is not congruent with the

language of instruction or the language of science, learning difficulties emerge. At that time, learning can be facilitated through the translations and negotiations between science language and an individual's own or everyday form of language. Non-traditional writing provides a context for the translation of language and negotiation of ideas. When individuals write about a science topic for a different audience, they engage in translation of three languages: everyday, audience, and science. First, they translate the scientific terminology into their own language so that they can understand the meaning of the scientific terms. Second, they translate what they understand about that topic to language that is appropriate for their intended audience. When writing to a particular audience, an individual needs to take into account the reader's background and negotiate the meaning between his/her own language and science language (Hand et al., 1999).

In many countries, including Turkey, traditional writing is conducted in a situation where students write down what the teacher says during the instruction. The main purpose of writing is note taking and evaluating. Students copy what the teacher says, they copy notes from the board and from the textbook, they draw and label diagrams, and they answer end-of-unit multiple-choice and short-answer type questions from the textbook. Much of the writing activities students engage in do not go beyond copying, which is undemanding. Some students prefer to copy from the notes of their peers instead of self-writing in the classroom; these students are not generally expected to engage in the sort of thinking processes involved in non-traditional writing discussed earlier. In line with recent revisions in elementary and middle school science curricula in Turkey, there is an emphasis on the use of language, including purposeful writing and using various communication tools (e.g., tables, graphics, and diagrams) in learning science (Ministry of National Education [MNE], 2005). However, the revisions in the high school chemistry curriculum only considered using different types of writing tasks for the purpose of evaluating student performance (MNE, 2011).

Taken as a whole, the studies of Gunel et al. (2009), Hand et al. (2007), and McDermott and Hand (2010) demonstrated that students engaged in non-traditional writing for particular audiences performed significantly better on conceptual questions and developed positive attitudes toward science and writing. Using non-traditional writing tasks in science education is a developing research area all over the world; there are fewer studies in the chemistry domain (Gunel, Hand, & Prain, 2007; Hand et al., 2007) and fewer national studies using writing-to-learn strategies (Atila et al., 2010; Erduran Avcı & Karaca, 2012; Gunel et al., 2006; Hand, Gunel et al., 2009).

Table 1. The frequency distribution of students across groups

	School A		School B		Total
	Teacher A	Teacher B	Teacher C		
Traditional Writing Group	87	79	15		181
Non-Traditional Writing Group					
Younger students	61	37	23		121
Peers	74	18	0		92
Teacher	45	46	39		130
Total	267	180	77		524

Due to chemistry's abstract nature (Garnett, Garnett, & Hackling, 1995), using technical terms in classrooms usually makes it difficult to understand because it may be hard to connect technical information to prior knowledge and experience. If the technical information is clarified using everyday words, new concepts may be easily embedded within the current concept structure (Wellington & Osborne, 2001). Furthermore, a scientifically literate person has the capability of using scientific knowledge in daily life; that is, individuals need to not only write traditional reports using scientific terminology but also practice writing about science for non-expert readers in different types of writing (Hand et al., 1999). For this reason, presenting chemistry information only by traditional writing is not sufficient for science literacy and understanding chemistry concepts; generally, it results in rote memorization. In this regard, using different types of writing tasks and writing to different audiences in representing the chemistry knowledge provides a context for translation of technical language into everyday language and thereby promotes meaningful learning. Building on these considerations, this study intended to add to this developing research area by introducing the investigation about the impact that non-traditional writing tasks and different audiences can have on student learning about mixture in the Turkish context.

Research questions that guided the study were:

- i. *Is there a significant mean difference between 9th grade students engaged in traditional and non-traditional writing tasks with respect to conceptual understanding of a chemistry unit on mixture?*
- ii. *Is there a significant mean difference in 9th grade students' conceptual understanding of a chemistry unit on mixture with respect to the audience?*
- iii. *Is there a significant mean difference in 9th grade students' end-of-unit writing scores with respect to the audience?*
- iv. *What are the perceptions of students in non-traditional writing groups about the end-of-unit writing task?*

METHODOLOGY

Sample characteristics, data collection tools, and the procedures followed in this study are described in this section.

Participants

A total of 524 regular 9th grade students (59% female, 41% male) attending two public high schools in a large city in Turkey participated in this study; these students were in the 16 chemistry classes of two female and one male chemistry teachers. One female taught in one school and the other female and male taught in another school; both schools were located in the same geographic region. Students' ages ranged from 15 to 17 years, and they came from middle-class families.

Procedure

A quasi-experimental, pretest-posttest design was used in this study because it was not possible get administrative approval to randomly select students from different classrooms. During the study, basic mixture concepts, classification of mixtures, solutions, solubility, factors affecting solubility, and separation of mixtures were covered as a part of the regular chemistry curriculum. The classes of each teacher were randomly assigned into either the traditional writing group or the non-traditional writing group. Students in the non-traditional group were further assigned into three groups writing to younger students, peers, and the teacher. Student distribution into groups across schools and teachers are shown in Table 1.

At the beginning of the instruction of the mixture concepts, students in both writing groups were given a unit test as a pretest in order to detect any group differences. Then, the major mixture concepts were taught to all the students according to the high school chemistry curriculum. The classroom instruction for all the groups included two 45-min periods per week and took place over a 4-week period. Equal amount of

instructional time was devoted for all the groups. The language of instruction and the data collection tools used in this study were Turkish.

The teachers mainly used lecture and discussion methods in all the groups. The chemistry textbook was the main source of knowledge, and the students were required to read the related topic prior to the class session. Teachers checked whether students did their assigned homework. Immediately afterward, they summarized the concepts taught in the previous class and asked questions to ensure that students had learned the concepts. Then, the teachers informed students about the goals of the current lesson. Teachers served as the main source of knowledge. They wrote the key terms on the board, defined and explained the concepts by giving examples. Through questioning, they encouraged students to rephrase their understanding of the concepts and give further examples to the concepts. They also tried to provide a context for the connection of concepts with everyday life. This discussion environment ended with a summarization of the concepts under consideration. Teachers asked students to take notes when they were summarizing the concepts. Toward the end of the class session, teachers wrote some algorithmic problems on the board and asked students to solve those problems individually for a few minutes. Teachers moved around the classroom and told disengaged students to try and solve the problems. After a while, teachers provided the correct answer and asked if any student could solve those problems correctly. The students who had the correct answer raised their hand. Teachers generally asked a student who could not solve the problem to come to the board and solve that problem. Teachers helped the students trying to solve the problems on the board. The problems that were not solved in class were given as homework. Over the course of the study, teachers did not use the chemistry laboratory in their teaching due to safety problems that may arise from having a crowded classroom or concerns about not being able to complete the syllabus on time. They sometimes used simple demonstrations while teaching the separation of mixtures. For example, one teacher used a filtration paper to separate an insoluble solid (sand) from a liquid (water), and a separating funnel to separate immiscible liquids (oil and water) as demonstration activities.

Upon completion of the unit, all the students engaged in different types of writing activities to ensure that the major concepts addressed in the mixture unit were reviewed by them. Students in the traditional writing group completed end-of-chapter questions and a study guide addressing the mixture concepts from the textbook. Students in the non-traditional writing groups completed a letter-writing task for different audiences (i.e., younger students - 6th graders, peers - 9th graders, and teacher) after receiving a handout informing them

how to write a letter. Students were asked to summarize the major mixture concepts (e.g., types of mixtures, separation of mixtures) in the form of a letter. They wrote their letters at home and submitted them within one week to the teacher. Finally, all students were given the same unit test as a posttest in order to compare the effect of the writing tasks on their understanding about mixtures. Only students from the non-traditional writing group were interviewed on completion of the unit so as to examine how these students perceived the letter-writing task. The traditional writing group did not complete this writing task and, thus, were not interviewed.

Data Collection

Data were collected using an achievement test, a writing assessment scale, and interviews of some students, which are explained below.

Mixture Achievement Test (MAT)

This instrument was developed to assess students' understanding of mixture concepts. Considering the objectives related to chemical change and mixture units determined by the national chemistry curriculum (MNE, 2011), 13 items were taken from Chemical Change and Mixture Achievement test (Kingir, Geban, & Gunel, 2012) and 4 items were developed by the researchers using textbooks, the Internet, and the University Student Selection Examination. The Mixture Achievement Test (MAT) consisted of 17 multiple-choice questions about the mixtures. The reason for preferring multiple-choice items is that it is relatively easy to administer and to score objectively. Each test item consisted of five alternatives: 1 correct answer and 4 distracters. Test items were related to classification of mixtures, solutions, solubility, factors affecting solubility, and separation of mixtures. See appendix for sample MAT items.

The MAT was examined by three chemistry educators to establish content validity and by two chemistry teachers and two Turkish language teachers for the appropriateness of language and student level. Cronbach alpha reliability coefficient was computed as 0.75 for this study. In the scoring process, each correct response was scored as 1, and each incorrect response was scored as 0; the total maximum score was 17, and the minimum was 0. This test was administered to all students as a pre- and posttest by the teachers during regular class sessions and took 25 minutes.

Writing Assessment Scale

A scale was developed by the researcher for assessing students' end-of-unit writing tasks. Using the

Table 2. Writing assessment scale

Criteria	Unsatisfactory (0)	Satisfactory (1)	Very Satisfactory (2)
1 The paper follows a typical letter structure.	○	○	○
2 The text is grammatically correct.	○	○	○
3 The writing sample is clear and understandable.	○	○	○
4 The writing sample is fluent.	○	○	○
5 Main conceptual idea is continually addressed throughout the paper.	○	○	○
6 Required topics are completely described in text.	○	○	○
7 Key terms are underlined, highlighted or identified in text.	○	○	○
8 The content is linked with daily life.	○	○	○
9 Chemistry concepts are scientifically correct.	○	○	○
10 The concepts are linked to each other accurately.	○	○	○
11 Everyday language is used in text.	○	○	○
12 Examples are carried throughout sample.	○	○	○
13 Visual representations are carried throughout sample.	○	○	○
14 Writing sample is informative for the audience.	○	○	○
15 Language and expression is appropriate for the audience.	○	○	○
16 The examples are appropriate for the audience.	○	○	○
17 The visual representations are appropriate for the audience.	○	○	○

relevant literature assessing student writings (McDermott, 2009; McDermott & Kuhn, 2011), it was determined that the items concerning language and expression, content, and audience could be combined to indicate how well students summarized the unit with respect to the specified audience and writing type. Mainly, the grammatical, accuracy, fluency, and clarity aspects of the text; usage of everyday language, examples and visual representations in the writing sample; and the appropriateness of the writing for the intended audience was assessed via this scale. Field notes were taken during the assessment of the writing samples to be used in explaining the differences among the groups writing for different audiences. Each item in this scale was scored on a 3-point scale (1 = unsatisfactory, 2 = satisfactory, 3 = very satisfactory). The scale included 17 items in total; these items were combined and referred to as total writing score for each writing sample. A sample of this scale is shown in Table 2.

To determine whether the writing assessment scale truly measures the intended variables, an expert in the field of writing-to-learn in science reviewed the items, scoring, and format of the scale considering the item

descriptions provided by the researcher and judged that it was appropriate for assessing student writing. For inter-rater reliability of the scale, writing samples were selected randomly and then scored by the author and an independent researcher until reaching consensus. The independent researcher was a master's student in science education who was experienced in assessing student writing tasks. The overall agreement attained by the researchers was 94% after the assessment of three writing samples. Cohen's kappa statistic was calculated as 0.89, which is almost perfect according to Cohen (1960).

Semi-structured Interviews

Interviews were conducted after the instruction in order to understand students' ideas about the non-traditional writing task. The interview protocol was constructed by the researchers and revised with the recommendations from experts. Interview protocol included 6 questions about writing a letter to different audiences. Students' ideas about their own learning (e.g., Do you think that you learned when you were writing a letter? How do you know that?), writing to an audience

(e.g., Do you think that writing to an audience contributed to your learning? How?), and their feelings (e.g., What did you feel when you were explaining mixture concepts through writing a letter?) were explored via semi-structured interviews. The interviews were conducted with 24 volunteers (21 females, 3 males) selected from each of the non-traditional writing groups. Of the 24 students, 9 wrote to younger students, 9 wrote to peers, and 6 wrote to their teacher. When choosing the volunteer students for the interview, the researcher considered the sample to be representative of able, average, and less able students based on teacher comments. One researcher interviewed the students individually at school and tape-recorded all sessions. The audiotapes were later transcribed in full. The interviews lasted about 10 minutes.

RESULTS

This section reports the analysis of the research questions with the major findings. There were two dependent variables, an independent variable, and a potential covariate in this study. The dependent variables were students' understanding of the mixture concepts measured by the post-MAT and total writing scores measured by the writing assessment scale. The independent variable was the grouping variable. The potential covariate was the students' previous knowledge about mixture concepts measured by the pre-MAT. In this study, the significance value of 0.05 was used for the statistical tests; it was adjusted by using the Bonferroni procedure when performing multiple tests with respect to the audience ($0.05/3 = 0.017$). Cohen's *d* index was interpreted as a measure of effect size. An effect size is small when Cohen's *d* is between 0.2 and 0.5 standard deviations, medium when it is between 0.5 and 0.8 standard deviations, and large when it is greater than 0.8 standard deviations (Cohen, 1992).

The Impact of Non-traditional Writing on Student Achievement

Descriptive statistics for pre- and post-MAT across groups are presented in Table 3. In order to take out the

unwanted effects of pre-MAT on the post-MAT, an analysis of covariance (ANCOVA) was conducted. Results indicated a significant difference between the groups, $F(1, 521) = 7.90, p < 0.05$. Students in the non-traditional writing group ($M = 6.69, SD = 2.01$) outperformed those in the traditional writing group ($M = 6.02, SD = 2.23$) with respect to measures of the posttest. The size of the mean difference between the groups was small, $d = 0.25$.

The Impact of Writing to Different Audiences on Student Achievement

ANCOVA was conducted to compare the groups writing to different audiences with respect to their understanding of the mixture concepts, by controlling the effects of the pretest scores. The results showed that there was a significant mean difference in students' understanding of mixture concepts with respect to the audience, $F(2, 339) = 4.07, p < 0.05, d = 0.31$. Further ANCOVA analyses explored the differences among the levels of audience. Those findings indicated that students writing to younger students performed significantly better on the posttest than those writing to the teacher, $F(1, 248) = 6.86, p < 0.017$, indicating a small effect size, $d = 0.33$. However, the difference between the groups writing to younger students and peers was not significant, $F(1, 210) = 0.004, p > 0.017$. The mean difference between the groups who wrote to peers and teacher was also not statistically significant on the posttest at the significance value of 0.017, $F(1, 219) = 4.65$, although it has a small practical significance, $d = 0.29$.

The Impact of Writing to Different Audiences on Student Writing Scores

ANOVA was conducted to compare the groups writing to different audiences with respect to total writing scores. The results showed that there was a significant mean difference in total writing scores with respect to the audience, $F(2, 335) = 23.99, p < 0.05, d = 0.76$. Bonferroni follow-up tests showed that all three groups differed significantly from each other. The

Table 3. Descriptive statistics concerning pre- and post-MAT across groups

	<i>Pre-MAT</i>				<i>Post-MAT</i>			
	<i>N</i>	<i>M</i>	<i>SD</i>	<i>Range</i>	<i>N</i>	<i>M</i>	<i>SD</i>	<i>Range</i>
Traditional Writing Group	181	5.82	2.62	11	180	6.02	2.23	11
Non-Traditional Writing Group								
Younger students	109	6.16	2.92	11	112	6.87	2.04	8
Peers	76	5.98	2.05	9	87	6.80	2.06	9
Teacher	119	6.17	2.27	12	120	6.44	1.94	10

students writing to younger students ($M = 23.34$, $SD = 5.32$) significantly outperformed those writing to peers ($M = 21.46$, $SD = 5.29$) and the teacher ($M = 18.73$, $SD = 5.16$). Similarly, students' writing performance for those writing to peers was significantly higher than for those writing to the teacher. The size of the mean difference between the groups writing to younger students and peers was small, $d = 0.35$; between the groups writing to peers and the teacher was medium, $d = 0.52$; and between the groups writing to younger students and the teacher was large, $d = 0.88$.

Moreover, six items (5, 6, 7, 8, 9, and 10) in the writing assessment scale (Table 2) that were related to conceptual understanding were combined in order to obtain those scores on students' writing. ANOVA with Bonferroni on the post hoc test was conducted to compare the mean differences among the groups writing to different audiences. The results revealed significant mean differences in students' conceptual understanding scores on writing with respect to the audience, $F(2, 335) = 58.31$, $p < 0.001$, $d = 0.56$. Bonferroni follow-up tests showed that students writing to younger students ($M = 8.45$, $SD = 2.08$) and peers ($M = 7.83$, $SD = 2.15$) demonstrated significantly better understanding of the concepts on writing than those writing to the teacher ($M = 7.07$, $SD = 2.07$). The size of the mean difference between the groups writing to younger students and teacher was medium, $d = 0.67$, and between the groups writing to peers and the teacher was small, $d = 0.36$. The mean difference between the students writing to younger students and peers was not significant.

Student Perceptions on Non-traditional Writing Task

For the analyses of the interview data, the audio recordings were transcribed verbatim. The first three interview transcripts were coded independently by the author and a PhD in chemistry education. Then, the codes and categories were compared. It was seen that the codes and categories were generally similar. After a thorough discussion about the discrepancies on some codes and categories, the researchers reached consensus. The Kappa coefficient was calculated as 0.92, which is almost perfect according to Cohen (1960). The remaining transcripts were coded by the author; the codes that were close to each other were collected and categorized into three general themes: attitudes toward writing, contribution of the writing, and comparison of traditional and non-traditional writing (Marshall & Rossman, 2006). Field notes were taken during the coding process. The interview data were interpreted based on the codes and categories as shown in Table 4 and the field notes.

Attitudes toward Writing

The students were asked what they felt about the writing task. Most (63%) claimed that writing a letter for different audiences was amusing, interesting, and enjoyable; 78% of the students writing to younger students and peers thought that writing a letter was easy, but 67% of the students writing to the teacher thought that it was difficult. All the students writing to the teacher and half of the students writing to peers and younger students felt that they had missing information about the mixture concepts. All the students found the writing activity useful for several reasons, including deeper learning, reviewing previously learned concepts, and having a higher grade from the examination. Writing for an audience made some students (29%) excited. For example, those writing to peers or younger students were excited for teaching the concepts to someone who is not knowledgeable. Likewise, students writing to the teacher were excited for being assessed by their teacher. On the other hand, some students (33%) found the writing activities stressful and boring. Students writing to the teacher found this an especially stressful situation because the teacher was perceived to know everything about the topic. Some students (12%) thought that writing in the form of a letter was boring because letter writing was not a part of their usual life.

Contribution of the Writing

All the students asserted that writing a letter contributed to their learning. Students claimed that they recognized their missing knowledge when they were writing, and they closed the gaps in their knowledge and changed some of their conceptions through writing. Half of the students expressed that they confused the terms homogeneous and heterogeneous mixtures. Their knowledge about these two concepts became clear through the writing activity. Some students (37%) stated that writing a letter to different audiences was effective in their learning because they were required to think about the audience before writing. Many students (87%) stated that they reviewed their already held conceptions before writing and searched for the information needed for writing to their audience. Some (25%) suggested that, without internalizing, a concept cannot be taught to anyone else; therefore, they engaged in a comprehensive investigation of the concepts from various sources. The students writing to younger students and peers stated that they attempted to use language appropriate for their audience in describing the concepts. Some (17%) said that they avoided using science terms; instead, they used everyday language in explaining the concepts. Some students (37%) writing to peers and younger students helped make themselves feel like a teacher. However, students writing to their teacher

Table 4. Categories and codes with examples

Category	Code	Example
Attitudes toward writing	<i>enjoyment</i>	"Writing activity was interesting, and amusing"
	<i>difficult</i>	"It was difficult to write to the teacher because she was expert about the subject matter"
	<i>easy</i>	"Teaching the mixture concepts to 6 th graders was easy for me because I was familiar with the mixture concepts"
	<i>feeling inadequate</i>	"I felt that I was inadequate when explaining the concepts to the teacher"
	<i>useful</i>	"Our teacher explained the mixture concepts briefly... We could get a chance to learn more about the mixture concepts through this writing task. Therefore it was useful for us"
	<i>excitement</i>	"I feel excited because I was wondering whether the audience would like my writing"
	<i>stressful</i>	"I was stressful when I was writing because I was thinking that my writing was going to be assessed"
Contribution of writing	<i>boring</i>	"I had never written a letter before this task because we are now in technology age... Writing a letter within the course context was boring for me"
	<i>learning</i>	"I learned more because I thought more when I was writing"
	<i>reviewing & investigating</i>	"By reviewing the concepts, I reinforced the concepts that I learned before" "When writing, I searched the mixture concepts from different source books and internet"
	<i>conceptual change</i>	"I was confusing the terms homogeneous and heterogeneous mixtures. I understood these concepts very well through the writing activity"
	<i>awareness</i>	"I thought what I now and I don't know before writing"
	<i>teaching experience</i>	"I am experienced enough to teach someone else something"
	Comparison of traditional and non-traditional writing	<i>understanding</i>
<i>audience</i>		"When writing a letter, you are explaining the concepts appropriate for an audience"
<i>use of language</i>		"When writing a letter, you take care to use appropriate and proper language and avoid from mistyping words"
<i>adding personal ideas</i>		"In a traditional writing you just write the definition of the terms ... but when writing a letter you can give your own examples and daily life examples"
<i>feeling</i>		"When writing traditionally, it is boring, that's just content specific; but when writing in the form of a letter, there is some amusement. We all students like amusement and therefore it makes us learn more"

expressed that they were required to be serious or formal in their writing. They used more technical language and claimed they were not comfortable when writing because they considered their teacher to be an expert.

Comparison of Traditional and Non-traditional Writing

Students were asked about the differences between traditional and non-traditional writing. The differences perceived by the students were about understanding of the concepts, audience, use of language, adding personal ideas and interpretation, and feeling. All the students agreed that explaining the concepts in the form of a letter helped them understand in a deeper manner.

Many students (83%) stated that writing to an audience was different for them. However, there were some discrepancies in the view of students about the benefits of writing to an audience. Students writing to younger students generally (78%) viewed that explaining the concepts to younger students was helpful in their learning. However, some students (12%) writing to their peers did not find it helpful because they were already explaining the concepts to their peers orally in the classroom. Two students writing to the teacher found it redundant to do so because the teacher was the main source of knowledge. The language used in traditional and non-traditional writing was also perceived differently by many students (58%). When writing a letter, students were instructed to use language appropriate for the audience. For example, when writing

to the teacher, they needed to be very serious and, when writing to younger students, they needed to think about what a 6th grader needed to know and could understand. While students writing to younger students and peers added their personal information and interpretation into their writing, students writing to the teacher preferred to use the exact information included in their textbooks or notebooks so as to avoid giving wrong information. Moreover, many students (87%) thought that non-traditional writing tasks were enjoyable while the traditional writings were boring.

DISCUSSION

This study mainly investigated the effect of using non-traditional writing tasks and different audiences on 9th grade students' understanding of mixture. Results showed that there were significant differences in posttest mean scores between the traditional and non-traditional writing group in the favor of non-traditional writing group when the effects of pretest scores were controlled. There were also significant differences between the groups writing to younger students and teacher and to peers and teacher in favor of the groups writing to younger students and peers when the effects of pretest scores were controlled. When the Cohen *d* indices calculated for the mean differences were interpreted, it is seen that the size of the mean differences were small. This finding is congruent with previous writing-to-learn studies that resulted in small or medium effect size (Bangert-Drowns, Hurley, & Wilkinson, 2004; Gunel et al., 2007). Detecting such a small effect size may be related to the type of question used for measuring students' understanding (Bangert-Drowns et al., 2004; Hand, Wallace et al., 2004). The instrument used for this study included multiple-choice items. Medium or large effect size might be obtained if essay-type questions are used for measuring students' understanding. In addition, significant differences in students' writing scores were detected with respect to the audience factor. Students writing to younger students and peers scored significantly higher than those writing to the teacher in the letter-writing task. Different from the results obtained from the posttest analysis, a significant difference in total writing scores was observed between the groups writing to younger students and peers in favor of that for the younger students. The size of the mean differences between the groups ranged from small to large.

Type of writing and audience may cause the difference among the groups in terms of understanding of mixture concepts. Contrary to traditional writing activities, the letter-writing activity was a purposeful act for the students (Flower & Hayes, 1981); and students used language consciously and retained more knowledge (Rivard, 1994). Students benefited most when they

wrote to younger students and peers because these audiences required the need for translation of science language into everyday language. When writing to younger students and peers, students used everyday language to unpack their science understandings; and they moved between everyday language and technical language. Providing students opportunities for the translation of science language into everyday language made them flexible, comfortable, and fluid in their scientific knowledge (Wallace, Hand, & Prain, 2007). On the other hand, students did not focus on the translation when writing to their teacher; they tended to use more science information in order to show what they know.

A second possible factor that may be related to difference between the groups is linking familiar concepts with new concepts. Students writing to younger students and peers discovered their prior understandings about the topic before writing; then they tried to explain the new conceptions by using familiar/known concepts in order to simplify the topic (Bangert-Drowns et al., 2004; Prain, 2007). The more the linkages among the concepts, the more meaningful the learning is.

A third possible factor of the group difference relates to manipulation of the content. Writing for younger students and peers in letter format provided students more opportunity to manipulate the information compared to those writing to the teacher. As the content is manipulated in more complex ways, it is more likely to be conceptualized and remembered (Langer & Applebee, 1987). The last factor in explaining the group difference may be related to stimulation of metacognitive awareness. Students thought what they already knew about the content and explored gaps in their own knowledge. This metacognitive thought further stimulated them to search for new knowledge and review the task. They tended to use more cognitive and metacognitive strategies (Bangert-Drowns et al., 2004; Hand, 2007).

Moreover, students' writing samples revealed some differences with respect to the audience. Based on the field notes taken during the assessment of the writing samples, students writing to their teacher generally began to write their letter by stating, "I am going to write what I understood from what you taught us" and ended their letter by stating, "If you recognize some gaps and misinformation in my letter, please let me know". These statements indicate that students perceived writing as an evaluation tool when they wrote to their teacher; they just iterated what their teacher transmitted to them in their writing. They were emphasizing their teacher as a main source of knowledge and paying attention to avoid giving wrong information, which limited them from adding their personal ideas and interpretations. It was apparent that

students writing to the teacher were not constructing their own knowledge. Previous research has shown that the majority of teachers view themselves as the sole audience for science writing and they find errors and correct them. Therefore, the primary goal of student writing becomes to get a higher grade when they write to the teacher (Chinn & Hilgers, 2000). On the other hand, students writing to peers or, especially, younger students were more flexible and comfortable in their writing and clarified their own understandings by using a more simplified language with personal examples and interpretations (Wallace et al., 2007).

The interview results revealed that students viewed non-traditional writing tasks helpful in their own learning. Students felt that they were more aware of their own learning, and they articulated their thoughts when writing to their peers and younger students. These findings are consistent with the findings of previous research (Gunel et al., 2009; Hand et al., 2007; McDermott & Hand, 2010; McDermott & Kuhn, 2011). Students thought that writing in letter format and for a particular audience was amusing but writing in a traditional format was boring. The reason for this may be explained by the power of writing as active engagement of students in their learning. Writing for authentic audiences required students to plan, organize, clarify, and unpack their understanding of science through simple language (Wallace, 2007). Students were both cognitively and metacognitively very active, resulting in higher understanding of the concepts (Hand, 2007; Yore & Treagust, 2006). However, in traditional writing, students usually iterated the information in their textbook or notebook rather than manipulating the content, which made them have little control over their own learning and ultimately led to boredom (Wallace, cited in Wellington & Osborne, 2001).

Traditional writing is very common in Turkey. Despite some curricular revisions, transmission of information is still dominant in chemistry lessons. Students copy from textbooks or from the words and drawings of the teacher. Most of the time in Turkish classrooms, the teacher speaks and then the students write. Writing is generally used for the purposes of copying and evaluation (MNE, 2011). Such kind of writing generally does not result in meaningful learning because it requires recalling knowledge from the short-term memory and reiterating previously acquired knowledge. Based on more contemporary views and recent theories of learning, learning occurs through the negotiation of ideas (Hand, Norton-Meier et al., 2009). Writing for different purposes by using various types of language for different audiences provides a context for the negotiation of ideas (Prain & Hand, 1996). By using a variety of non-traditional writing activities considering student characteristics and needs at all levels of

education, science literacy skills of the individuals can also be developed. Explanation of a topic for a particular audience in a specified format looks like what scientists do in representing science, because a scientist reaches a conclusion following his/her research and then presents the findings to an audience in an appropriate written format. Thus, writing for an audience facilitates student understanding of the writing practices of scientists and further develops science literacy skills (McDermott & Hand, 2010; Prain, 2007). However, Turkish students are not familiar with alternative writing tasks and science teachers are neither experienced nor educated enough to use a broad range of writing types within their classrooms. There is a need for the development of preservice and inservice teacher education programs that focus on the development of pedagogy, beliefs, and attitudes about writing-to-learn strategies (Prain & Hand, 1996; Rivard, 1994). This study suggests a shift from traditional writing tasks to non-traditional writing tasks in line with the curricular revisions done in different science domains (MNE, 2005). In addition, this study showed teacher reluctance toward using chemistry laboratory and inquiry-based activities. However, just having experiments in a laboratory does not always result in meaningful learning (Urbancic & Glazar, 2012). A considerable number of studies demonstrated the benefits of using non-traditional writing embedded within inquiry-based laboratory activities on students' conceptual understanding (Hand, Wallace et al., 2004; Hohenshell & Hand, 2006). Therefore, this study also suggests that preservice and inservice education programs encourage teachers' use of non-traditional writing tasks within inquiry-based chemistry classes using the laboratory.

The present study has a few important limitations that need to be considered in interpreting the results. First, students' positive attitudes toward the non-traditional writing task might arise from the novelty effect (Fraenkel & Wallen, 2003) rather than the nature of the task because students wrote to a different audience only once. Second, the groups were compared with respect to writing scores without controlling students' prewriting scores. Students may be given a writing task at the beginning of the study and then their writing scores could be compared in order to have an idea about their writing ability prior to the study.

Despite some limitations discussed above, the findings obtained from this study are encouraging for using diversified types of non-traditional writing tasks in larger and different contexts at all levels of education to examine its effect on self-regulation and metacognition as well as conceptual understanding. This study may convince chemistry teachers and professors that such non-traditional writing activities are valuable for students in learning chemistry. This study may be expanded to include two or more units rather than one

because longer-term interventions may yield more positive effects (Bangert-Drowns et al., 2004; Hand, Hohenshell et al., 2004). Further studies may consider re-drafting the writing task based on the audience feedback (McDermott & Hand, 2010).

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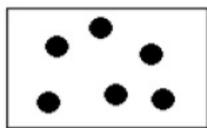
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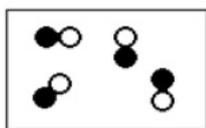
APPENDIX. Sample mixture achievement test items

1. The diagrams given in below represent a mixture. In these figures, the symbol \bigcirc represents a single atom of a certain type; the symbol \bullet represents a single atom of another type. If the symbols for atoms touch, they are part of a molecule. The symbols, $\bigcirc\bullet$, $\bigcirc\bigcirc$ and $\bullet\bullet$, represent different molecules.

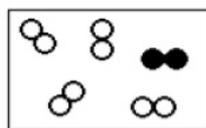
Which of the following diagram(s) represent a mixture?



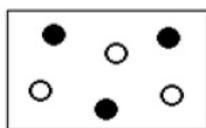
I



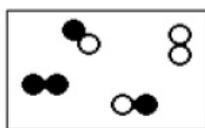
II



III



IV



V

- A. Only IV B. I and II C. I and IV D. II, III and V E. III, IV and V

2. Filtration using the equipment shown at right can be used to separate which materials?

- A. a mixture of salt and water
 B. a mixture of alcohol and water
 C. a mixture of sand and wood shavings
 D. a mixture of pepper and water
 E. a mixture of salt and pepper

