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RESEARCH ARTICLE

Evaluating University Students' Understanding of Atmospheric Environmental Issues Using a Three-Tier Diagnostic Test**

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Abstract

The objective of this study was to evaluate university students' understanding of atmospheric environmental issues according to gender and attending (or not) a college level environmental course (CLEC) including topics such as global warming (GW), greenhouse effect (GE), ozone layer depletion (OLD) and acid rain (AR), and to investigate their misconceptions about the examined content using a three-tier diagnostic test. In this study, the survey method was used. The sample of the study consisted of 170 students enrolled in the College of Science at San Jose State University in the USA. To collect the data, "The Atmosphere-Related Environmental Problems Three-Tier Diagnostic Test (AREPDiT)" was used. The data were statistically analyzed using variance analysis (two-way ANOVA) to determine possible differences in students' understanding of atmospheric environmental issues. In addition, they were descriptively analyzed to find out what misconceptions students had. The results of the analysis indicated that male students' conceptual understanding of atmospheric environmental issues was significantly higher than that of their female counterparts and that students who had attended a CLEC had a higher conceptual understanding of atmospheric environmental issues than those who had not. It was also found that university students had various misconceptions about atmospheric environmental issues.

Keywords: Global warming, ozone layer depletion, acid rain, misconception, three-tier diagnostic test, university students, gender

Introduction

Especially since the industrial revolution, the world is threatened by many anthropogenic reasons such as fossil-fired power generation, human-made chemicals and deforestation. Although the tendency to use clean energy resources to meet the energy people need has grown continuously, the majority of the energy is still supplied by fossil fuels and, unfortunately, the consumption of fossil fuels dramatically contributes to some atmospheric environmental problems such as acid rain (AR) and global warming (GW) (EPA, 2014; Menz, & Seip, 2004). Similarly, the ozone layer that shields the earth from the harmful UV rays of the sun is damaged by human-made chemicals such as CFCs and halons (Boyes, Stanisstreet, & Papantoniou, 1999; Daniel, Stanisstreet, & Boyes, 2004). The negative effects of these atmospheric environmental problems on both health and the environment have often been reported in the literature (Haines, Kovats, Campbell-Lendrum, & Corvalán, 2006; Likens, Driscoll, & Buso, 1996; Menz, & Seip, 2004).

Conscious or unconscious individual actions such as excessive energy consumption generate substantial cumulative impacts on the environment. Therefore, individuals with knowledge and awareness of the environment are considered as an important factor in

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minimizing environmental problems (Carrier, 2009; Tikka, Kuitunen, & Tynys, 2000). Environmental education (EE) has a critical role in developing individuals who have scientific knowledge of environmental issues and high environmental awareness (Grimmette, 2014). Therefore, local and national governments organize training programs and organizations that have the potential to enhance participants' awareness and understanding of environmental issues. For example, Australian government organized sun awareness campaigns, which would help the public enhance their awareness of dangers of sun related diseases (Cordero, 2000). However, although EE that allows individuals to explore environmental issues, engage in problem solving, and take action to improve the environment is provided to students in their science classes at various points, it has still been reported that students at different levels have various misconceptions about global warming (GW), ozone layer depletion (OLD) and acid rain (AR) (Kahraman, Yalcin, Ozkan, & Aggul, 2008; Khalid, 2003; Kilinc, Stanisstreet, & Boyes, 2008).

Misconceptions are cognitive structures that are typically resistant to change (Pesman, & Eryilmaz, 2010; Schmidt, 1997) and may become a hindrance for learners to learn advanced science concepts (Nakhleh, 1992). Therefore, it is very important to identify students' misconceptions about the examined content prior to teaching it. To date, various approaches have been used to probe students' conceptual understanding and misconceptions of atmospheric environmental issues. One of these approaches is the use of open-ended questions and interviews (Kahraman, et al., 2008; Papadimitriou, 2004; Rye, Rubba, & Wiesenmayer, 1997). Although open-ended questions and interviews provide researchers with opportunity to obtain more insight into participants' thinking, the generalizability of the results of such studies is rather limited. Studies in which interviews are used are generally performed on small samples, since interviewing takes a long-time and requires substantial training (Treagust, 1988). The other common approach is the use of close-ended questions such as true-false questions, Likert-type questions and multiple-choice questions (Groves, & Pugh, 1999; Khalid, 2003; Pekel, & Ozay, 2005), and multiple-choice questions that are less time-consuming and allow researchers to obtain data from a large sample are one of the most commonly used among close-ended questions (Tsui, & Treagust, 2010). However, conventional multiple-choice questions may not always be successful in revealing students' understanding and in identifying their misconceptions (Tsui, & Treagust, 2010). Therefore, two-tier multiple-choice diagnostic questions, which have distractors specifically designed by choosing from students' responses identified as misconceptions on earlier tests, were developed as an alternative way in which researchers and educators could identify students' misconceptions easily (Treagust, 1986) and, to date, such questions have been used by many researchers to identify students' conceptions in different content areas (Chandrasegaran, Treagust, & Mocerino, 2007; Lin, 2004). However, although two-tier diagnostic tests provide more information about students' understanding and misconceptions of the subject matter than do conventional multiple-choice tests, they are insufficient to differentiate students with misconceptions from those with lack of knowledge (Caleon, & Subramaniam, 2010). Therefore, an additional tier that provides researcher with opportunity to eliminate the disadvantage of two-tier diagnostic tests was suggested to integrate into two-tier diagnostic tests (Hasan, Bagayoko, & Kelley, 1999; Pesman, & Eryilmaz, 2010).

Although the literature includes numerous studies investigating students' (from primary education to post-secondary education) understanding and misconceptions of atmospheric environmental issues, a study that had used a three-tier diagnostic test was not found (except the study by Arslan, Cigdemoglu and Moseley (2012) in which the instrument used in this study was developed). Additionally, everyone, regardless of gender, is responsible for the sustainability of the environment and if there is a difference between female and male students' environmental knowledge, the first step of narrowing the gender gap is to determine that difference. If any, further studies may deeply investigate the reasons underlying the gender gap using qualitative research design. However, the research literature that focused on the gender differences in scientific knowledge of atmospheric environmental issues is largely limited (Hayes, & Tariq, 2000; McCright, 2010). Therefore, this study aimed to investigate whether there were statistically significant differences in university students' conceptual understanding of atmospheric environmental issues according to gender and attending (or not) a college level environmental course (CLEC) including topics such as GE, GW, OLD and AR, and to identify their misconceptions about the examined content using a three-tier diagnostic instrument.

Methodology

In this study, survey method, which is used to learn about peoples' attitudes, beliefs, values, demographics, behavior, opinions, habits, desires, ideas and other types of information, was used. There are three reasons why surveys are commonly used in education: versatility, efficiency, and generalizability (McMillan, & Schumacher, 2006, p.233).

Working Group

In this study, the data were collected using a convenience sampling method in which a group of subjects is selected on the basis of being accessible and expedient (McMillan, & Schumacher, 2006, p.125). The data of the study were collected from 175 students enrolled in the College of Science at San Jose State University (SJSU) in the USA but five respondents were removed from the analysis because of missing data. Therefore, the sample of the study consisted of 170 university students who were attending General Chemistry. In the sample, there were 90 females (52.9%) and 80 males (47.1%). The mean age of the participants was 19.99 years old (SD = 2.39) ranging from 17 to 30 years old. In addition, 28 (16.5%) participants reported that they had attended a CLEC while 142 (83.5%) reported that they had not. Although most of the participants were enrolled in science programs such as biology and chemistry, there also were those who were enrolled in different majors such as geology, engineering etc.

The Instrument

In the study, the Atmosphere-related Environmental Problems Diagnostic Test (AREPDiT) developed by Arslan, et al., (2012) was used. Prior to the study being performed, I obtained the permission from the corresponding author to use the AREPDiT. The AREPDiT consisted of 13 three-tier questions. The first (content tier) tier included multiple-choice questions evaluating the content knowledge of respondents. The second tier (reason tier) included multiple-choice questions assessing whether the respondents knew the reason of the answer they provided for the first tier. The third tier (confidence tier) included a question assessing whether the respondents were certain about their answers for the first two tiers.

McMillan and Schumacher (2006, p.130) stated that "validity is a situation-specific concept; it is dependent on the purpose, population, and situational factors in which measurement takes place". Therefore, I re-examined the validity and reliability of the AREPDiT on the collected data and presented the results in the Table 1 and 2.

Table 1.

The descriptive statistics for the AREPDiT

Statistic	n	M	SD	KR-20
Participants	170			
Items	13			
Reliability Coefficient				.81
Minimum/Maximum score	0/11			
Difficulty indices		.27	.09	
.30 - .40	5			
.20 - .30	5			
<.20	3			
Point-biserial correlation coefficient		.54	.10	
.70 - .80	1			
.60 - .70	4			
.50 - .60	3			
.40 - .50	4			
.30 - .40	1			

The item difficulty expresses the proportion or percentage of test takers who answered the item correctly (Reynolds, Livingstone, & Willson, 2006, p.142). The results indicated that five items (between 30% and 70%) had desirable difficulty while eight items (under %30) were difficult (see Table 1). The mean of difficulty indices was found to be .27, suggesting that the AREPDiT was a difficult test for university students. Item discrimination refers to how well an item can accurately discriminate between examines who differ on the construct being measured (Reynolds et al., 2006, 144). An item is considered to be good if its discrimination index is between .30 and .39, and is considered excellent if the index is .40 or higher (Reynolds et al., 2006, p.146). As shown in the Table 1, one item was good while the others were excellent. The average score of point-biserial correlation coefficient was .54, suggesting that the AREPDiT was an instrument which had the potential to distinguish examinees who performed well on the test from those who doing poorly.

Additionally, I examined both the content and construct validities. The positive correlation between the first two scores and confidence scores is considered as an evidence of the construct validity because students with high scores were expected to be more confident than were those with low scores (Cataloglu, 2002). To test the construct validity of the AREPDiT, the correlation between the scores of both two tiers and those of the reason tier was calculated and the results showed the AREPDiT had an acceptable construct validity ($r = .39$, $p < .01$).

Table 2.

Percentages of false negatives and false positives

	Items (%)														
Variable	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13	M	SD
False Positives	15.1	.6	7.0	5.8	10.5	1.7	1.7	0.0	2.3	.6	6.7	1.7	1.2	4.2	4.4
False Negatives	3.5	0.0	1.2	4.1	0.0	.6	2.3	.6	5.8	1.2	2.9	2.9	2.3	2.1	1.7

Hestenes and Halloun (1995) reported that the probabilities of false positive and false negative should be estimated to determine the content validity of a test and that the probability of false negative should be less than 10%. As shown in the Table 2, all the probabilities of false negatives were under ten percent, suggesting evidence for the content validity of the AREPDiT.

To evaluate the internal consistency, KR-20 is recommended instead of Cronbach's Alpha when items are scored dichotomously (e.g., right or wrong) (Reynolds et al., 2006). Therefore, in this study, KR-20 calculated for the first tier, the first two tiers, and all the tiers were found to be .66, .71, and .81, respectively. In general, instruments with internal consistency of .70 or more are considered to be good (Reynolds et al., 2006) but some researchers advocate that misconception tests with an internal consistency of .60 or higher are considered to be good (Kaltakci, 2012). Consequently, it could be concluded that the AREPDiT was deemed to be sufficiently reliable and valid for evaluating university students' understanding of atmospheric environmental issues.

Data Collection and Analysis

Prior to the study being conducted, all documentation by SJSU Human Subjects Institutional Review Board (IRB) was submitted, and the IRB approval was obtained to collect data from the students enrolled in the College of Science at SJSU. An informed consent form including a statement, that participant was totally voluntary and that all answers to the questions would be kept confidential was prepared. The researcher's contact information was provided for respondents to ask any questions about the research.

With the help of the instructor, the tests in paper-pencil format were distributed to the students who were in the chemistry lesson. Students who accepted to participate voluntarily completed the test in approximately 20-25 minutes. Besides their answers to the questions about atmosphere-related environmental problems, the respondents were asked to mark their gender as well as to provide information about whether or not they had attended a CLEC including topics such as GE, GW, OLD and AR. Moreover, the students were asked to write their majors. Respondents' names or their other identity details were not asked.

I analyzed the data both descriptively and statistically. First, based on the data, I calculated the following parameters by considering the scoring diagram by Arslan et al., (2012):

- *First Tier [FT] score:* Respondents who answered the first tier correctly were scored 1, the others 0.
- *Both Tiers [BT] score:* Respondents who answered both the first and second tier correctly were scored 1, and the others 0.
- *All Tiers [AT] / Scientific Knowledge [SK] score:* Respondents who answered both the first two tiers correctly and were certain about their responses to the first two tiers were scored 1, and the others 0.
- *Lack of Knowledge [LK] score:* Respondents who answered either the first, the second tier, or both of them incorrectly and were not certain about their answers were scored 1, and the others 0.
- *Lucky Guess [LG] / Lack of Confidence [LC] score:* Respondents who answered the first two tiers correctly and were not certain about their answers were scored 1, the others 0.

Additionally, students' misconceptions were calculated using the misconception list developed by Arslan et al. (2012). The following parameter was calculated for each of 33 misconceptions in the list:

- *Misconception-All Tiers [M-AT] score:* Respondents who selected one of the alternatives which included misconceptions in both the first and second tier of the AREPDiT (alternative selected in the second tier should be related with that in the first tier) and were certain about their answers were scored 1, and the others 0.

AT/SK scores were used to determine whether there were statistically significant differences in students' understanding of atmospheric environmental issues according to gender and attending (or not) a CLEC. In this study, I would compare groups formed by combining two independent variables. Variance analyses (two-way ANOVA) was an appropriate statistic to solve this problem (Leech, Barrett, & Morgan, 2005). Before using this statistic, I checked the assumptions of factorial ANOVA. To determine whether the data met the assumption of normality, I taken into account skewness and kurtosis statistics. I used Levene's test to test the assumption of homogeneity of the variances.

Findings

The data were analyzed both descriptively and statistically using SPSS and MS Excel 2013, and the results were presented under sub-headings.

The Statistical Analysis of the AREPDiT Data

The AT/SK scores were analyzed through two-way ANOVA and the results were presented in the Table 3, 4, and 5.

Table 3.

Normality statistics for the AT/SK scores

		Skewness	Kurtosis
Gender	Female	1.05	.34
	Male	.63	-.51
CLEC	Yes	.31	-.84
	No	1.08	.62

Skewness and kurtosis statistics calculated for each sub-group were found to be between almost +1 and -1 (Table 3). Factorial ANOVA is quite robust to violations of the normality assumption and so even skewness of more than +/-1 may not change the results much (Leech et al., 2005). The Levene's test performed to determine whether the variances of the groups were equal indicated that the assumption of homogeneity of variances was violated ($F(3,166) = 2.939$; $p = .035$). Luckily, SPSS uses the regression approach to calculate ANOVA, so this problem was less important (Leech et al., 2005).

Table 4.

Mean, standard deviation, and n for AT/SK scores as a function of gender and CLEC

CLEC	Female			Male			Total		
	n	M	SD	n	M	SD	n	M	SD
Yes	12	3.25	2.93	16	6.06	3.00	28	4.86	3.24
No	78	1.83	2.17	64	3.44	3.02	142	2.56	2.70
Total	90	2.02	2.32	80	3.96	3.18	170	2.94	2.92

The mean AT/SK score of students was calculated to be 2.94 regardless of gender and whether the students had attended a CLEC (Table 4). It was clear that the mean AT/SK score was quite low when compared with the maximum score of 13, which could be obtained from the AREPDiT. In other words, university students had a poor understanding of atmospheric environmental issues. The mean AT/SK scores for female and male participants were 2.02 (SD = 2.32) and 3.96 (SD = 3.18), respectively. Although the mean AT/SK scores of both females and males were rather low, the mean of males was relatively higher than that of females. On the one hand, not surprisingly, the mean AT/SK score of students who had attended a CLEC (M = 4.86, SD = 3.24) was found to be higher than that of those who had not (M = 2.56, SD = 2.70).

Table 5.

Two-way analysis of variance for AT/SK scores as a function of gender and CLEC

Source	Sum of squares	df	Mean square	F	p	η^2
Gender	111.93	1	111.93	15.91	.00*	.087
CLEC	93.73	1	93.73	13.32	.00*	.074
Gender*CLEC	8.38	1	8.38	1.19	.28	.007
Error	1167.77	166	7.04			

*p < .05

Although Table 4 showed there were differences in students' mean AT/SK scores according to gender and CLEC, it did not provide any information regarding whether these differences were statistically significant. Therefore, variance analysis (two-way ANOVA) was performed to reveal whether the subjects' mean AT/SK scores were different according to gender and CLEC. It is important to look at the interaction first because it may affect the interpretation of the separate "main effects" of each independent variable (Leech et al., 2005). The results of variance analysis (Table 5) indicated that there was no a significant interaction between gender and CLEC (F(1,166) = 1.19, p > .05). Figure 1 provided an evidence to support that the interaction was not significant because the lines in the Figure 1 were almost parallel with each other. Thus, the effect of independent variables on the dependent variable was separately examined. The results of the variance analysis indicated that there was a statistically significant difference in students' mean AT/SK scores in terms of both gender and CLEC (Table 5). In other words, the difference in the mean AT/SK scores between female and male students was statistically significant (F(1,166 = 15.91, p < .05). That is, the mean AT/SK score of male students (M = 3.96) was significantly higher than that of female students (M = 2.02). Similarly, a statistically significant difference between students who had attended a CLEC (M = 4.86) and those who had not (M = 2.56) was found (F(1,166 = 13.32, p < .05). In other words, students who had attended a CLEC had significantly higher understanding of atmospheric environmental issues as compared to those who had not. Additionally, the eta squared for gender was higher than that for CLEC and 8.7% of the variance in AT/SK scores can be predicted from gender.

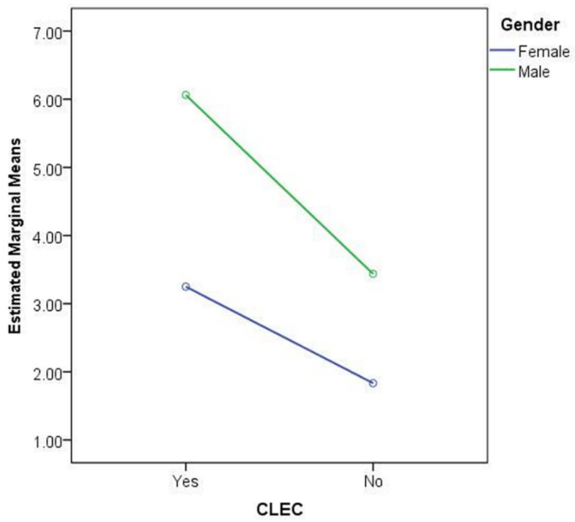

Figure 1. Interaction between gender and CLEC with respect to the AT/SK score

The Descriptive Analysis of the AREPDiT Data

The data were also analyzed descriptively. The percentages of FT, BT, AT/SK, LK and LC/LG calculated for each question according to gender and CLEC were presented in Table 6 and 7, respectively. In addition, the percentages of M-AT calculated regardless of gender and CLEC were presented in the Figure 2.

Table 6.

Analysis of the students' responses by gender

Content Area	AREPDiT Item	Gender	Correct responses by tier (%)			LK (%)	LC/LG (%)
			FT	BT	AT/SK		
GW	1	Female	54	31	14	52	17
		Male	66	30	21	31	9
	2	Female	43	34	10	50	24
		Male	44	33	18	28	15
	5	Female	41	28	7	52	21
		Male	60	33	11	24	21
	6	Female	28	27	17	50	10
		Male	50	48	35	25	13
GE	3	Female	68	49	22	37	27
		Male	74	45	34	36	11
	4	Female	62	52	31	31	21
		Male	78	60	49	13	11
OLD	7	Female	61	58	32	32	26
		Male	69	60	56	16	4
	8	Female	28	28	12	61	16
		Male	49	48	36	24	11
	9	Female	17	13	9	54	4
		Male	35	29	28	24	1
	10	Female	41	37	11	46	26
		Male	45	44	31	24	11
AR	11	Female	40	26	6	56	20
		Male	60	31	20	39	11
	12	Female	34	30	21	56	9
		Male	46	40	31	39	9
	13	Female	50	41	10	51	31
		Male	53	45	26	25	19

As would be expected, the proportion of both female and male students who responded the items correctly decreased with increasing tiers (Table 6). In other words, the proportion of the students who responded the first tier of each question in the AREPDiT correctly was higher than that of those who responded the first two tiers of each question correctly. Similarly, the proportion of the students who answered the first two tiers of each question correctly was higher than that of those who not only answered the first both tiers correctly, but also were certain about their answers. In all the items, the proportion of male students who responded the first two tiers correctly and were certain about their responses was higher than that of female students. In parallel with this finding, the percentage of female students with lack of knowledge about GE, GW, OLD and AR was higher than that of male students with lack of knowledge. However, in the majority of the items, LC/LG scores of female students were higher than those of male students. In other words, the proportion of female students who either made lucky guesses or were lack of confidence about their responses was higher than that of male students.

Table 7.

Analysis of the students' responses by CLEC

Content Area	AREPDiT Item	CLEC	Correct responses by tier (%)			LK (%)	LC/LG (%)
			FT	BT	AT/SK		
GW	1	Yes	82	46	36	18	11
		No	56	27	14	47	13
	2	Yes	46	46	36	25	11
		No	43	31	9	42	22
	5	Yes	50	14	7	25	7
		No	50	33	9	42	24
	6	Yes	54	54	39	21	14
		No	36	33	23	42	11
GE	3	Yes	68	61	54	25	7
		No	71	44	23	39	22
	4	Yes	61	54	50	21	4
		No	71	56	37	23	19
OLD	7	Yes	71	68	57	18	11
		No	63	57	41	27	16
	8	Yes	57	57	43	32	14
		No	64	33	20	46	13
	9	Yes	43	39	39	18	0
		No	22	17	13	44	4
	10	Yes	64	64	36	4	29
		No	39	35	18	42	17
AR	11	Yes	46	29	18	36	11
		No	50	28	11	52	17
	12	Yes	64	54	50	32	4
		No	35	31	21	52	10
	13	Yes	54	54	21	25	32
		No	51	41	17	42	24

As shown in the Table 7, the proportion of students who had scientific knowledge of atmospheric environmental issues was higher in the group that had received a CLEC than in the group that had not. In other words, AT/SK scores attained by students who had attended a CLEC were higher in all the items (except question 5) in the AREPDiT than those attained by students who had not. This finding supports the significant difference in the AT/SK scores between students who had attended a CLEC and those who had not. In parallel with this finding, in all the items, LK scores of CLEC group students were lower than those of non-CLEC group students. In other words, the proportion of students with lack of knowledge of atmospheric environmental issues in the non-CLEC group was higher than that of those with lack of knowledge in the CLEC group. In 10 out of 13 items, LC/LG scores of students who had attended a CLEC were lower than those of students who had not. In other words, in ten items of the AREPDiT, the proportion of students who either luckily answered correctly for the first two tiers or were lack of confidence about their responses was higher in the non-CLEC group than in the CLEC group

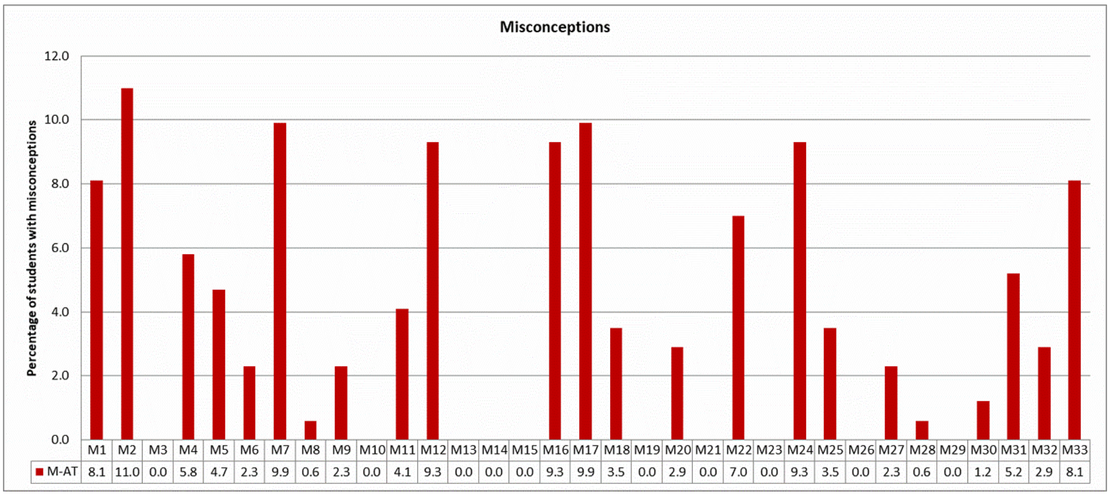

Figure 2. The misconceptions held by students

One of the objectives of this study was to identify misconceptions held by university students. Therefore, M-AT scores were calculated regardless of gender and CLEC and the results were graphically presented in the Figure 2. Three-tier diagnostic tests enable researchers to differentiate students with misconceptions from those with lack of knowledge. The findings of the study demonstrated that the proportion of students with lack of knowledge was considerably higher than that of those with misconception. However, according to the Figure 2, one of the misconceptions commonly held by students (11%) is that GW will cause skin cancer (M2). The other prevalent misconception held by 9.9% of the students is that CO_2 depletes the ozone layer in the stratosphere (M17). The same percentage of students believes that chemical waste released into rivers is one of the reasons of GW (M7). Some students (9.3%) believes that the ozone layer keeps the earth livable by holding the earth's temperature stable (M16).

Discussion and Conclusion

This study aimed to investigate whether there were statistical differences in university students' understanding of atmospheric environmental issues according to gender and attending (or not) a CLEC and to identify their misconceptions about that subject matter. The reliability and validity of the AREPDiT that would be used for this purpose in this study were re-examined on the collected data and the statistics indicated that it could be used as a reliable and valid instrument to measure university students' understanding of atmospheric environmental issues.

The results of the variance analysis that was performed to determine whether there was a significant difference in conceptual understanding of atmospheric environmental issues between female and male students indicated that male students had significantly higher understanding of the examined content compared to their female counterparts. The results of the studies, in the literature, examining gender differences on environmental knowledge confirm to a large extent those reported in this study. For example, Hayes and Tariq (2000) who investigated gender differences in scientific knowledge using 12 item-quiz including both general scientific knowledge and knowledge of environmental issues reported that male participants tended to demonstrate a greater environmental knowledge than did female participants. Similarly, Tikka, Kuitunen and Tynys (2000) found that although male students had a more negative attitude towards nature and the environment than female students, male students' knowledge of environmental issues was significantly higher than that of their female counterparts. A similar finding was also reported by Arcury, Scollay and Johnson

(1987) who examined gender difference in concern and knowledge relative to acid rain, which is one of the global environmental problems. The literature includes numerous studies documenting that male students' environmental knowledge was significantly higher than that of female counterparts (Dijkstra, & Goedhart, 2012; Ocal, Kisoglu, Alas, & Gurbuz, 2011; Salehi, Nejad, Mahmoudi, & Burkart, 2016). This was not surprising given the stereotypical relationship female and science. Studies have reported that science-related activities experienced by female students are not the same with those by male students even when they enroll in the same science courses (Greenfield, 1996) and that male students are more likely to experience out-of-class science activities than female students (Jones, Howe, & Rua, 2000). In addition, females generally tend to have lesser interest in studying science (Jones et al., 2000), lower confidence in their science and math abilities (McCright, 2010) and poorer attitudes towards science (Weinburgh, 1995) than do males, and science is perceived as more difficult to grasp by females than by males (Jones et al., 2000). These differences between females and males typically first emerge in elementary school, gradually increase in high school and continue through post-secondary education and beyond (Jones et al., 2000; McCright, 2010). However, the literature includes limited number of studies reporting that there was no gender difference on environmental knowledge (Alp, Ertepinar, Tekkaya, & Yilmaz, 2006; Spellman, Field, & Sinclair, 2003). Gender is the factor that can be associated with students' understanding of environmental issues. Educational researchers need to address the disparities between females and males and investigate the influential factors as well as strategies that could narrow the gender gap in environmental knowledge.

Although local and national governments, non-governmental organizations, universities and mass media have responsibility to reduce global environmental problems, the solution of these problems is, to a significant extent, based on individual actions of people. In other words, cumulative acts of millions of people contribute to atmospheric environmental problems as well as the other environmental problems. Therefore, people may be a part of solution by reducing their contribution to these problems. For example, each person can directly contribute to reducing acid rain and global warming by saving electricity. Most energy around the world comes from burning fossil fuels such as coal and oil. Therefore, everyone should turn off the appliances (e.g. computer and lamp) that run with electricity when no one is using them and should use electricity more efficiently. Public transportation and even bicycle should be used to minimize the emission of gases that contribute to environmental problems. However, such sensitive and conscious acts may only be performed by a well-informed public. In addition, high environmental knowledge contributes to positive attitude towards the environment (Esa, 2010). The relationship between environmental knowledge, environmental attitude and pro-environmental behavior is very complex but having correct and complete knowledge about the environmental issues is a critical factor in acting pro-environmental behaviors (Kollmuss, & Agyeman, 2002). However, this study found that although the mean AT/SK score attained by the students who reported that they had attended a CLEC was significantly higher than that attained by those who reported that they had not, the mean AT/SK score of students who had attended a CLEC was also quite low when compared with the maximum score that could be obtained from the AREPDiT. In other words, even students who had attended a CLEC had a low level of scientific knowledge about atmospheric environmental issues. Environmental issues are presented at almost all levels of education and therefore, the expectation in this study was that university students would have sufficient scientific knowledge about atmospheric environmental issues. However, the results were contrary to the expectation. Moreover, I found that the participants had various misconceptions. The misconceptions identified showed the atmospheric environmental problems are confused by students with each other. Some common misconceptions which had been determined in the previous studies (Ocal et al., 2011; Yalcin, & Yalcin, 2017) were found again and they were presented as follows:

- GW will cause skin cancer
- CO_2 depletes the ozone layer in the stratosphere
- Chemical waste released into rivers is one of the reasons of GW
- The ozone layer helps to keep the Earth's temperature stable to make it livable

There may be a number of reasons why students have insufficient knowledge and misconceptions about science concepts. The Internet, daily language and textbooks are some of these reasons (Nakhleh, 1992; Sanger, & Greenbowe, 1997; Sesen, & Ince, 2010). However, teaching strategies used in classrooms may be one of the most important reasons for misconceptions and lack of knowledge. Because, teacher-centered teaching strategies that are incapable of attracting the attention of students and of engaging them in the learning environment are commonly used in science classrooms (Bahar, Bag, & Bozkurt, 2008). In addition, atmospheric environmental concepts are abstract and complex in nature (Arslan et al., 2012; Boyes, Stanisstreet, & Pui-ming Yeung, 2004; Cordero, 2000) and therefore, it is rather difficult for students to grasp these concepts without using teaching materials that help them visualize abstract and complex concepts in their minds. Luckily, computer-generated instructional materials such as animation and simulation enable students to visualize abstract concepts or phenomenon that cannot be observed or experienced directly. It is often reported that computer-generated instructional materials had a positive effect on students' conceptual learning (Springer, 2014; Williamson, & Abraham, 1995). Therefore, integrating contemporary teaching methods that consider the principles of constructivism into classrooms and using teaching materials which help students visualize abstract and complex concepts in their minds may help students to understand atmosphere-related environmental issues.

The most important limitation of the study was that the data of the study were collected from only 170 university students with different majors in chemistry classroom. Therefore, a similar study may be repeated on a larger and more homogenized sample to confirm the results of the current study.

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RESEARCH ARTICLE

Üniversite Öğrencilerinin Atmosferik Çevre Konularındaki Anlamalarının Üç Aşamalı Tanılayıcı Bir Test Kullanılarak Değerlendirilmesi**

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Özet

Bu çalışmanın amacı, ünivesite öğrencilerinin atmosferik çevre konularındaki anlamalarının cinsiyet ve küresel ısınma, sera etkisi, ozon tabakası incelmesi ve asit yağmurları konularını içeren üniversite seviyesinde bir çevre dersi alıp almamalarına göre değerlendirilmesidir. Bu çalışmada tarama (survey) yöntemi kullanılmıştır. Bu çalışmanın örneklemi Amerika Birleşik Devletleri'nde ki San Jose Eyalet Üniversitesi'nin Fen Fakütesi'nde öğrenim gören 170 öğrenci oluşturmaktadır. Veri toplamak için, "*Atmosfer ile İlgili Çevre Problemleri Üç Aşamalı Tanılayıcı Testi"* kullanılmıştır. Veriler, öğrencilerin atmosferik çevre konuları anlamalarındaki olası farklılıkları belirlemek için varyans analizi (iki-yönlü ANOVA) kullanılarak analiz edilmiştir. Ayrıca, veriler öğrencilerin hangi kavram yanılgılarına sahip olduklarını saptamak için betimsel olarak ta analiz edilmiştir. Analiz sonuçları, erkek öğrencilerin atmosferik çevre konularındaki anlamalarının kadın öğrencilerinkinden önemli düzeyde yüksek olduğunu ve üniversite seviyesinde çevre dersi alan öğrencilerin almayan öğrencilere göre atmosferik çevre konularında daha yüksek bir kavramsal anlamaya sahip olduklarını ortaya koymuştur. Aynı zamanda öğrencilerin atmosferik çevre konularında çeşitli kavram yanılgılarına sahip oldukları belirlenmiştir.

Anahtar Kelimeler: Küresel ısınma, ozon tabakası incelmesi, asit yağmuru, kavram yanılgısı, üç-aşamalı tanılayıcı test, üniversite öğrencisi, cinsiyet

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