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Engineering Major Students' Perceptions of Nanotechnology

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Abstract

Nanotechnology will be among the most needed workforce areas in the near future. It is also a creative and highly dynamic field of innovative research areas that displays numerous open fields for future graduates. The central thesis of this paper is to better understand undergraduate engineering students' awareness, exposure, and motivation towards nanotechnology, how those constructs correlate with each other, and whether there are differences by gender or year of study. This exploratory study used mixed methods to answer the research question. Results revealed that engineering students have more motivation to pursue further nanotechnology knowledge or study than they have exposure or awareness about nanotechnology. The results showed that male students have more awareness about nanotechnology than female students. Educational implications are that it is necessary to provide students with more opportunities to learn about and study nanotechnology during their undergraduate experience. While students are interested in learning more, their current levels of awareness and exposure may hold them back in pursuing nanotechnology-related careers.

Key words: Nanotechnology, Engineering students, Perception

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Introduction

For the first time Richard Feynman, an American physicist, mentioned the nanoworld with his famous speech “There's Plenty of Room at the Bottom," at an American Physical Society meeting at Caltech on December 29, 1959. Since then, Taniguchi Norio, a professor of Tokyo University of Science, coined the term *nano-technology* in 1974 (Taniguchi, 1974). Shortly after that, an American engineer named Drexler first popularized molecular nanotechnology in the late 1970s. The field of nanotechnology in the 1980s was brought on by the union of research and technical advances, for example, the innovation of the scanning tunneling microscope in 1981 and the discovery of fullerenes in 1985. The field came into prominence in the mid-2000s with governments moving to advance and create research into nanotechnology. Since that time nanotechnology research and government investments have been rising.

The term nanotechnology has come to be used to refer to the arrangement of molecules and atoms at sizes between 1 and 100 nanometers (Blonder & Sakhnini, 2012; Ramsden, 2014). Material shows different properties at the nanoscale than at the macroscale. Material scatters light at different wavelengths, the melting point [increases or decreases], and catalysis and magnetism properties are changed with particle size. For instance, gold is known as yellow a nobel metal but at 10 nanometers (nm) gold particles absorb green light and appear red (Roduner, 2006). Building material at the nanoscale offers many advantages that make it a preferred product, one of which is its superior properties (Sobolev, 2016). Nanotechnology is used in many fields such as environmental production, energy, electronics, military, drug delivery, security and foods (Pagliaro, 2015). It includes many research disciplines and is becoming the driving force in fields such as chemistry, physics, biology, engineering, materials science and medicine (Pagliaro, 2015; Porter & Youtie, 2009).

Nanotechnology became an emerging research field in the 21st century (Jackman et al., 2009). Since then, billions of dollars have been invested in nanotechnology investigations. For example, the president of the United States’ 2015 Budget provides over $1.5 billion for the National Nanotechnology Initiative (NNI) (Bhushan, 2015). In the last decade many scientists around the world have conducted research in the area of nanotechnology. As such, there has been an increasing amount of research papers and published studies on nanotechnology, including several top journals focused on nanoscience research (e.g., Nature Nanotechnology, Nano Letters, ACS Nano). Due to this rapid growth, nanotechnology will be one of the most needed workforce areas in the near future (Greenberg, 2009; Malsch, 2014; Roco, 2003). With this in mind, it is becoming more necessary for engineering students to gain some nanotechnology skills, as these skills are needed by industry (Roco, 2003). Uddin et al. (2001) described nanotechnology-related abilities as those which, ‘Provide understanding, characterization and measurements of nanostructure properties…[the] ability for synthesis, processing and manufacturing of nanocomponents and nano systems… [the] ability for design, analysis and simulation of nanostructures and nanodevices…and [which] prepare students to conduct research and development of economically feasible and innovative applications of nanodevices in all spheres of our daily life’.

Researchers have advocated the integration of nanotechnology into the undergraduate engineering curriculum (Drane, Swarat, Light, Hersam, & Mason, 2009; Newberry, 2011; McNally, 2013; Balasubramanian & Meliabari, 2016) and into education as a whole (Jones et al., 2013). Following a review of the literature, Ghattas and Carver (2012) argue that there is a strong need for integration of nanoscience topics into the school curriculum. Greenberg (2009) further argued for the integration of nanoscience into the classroom; in particular stating that the undergraduate classroom presents less barriers to integration than the secondary education level. It follows that universities have increasingly been seeking to educate their students in this field (Goodhew, 2006). Nonetheless, nanotechnology integration has not yet been fully achieved in the undergraduate curriculum. Since nanotechnology is a new and rapidly evolving field, there is a gap between research studies and their application in education. A main challenge for nanotechnology is the education and training of engineering students for the rapid knowledge generation and research in this field (Chang, 2006; Jones et al., 2013; Uddin et al., 2001). Educators are needed to fill this gap between nanotechnology research and educational programs. Ineke (2014) demonstrated that workers in manufacturing as well as teachers have not learned about nanotechnology during their education, and thereby identified European employers' needs for nano-education (Malsch, 2014). That being said, several attempts have been made to integrate nanotechnology in education (Ambrogi, Caselli, Montalti, & Venturi, 2008; Ron Blonder & Dinur, 2011; Moyses, Rivet, & Fahman, 2010; O'Connor & Hayden, 2008; Pagliaro, 2015; Moyses, Rivet, and Fahlman 2010; Sakhnini & Blonder, 2015) but more research is needed. In order for successful nanotechnology research, development, and social discourse to take place in this field, education research is needed to inform the development of standards, course development, and workforce preparation (Jones et al., 2013).

Research across several countries has demonstrated that there is a general lack of understanding about nanotechnology. In the United States, previous research has reported a public lack of understanding of nanotechnology and its applications (Cobb & Macoubrie, 2004; Waldron, Spencer, & Batt, 2006; Macoubrie, 2005; Cobb, 2011). In Turkey, Senocak (2014) has also questioned the public's perception of nanotechnology, by collecting data from 513 Turkish participants of different backgrounds. He found that the Turkish public is unfamiliar with nanotechnology, while most of the sample had heard little to nothing about nanotechnology; however, participants often have positive emotions toward nanotechnology. Another study examined public perceptions of nanotechnology in France and found that the majority of participants had never heard of nanotechnology, and participants who had heard of nanotechnology had little knowledge about the subject (Vandermoere, Blanchemanche, Bieberstein, Marette, & Roosen, 2011).

This lack of awareness applies to the student population as well as the general public. In an investigation into middle school (6th, 7th and 8th grade) students' awareness of nanotechnology, Sahin and Ekli (2013) found that students have low awareness of nanotechnology, yet most students have positive feelings towards nanotechnology. Karataş' (2015) research with science and chemistry undergraduate students found that students' nanotechnology knowledge level is low and students are thus unable to transfer their science information to nanotechnology. Another study with Turkish undergraduates, this time with science education students, found that before a curriculum module students had little or no prior knowledge of nanotechnology (Senocak, 2015). In the United States, Diefes-Dux, Dyehouse, Bennett, and Imbrie (2007) found that first year undergraduate food and agriculture students showed little to no awareness of nanotechnology. Marikar et al. (2014) conducted a study with 80 medicine students' awareness about nanotechnology in Sri Lanka. The authors concluded that students gave strong responses on basic knowledge of nanoscale concepts; however, they found that students show a lack of knowledge about the relationship between nanotechnology and nanomedicine. Although some of these studies did not take place with undergraduate engineering students, they provide a general overview of the lack of awareness regarding nanotechnology in the public and with students. Overall these studies highlight the need for understanding students' perceptions of nanotechnology before planning a training program.

One of the areas in which nanotechnology is most used is engineering. However, to the best of our knowledge, no report has been found so far investigating engineering students' perceptions of nanotechnology in Turkey. This study aims to fill this research gap by examining Turkish engineering students' exposure, awareness and motivation levels towards nanotechnology.

The paper seeks to address the following main research question.

How do engineering students perceive nanotechnology?

Our research sub-questions are as follows:

Are there significant differences between male and female students with regards to exposure, awareness and motivation towards nanotechnology?

Are there any significant differences among first year, second year and third year engineering students in terms of exposure, awareness and motivation towards nanotechnology?

Are there any correlations among students' exposure, awareness, and motivation towards nanotechnology?

Methods

Participants

Participants were selected from engineering classrooms with faculty permission in a state university in Turkey that does not have a nanotechnology program. The initial sample consisted of 145 undergraduate engineering students, of which we eliminated 33 of whom did not complete all of the items. 112 surveys were found useful for this empirical analysis. The independent variables included by gender between year of study; the sample distribution is given in Table 1. Approximately half of those surveyed did not comment on open ended questions. The total number of responses for open ended questions was 51.

Table 1. Sample Profile

	1st Year	2ndYear	3rd Year	Total
Male	26	18	33	35
Female	9	9	17	77
Total	35	27	50	112

Study design

In this study we used mixed-methods to address our research questions. An explanatory sequential design was used; quantitative analysis findings clarify with qualitative analysis results (Creswell et al., 2008). We collected quantitative data using a survey and qualitative data using open-ended questions. Qualitative analysis was used to provide more in-depth understanding of students' responses.

Data collection

We used the Nanotechnology Awareness Instrument, which was developed and validated for use with undergraduate students (Dyehouse et al., 2008). The instrument was developed to measure three constructs of nanotechnology perceptions: nanotechnology awareness, nanotechnology exposure, and motivation to pursue further knowledge or careers in nanotechnology. An exploratory factor analysis took place to determine the dimensionality of the instrument, and Cronbach's α coefficient determined that there was high internal consistency reliability among the three subscales (Dyehouse et al., 2008). The instrument shows acceptable psychometric properties in three subscales: Nano-Awareness, Nano-Exposure, and Nano-Motivation. Cronbach's α coefficient was 0.91 for the Nano-Awareness scale, 0.82 for the Nano-Exposure subscale, and 0.94 for the Nano-Motivation subscale, which is a high level of internal consistency reliability (Dyehouse et al., 2008). Firstly, the exposure scale items have five answer choices ranging from strongly disagree to strongly agree. Some of those items are 'Heard the term nanotechnology', 'Read [something] about nanotechnology', and 'Taken a class about nanotechnology'. Secondly, the awareness scale items have five answer choices ranging from strongly disagree to strongly agree. Some of items are 'I can name an application of nanotechnology', 'Describe a process to manufacture objects at the nanoscale' and 'Name an instrument used to make measurements at the nanoscale'. Finally, the motivation scale has answer choices ranging from strongly disagree to strongly agree. Some items for this scale are 'I plan to read a research journal article about nanotechnology', 'Enroll in a course about nanotechnology', 'Obtain a work experience or undergraduate research opportunity related to nanotechnology'. Qualitative data were collected with open-ended questions focused on students' exposure, background, and plans regarding nanotechnology (e.g., 1. Where did you encounter the concept of nanotechnology? 2. What do you know about nanotechnology? 3. What are the things you plan to do regarding nanotechnology?)

Data analysis

Data management and analysis were performed using SPSS 20.0. Descriptive data were generated for all variables. Because of the ordinal-level data, we used nonparametric tests as well as the mode for descriptive analysis. Mann-Whitney U Tests were used to analyze the relationship between gender and students' nanotechnology perceptions. In order to assess year of study, Kruskal-Wallis Tests were used. In addition, Kendall's tau_b correlation coefficients were used to examine the relationships between the variables that were measured on an ordinal scale. A content analysis using a classification approach was used for qualitative data analyses. First, response phrases were categorized and then analysed according to the recurring themes. An example of coding for Exposure is: TV; Daily life product; Internet; School. Examples for the Background theme were: Small technology; Advanced Technology; Something that makes life easier. Finally, examples of coding for the Motivation theme were: Education, Work.

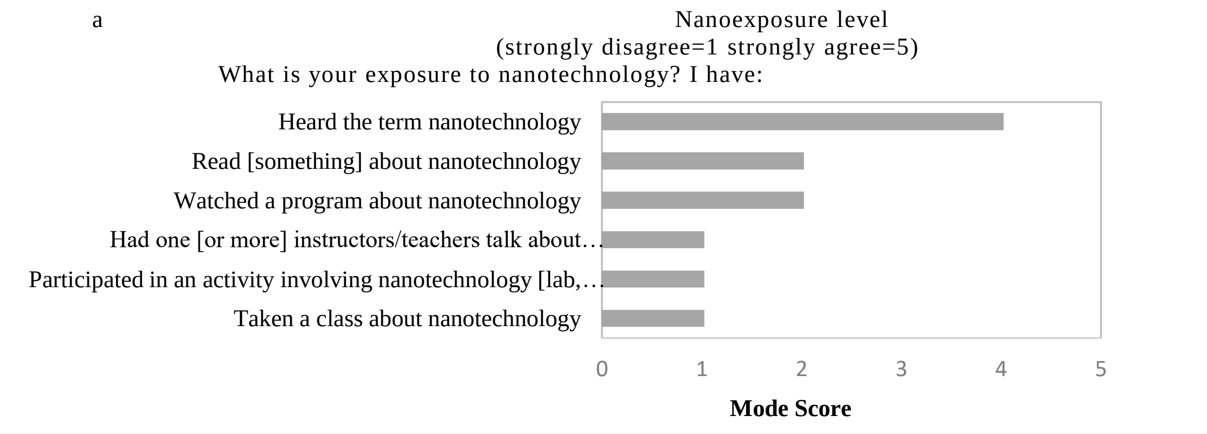
Results

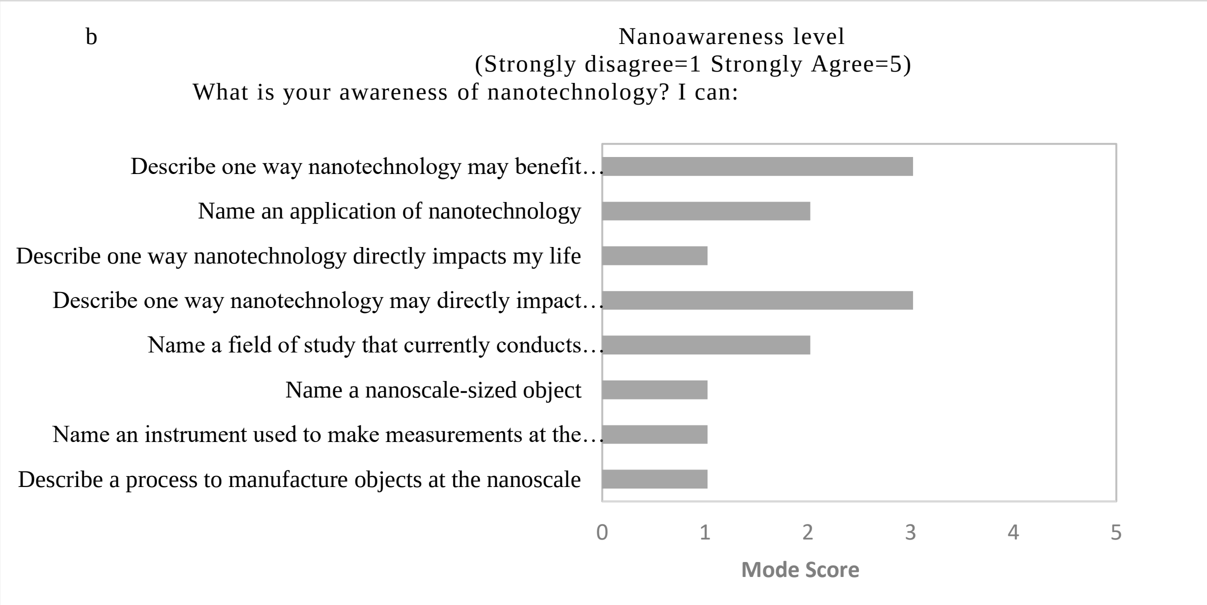
The quantitative results are presented in the following tables and figures including first descriptive statistics and then inferential statistics. Table 2 presents the results of the Mann-Whitney U Tests to examine the relationship between gender and nanotechnology perceptions. To determine whether there were any year of study effects, the results of Kruskal-Wallis Test tests are presented in Table 3.Lastly, to understand the relationships between variables, Kendall's tau_b correlation correlation was used (Table 4). The qualitative results include analysis of responses given to open-ended questions shown in Table 5.

Quantitative results

Descriptive statistics

The descriptive data analysis was used to answer the research question: How do engineering students perceive nanotechnology? More specifically, what are students' perceptions about nanotechnology in terms of exposure, awareness and motivation towards nanotechnology? Because the data were ordinal, the mode rather than the mean score was used.


a
Nanoexposure level
(strongly disagree=1 strongly agree=5)
What is your exposure to nanotechnology? I have:
Heard the term nanotechnology
Read [something] about nanotechnology
Watched a program about nanotechnology
Had one [or more] instructors/teachers talk about…
Participated in an activity involving nanotechnology [lab,…
Taken a class about nanotechnology
0
1
2
3
4
5
Mode Score


b
Nanoawareness level
(Strongly disagree=1 Strongly Agree=5)
What is your awareness of nanotechnology? I can:
Describe one way nanotechnology may benefit…
Name an application of nanotechnology
Describe one way nanotechnology directly impacts my life
Describe one way nanotechnology may directly impact…
Name a field of study that currently conducts…
Name a nanoscale-sized object
Name an instrument used to make measurements at the…
Describe a process to manufacture objects at the nanoscale
0
1
2
3
4
5
Mode Score

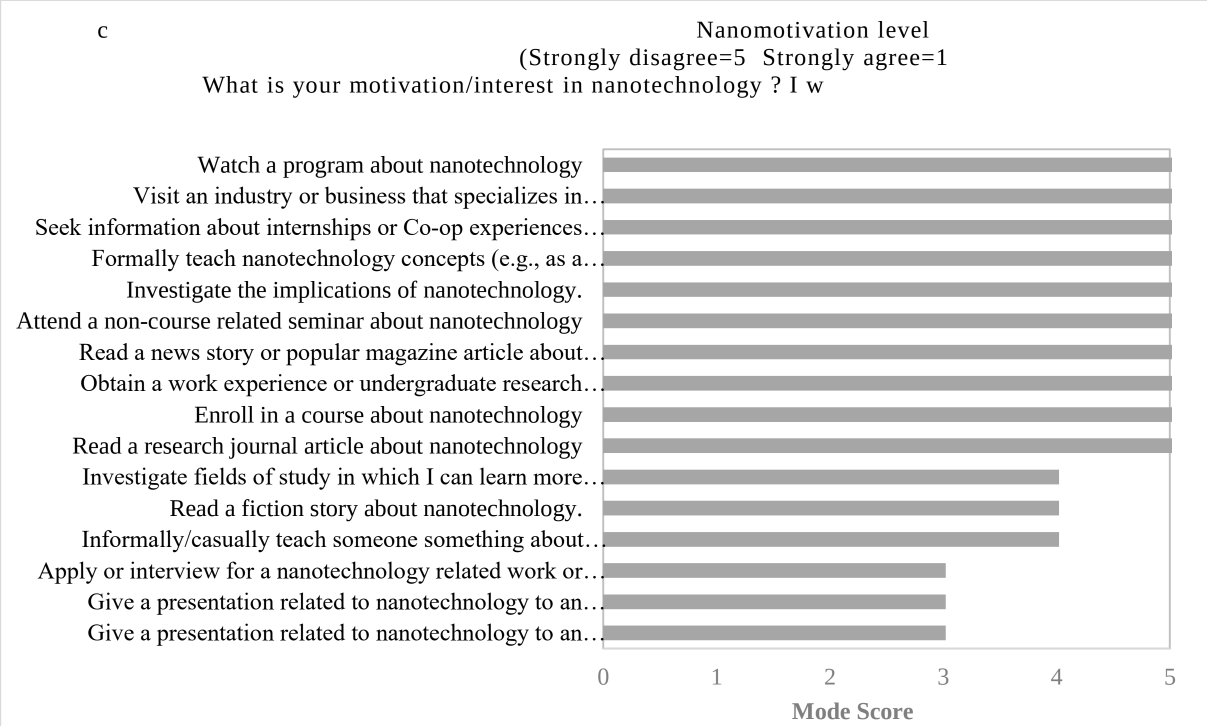


Fig.1. Mode scores for the respondents' nano (a) exposure (b) awareness (c) motivation

Figure 1 provides detailed descriptive statistics regarding the participants' nano-exposure, nano-awareness and nano-motivation mode scores. From the data in Figure 1a, it is apparent that almost all students have heard about nanotechnology (mode: 4). Some students have read or watched something related to nanotechnology (mode: 2). A small number of students listened to something about nanotechnology from their teachers, participated in an activity involving nanotechnology, or have taken a class about nanotechnology (mode: 1).

Results showed that the modes of almost all items that belong to nanotechnology awareness were under the score of 3.0 (see Figure 1b), meaning that most students lack awareness about nanotechnology. Fewer than half of students have awareness about societal benefits. Students cannot describe one way that nanotechnology may impact their daily life, but they can describe one way that nanotechnology may directly impact their life in the future. Only a few students can describe the manufacturing process at the nanoscale and can name an instrument used to make measurements at the nanoscale (mode: 1).

Finally, it Table 1c shows that the mode score for all items that belong to nanotechnology motivation were above 3.0. That is, students' motivation to learn, work and take part in research experiences related to nanotechnology is high (mode: 5). Students willing to apply or interview for nanotechnology-related work is moderate (mode: 3).

Inferential statistics

Inferential statistics, including Mann-Whitney U Test, were used to answer the first research sub-question: Are there significant differences between male and female students with regards to exposure, awareness and motivation towards nanotechnology?

Table 2. Mann-Whitney U Tests results for the comparison by gender with nano-exposure, awareness and motivation

Nano-exposure	n	Mean Rank	Sum of Rank	U	p
Female	35	54.06	1892.00		
Male	77	57.61	4436.00	1262.00	0.590
Nano-awareness					
Female	35	43.63	1527.00		
Male	77	62.35	4801.00	897.000	.005
Nano-motivation					
Female	35	48.04	1681.50		
Male	77	60.34	4646.50	1051.500	.063

As shown in Table 2, there was no significant difference between males and females on the subscale measuring students' exposure to nanotechnology ($p > 0.05$). That is, we found that both female and male students have a similar self-reported level of exposure to the field of nanotechnology. As can be seen from the data in Table 2, there were significant differences between males and females in term of nano-awareness ($p < 0.05$), with males showing a higher mean rank than females. That is, males had significantly higher awareness about nanotechnology than did females. Finally, results showed no significant difference between males and females in terms of motivation to pursue further exploration of nanotechnology ($p > 0.05$). Thus, both males and females showed similar levels of their self-reported plans to pursue further knowledge or careers in the field of nanotechnology.

Inferential statistics including a Kruskal-Wallis Test were used to answer the second research sub-question: Are there any significant differences among first year, second year and third year engineering students in terms of exposure, awareness and motivation towards nanotechnology?

Table 3. Kruskal-Wallis Test results in terms of year of study

Nano-exposure	n	Mean Rank	df	x^2	p
Year 1	35	38.06	2	16.681	.000
Year 2	27	62.87			
Year 3	50	65.97			
Nano-awareness					
Year 1	35	48.63	2	3.371	.185
Year 2	27	63.15			
Year 3	50	58.42			
Nano-motivation					
Year 1	35	72.90	2	13.751	.001
Year 2	27	44.67			
Year 3	50	51.41			

There were significant differences between year of study in terms of nano-exposure ($p < 0.05$), indicating that year in university program has effects on students' self-reported exposure to nanotechnology (Table 3). Next, there were no significant differences between year of study in terms of students' awareness of nanotechnology ($p > 0.05$), indicating that students in different years of study have similar levels of awareness. We also found significant differences between year of study in terms of motivation ($p < 0.05$). Surprisingly, first year students have a higher nano-motivation mean rank score than second and third year students.

Kendall's tau b was used to answer the third sub-research question: Are there any correlations among students' exposure, awareness, and motivation towards nanotechnology?

Table 4. Kendall's tau_b correlation values between variables.

		Nano-exposure	Nano-awareness	Nano-motivation
Nano-exposure	Correlation Coefficient	1.000	.551**	.039
	p		.000	.558
Nano-awareness	Correlation Coefficient	.551**	1.000	.144*
	p	.000		.028
Nano-motivation	Correlation Coefficient	.039	.144*	1
	p	.558	.028	
	n	112	112	112

**. Correlation is significant at the ($p < 0.01$ level).
*. Correlation is significant at the ($p < 0.05$ level).

Table 4 shows the Kendall's tau_b correlation between variables. We found positive correlations between the nano-exposure subscale and the nano-awareness subscale in addition finding positive correlations between the nano-motivation subscale and the nano-awareness subscale. This indicates that students' awareness about nanotechnology increases with their exposure to nanotechnology. Furthermore, students' motivation to pursue further knowledge or careers in nanotechnology increases with their awareness about the field.

Qualitative data analysis

To provide further information about students' perceptions about nanotechnology, we performed a content analysis on the qualitative data. The results of the qualitative data analysis are presented in Table 5.

Table 5. Themes, codes, students' frequency and percent

Themes	Codes	Frequency	%
Encountering the concept of nanotechnology	Daily life product	9	21
	TV, internet	16	37
	Nowhere	10	23
	School	7	16
Background about nanotechnology	Something that makes life easier	10	26
	Advanced technology	7	18
	I have no information	16	41
	Small technology	6	15
Future plans regarding nanotechnology	Education	15	48
	Work	6	19
	I have no plan	10	32

Regarding where students have encountered the concept of nanotechnology, we found that the largest percentage of students responded that they have encountered nanotechnology on the TV or internet (37%). However, many students (23%) responded that they have not encountered nanotechnology anywhere. Surprisingly, the smallest percentage of students have encountered nanotechnology in the school environment (16%).

Next, we examined students' responses to better understand what background they have in nanotechnology. Almost half of the respondents reported that they have no information about nanotechnology (41%). However, on the positive side, a small number of respondents believe that nanotechnology is something that makes life easier (26%). The smallest percentage of students know that nanotechnology is an advanced technology and a small technology (18% and 15%, respectively).

Examining the open-ended responses regarding students' future plans, we found that approximately half of the respondents have motivation to get nanotechnology training (48%). A smaller number of participants have motivation to work on nanotechnology related areas (19%). Finally, fewer than half of the respondents have no plans regarding nanotechnology (32%).

Discussion

The main research question that this study sought to answer was: How do engineering students perceive nanotechnology? Results revealed that students have low exposure and awareness regarding nanotechnology and high motivation towards learning more about nanotechnology. It seems that while that students have a belief about the importance of nanotechnology, they also have insufficient knowledge about nanotechnology. These results could possibly be due to a lack of nanotechnology education (Jackman et al., 2009; Jones et al., 2013; Malsch, 2014). Students' information is limited to the internet, TV and some products which used nanotechnology in the production process. At the same time, while students have high motivation to visit an industry and business that specializes in nanotechnology, they have low motivation to apply or interview for related nanotechnology work. In sum, the majority of the students have encountered nanotechnology, but they are lacking information about the field. Additionally, the majority of students are willing to learn nanotechnology and report that they want to enroll in nanotechnology education. Students' lack of motivation to apply for a job related to nanotechnology could be a result of their low nanotechnology knowledge, which would not be sufficient for a nano-related career. These results are consistent with those of other studies (Chen et al., 2013; Farshchi, Sadrnezhaad, Nejad, Mahmoodi, & Abadi, 2011; Hanoglu, Douglas, Madhavan, & Diefes-Dux, 2015; Waldron et al., 2006), which show lower awareness about nanotechnology but a higher interest in pursuing additional knowledge.

We also found a lack of exposure to nanotechnology in the classroom on both quantitative and qualitative responses. Most students reported that they have not had one or more instructors/teachers talk about nanotechnology and that only a small percentage have encountered nanotechnology in a school setting. We found this surprising for engineering students, because of the wide applications for nanotechnology across all engineering fields. This lack of exposure is consistent with students in other fields of study and other educational levels (Sahin & Ekli, 2013; Marikar et al., 2014; Karatas, 2015; Senocak, 2015).

The first research sub-question asked whether there are significant differences between male and female students with regards to exposure, awareness and motivation towards nanotechnology. These results indicated that there is no significant difference between gender for students' exposure and motivation regarding the field of nanotechnology. That is, both males and females have similar exposure and motivation levels towards nanotechnology. However, significant differences were found between males and females regarding their level of awareness about nanotechnology; specifically, male students showed higher levels of awareness than female students. Many engineering fields, which are associated with hardware and technical tools, such as mechanical and electrical engineering, are populated by many more men than women (Miller et al., 2000). Su, Rounds, and Armstrong (2009) performed a meta-analysis of sex differences in career interests and found that men prefer working with things and women prefer working with people, with women showing a greater preference for socially-oriented occupations. Furthermore, women tend to leave engineering for majors that are perceived to be more likely contributors to social good (Borrego et al., 2005). It may be that because nanotechnology is perceived as a highly technical field that women lack enough interest to increase their awareness about the field. This difference between genders should be more closely examined in future research.

Our second research sub-question asked, 'Are there any significant differences among first year, second year and third year engineering students in terms of exposure, awareness and motivation towards nanotechnology'? The results showed a significant difference in students' nano-exposure level across years of study. These results showed that as students move through their program of study they gain increasing exposure to nanotechnology. However, we are unable to say if this exposure is the result of the university environment. Results also showed no significant differences for students' levels of awareness towards nanotechnology between years of study. It is unclear why students' exposure increases over the years but awareness does not. It may be that exposure to nanotechnology does not necessarily lead to awareness. Because awareness indicates some level of knowledge or learning about nanotechnology, such as the ability to name a nanoscale sized object, students who are exposed to nanotechnology (i.e., hearing about it in the classroom) may not be willing to seek out more information or be interested enough to retain any information. However, significant differences were found for students' motivation towards nanotechnology by year of study. Surprisingly, students' nano-motivation decreases as they increase in their years of study. The findings of the current study are consistent with those of Hanoglu et al. (2014) who found students' exposure and awareness increases but not motivation towards nanotechnology after an educational intervention. The reason for this may have something to do with self-efficacy, behavioral (e.g., enrolling a laboratory course) and environmental factors (e.g., high school) (Pintrich, 2003).

Finally, the third research sub-question asked 'Are there any correlations among students' exposure, awareness, and motivation towards nanotechnology'? Results showed a high positive correlation between nano-exposure with nano-awareness and again between nano-awareness and nano-motivation. A possible explanation for these results are that students' awareness increases with their exposure level and in turn as students become more aware of the field, they increase in their motivation to pursue further information. However, there was no direct correlation between exposure and motivation level. In this case, exposure could indicate a more passive attentiveness about nanotechnology, while awareness may indicate a conscious effort to understand nanotechnology. In the psychology literature, exposure alone does not increase liking of a certain object, whereas conscious awareness can have an effect (de Zilva et al., 2013). For example, if students have read a newspaper that mentioned nanotechnology but skimmed over it or if nanotechnology was mentioned in a class and they were not attentive, then their exposure does not necessarily indicate any understanding or awareness of nanotechnology, thus not leading to motivation to pursue further information.

Conclusion

This study set out to determine engineering students' perceptions of nanotechnology. The most obvious finding to emerge from this study is that students' exposure to nanotechnology and awareness about nanotechnology is low, but their motivation to pursue nanotechnology knowledge or careers is high. This lack of exposure and awareness is problematic at a time when nanotechnology is becoming increasingly important to the field of engineering. As this study has shown, engineering students have little to no exposure to nanotechnology in a classroom setting. Educators can take advantage of students' motivation to learn more about nanotechnology by integrating information about the field into the engineering curriculum, thereby increasing students' exposure and awareness.

Additionally, although students' exposure to nanotechnology and awareness about nanotechnology were low, there were still significant differences found between males and females with regard to levels of nanotechnology awareness. Because females show a lower awareness of nanotechnology than males, it may be helpful for educators who integrate nanotechnology into their curriculum to emphasize the more socially relevant aspects of nanotechnology that may interest women in particular, such as how nanotechnology can improve society.

Surprisingly, no significant differences were found between year of study in terms of awareness towards nanotechnology. We found a high positive correlation between the constructs of exposure with awareness and awareness with motivation. It is important that educators integrate nanotechnology into the curriculum in meaningful, relevant ways in order to engage students and move beyond mere exposure to nanotechnology.

In sum, the evidence from this study suggests that engineering faculty should amend their curriculum to give more attention to nanotechnology education given the prevalence and need for nanotechnology-trained engineering graduates. The high levels of motivation to pursue further information about nanotechnology among engineering students is encouraging. This is the first time that perceptions about nanotechnology have been studied with Turkish engineering students. These findings enhance our understanding of engineering students' perceptions of nanotechnology, specifically with regards to exposure, awareness, and motivation. The current investigation was limited to a state university. Further research should explore nanotechnology awareness at other types of institutions, in addition to examining more closely the links between year of study and gender with regards to nanotechnology perceptions.

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