Awareness, exposure, and knowledge levels of science teachers about nanoscience and nanotechnology

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Advances in nanotechnology have drawn attention to nanotechnology education. The aim of this study is to determine awareness, exposure, and knowledge levels of science (physics, chemistry and biology) teachers about nanoscience and nanotechnology. Teachers (N=624) from secondary schools in Turkey comprised the working group. Descriptive methods were used in data analyses. Awareness and exposure subscales were adopted from the *Nanotechnology Awareness Instrument* developed by Dyehouse et al. (2008), and the knowledge subscale, developed by the authors, was added to the Turkish version. Differences among or between the teachers' awareness, exposure, and knowledge levels regarding nanoscience and nanotechnology were determined. No significant differences were found in levels of awareness, exposure, and knowledge of teachers in terms of subject specialisation and educational levels; however, some significant differences were found in gender, tenure, grade and type of school, in-service training participation, following scientific publications, documentary watching frequency and school localisation variables. In general, nanoscience and nanotechnology awareness, exposure, and knowledge levels of the teachers were at a "neutral" level. This study shows needs for further training of science teachers in nanoscience and nanotechnology, to increase their level of awareness and knowledge and to ensure their preparedness for teaching this topic.

Introduction

During the past decade, nanoscience and nanotechnology (NSNT) has become a major field of scientific research and technological innovation. Nanotechnology generates great opportunities for cutting-edge research in science and for innovation in industrial production, and also affects the everyday lives of individuals (Bowman & Hodge, 2007; Hingant & Able, 2010; Roco, Mirkin & Hersam, 2011). Economists have estimated that nanotechnology will accomplish development aims in diverse fields by 2025 as an emergent technology and new industrial revolution, leaving its mark on the 21st century (Roco et al., 2011). Progress and standing of countries in this field will be considered as indicators of economic strength; already USA, Japan, Germany, UK, China, France, Republic of Korea, and Canada perceive nanotechnology as significant and invaluable, and are engaging in extensive research and development investments in various fields of nanotechnology (Turkan, 2015). However, gaps and shortages in skills in nanotechnology fields may occur if education and training systems do not react in time; leading to setbacks in growth potential and employment. Turkey is also allocating funds to nanoscience to promote research and development to boost its economy (Tubitak, 2004); however, publications in the open literature are limited; and public comprehension low (Güzeloğlu, 2015; Karataş & Ülker 2014). Developing countries must take their positions in the world nanotechnology market and industry, so planning for good NSNT training is especially important for developing countries.

Although modern nanotechnology is well-established, the current generation of science teachers typically has little exposure to NSNT, and few opportunities to understand the basic concepts of NSNT (Pas, Vogrinc, Knezevic & Zajc, 2019). Therefore secondary level students may experience only a minimal NSNT exposure, with risks in learning abstract and complex NSNT concepts, thus necessitating an improved introduction to NSNT. Ekli and Şahin (2010) emphasised conveying advantages of NSNT to students, and other authors have maintained that NSNT education may start early, at pre-school level, continuing to secondary education (Ban & Kocijancic, 2011; Chang, 2006; Alpat, Uyulgan, Şeker, Altaş & Gezer, 2017; Roco & Bainbridge, 2005; Sagun-Gököz & Akaygün, 2013). Furthermore, exposure to science develops positive attitudes, which can be pursued and further developed in a formal way (Ban & Kocijancic, 2011; Alpat et al., 2017; Saidi & Sigauke, 2017; Andina, Rahmawati & Budi, 2019), contributing to analytical thinking (Winkelmann & Bhushan, 2016) and promoting next generation scientists/researchers firmly grounded in the discipline. In the present study, we explore physics, chemistry and biology teachers' awareness of NSNT, believing that our study contributes towards promoting NSNT as a next generation topic for science teachers.

Theoretical framework

Though NSNT is a relatively new field, it has become an interesting and important field from an educational perspective, and introducing NSNT in schools is gaining importance (Hingant & Able, 2010; Jones et al., 2013; Laherto, 2011; Lin, Chen, Shih, Wang & Chang, 2015; Roco & Bainbridge, 2005; Stavrou, Michailidi & Sgourus, 2018). Developments and economic impact on commerce and society have brought nanotechnology education to the forefront (Hingant & Able, 2010; Laherto, 2010). In several countries, specialised institutions offer exhibitions or organise visits to NSNT institutions (Ban & Kocijancic, 2011; Chang, 2006; Murriello, Contier & Knobel, 2009; Flynn, Johnson & Penn, 2007; Sagun-Gököz & Akaygün, 2013). Furthermore, recent studies discuss use of different instructional methods to improve student understanding and to increase interest in NSNT (Andina, Rahmawati & Budi, 2019; Blonder & Sakhnini, 2012; Hingant & Able, 2010; Hutchinson, Bonder & Bryan, 2011; Alpat et al., 2017; Sagun-Gököz & Akaygün, 2013; Stavrou, Michailidi, Sgourus & Dimitriadi, 2015; Swarat, Light, Park & Drane, 2011). Some argue that cross-disciplinary concepts make NSNT a theme difficult to present, leading to students experiencing difficulties in understanding and comparing sizes at nano-level (Greenberg, 2009; Hingant & Able, 2010; Lin et al., 2015; Magana, Brophy & Bryan, 2012; Stavrou et al., 2015; Swarat et al., 2011).

The flourishing of NSNT has extensive implications for society: nano-literacy will soon be a requirement for citizens to navigate through important science-based issues related to their everyday lives, ethics and society (Ban & Kocijancic, 2011; Saidi & Sigauke, 2017; Stavrou et al., 2018). A number of interesting programs (*Nanokids, NanoLeap, NanoAventure, Nanonet*, young researchers exchange, etc.), projects (*Nanoyou, Time for Nano,* *Nanototouch, National Nanotechnology Initiative, Nanotruck, Saarlab Initiative, Irresistible*, etc.) and web pages about nanotechnology are available for educational purposes. However, education and training programs need to be planned in a wider context, at primary, secondary, undergraduate and graduate levels, to meet needs in academia, the labour market and industry.

Communicating NSNT to different levels of students places the teacher at the centre of learning and teaching activities for NSNT; a significant responsibility (Hingant & Able, 2010). If teachers are not familiar with NSNT, teaching these topics will be a major challenge for them (Greenberg, 2009). Therefore, teachers need to develop their own knowledge and awareness of NSNT to understand and be able to communicate these issues to their students (Blonder, Parchmann, Akaygun & Able, 2014).). For example, the study showed that the 8E learning cycle which is based on constructivist learning theory where students build their understanding based on their initial knowledge can be used to develop pre-service science teachers' conceptual understanding of nanoscience and nanotechnology and social skills (Andina, Rahmawati & Budi, 2019). Comprehensive research must be done on the constructing of interest by education researchers, to prepare teachers for the age of nanotechnology, and attain a positive impact on student learning in nanotechnology (Jones et al., 2013; Lamb, Annetta, Meldrum & Vallett, 2012). Integration of NSNT, an interdisciplinary field, in science courses may enhance students' understanding of interconnections between traditional disciplines, and raise awareness of cutting-edge research and innovation (Quirola, Marquez, Tecpan & Baltazar, 2018). There is also need for research to measure teachers' awareness, attitudes and knowledge about nanotechnology (Hingant & Able, 2010). To this end, our study investigates teachers' awareness, knowledge and exposure, to assist strategic planning for science teachers' training needs.

Many of the cited studies underline progress in NSNT education and developing resources and materials for teachers and students. Research and the necessary regulations are being elaborated at the primary, secondary and tertiary levels of education, together with communication to the public (Laherto, 2010; Wansom et al., 2009). Along this line, developed countries have made NSNT education a priority, with intensive education planning and research at primary level being launched. The significance of awareness should be emphasised as an initial step in all nano education processes. However, NSNT is not addressed in secondary level education in Turkey (Enil & Köseoğlu, 2016; Karataş & Ülker, 2014; Alpat et al., 2017). Presently, topics of nanotechnology are not included in primary science and secondary biology curricula in Turkey. In the secondary school physics curriculum, there are two lecture hours of nanotechnology topics under the heading "Energy resources and scientific developments" in the 12th grade *Modern Physics Applications in Technology* unit and in the chemistry curriculum (Ministry of National Education [MoNE] 2017). The MoNE Turkey's *Education Vision 2023* document (Ministry of National Education, 2019) does not mention nanotechnology or nanotechnology education. So, in this study we emphasise the importance of a nanoscience education, and advance recommendations for improvement of MoNE's current curriculum. In this context, the current situation of science teachers' awareness and knowledge levels became the initial stage of our study.

Problem statements

1. What are secondary school biology, physics and chemistry teachers' awareness, exposure, and knowledge levels concerning nanoscience and nanotechnology?
2. Are there any significant differences in teachers' awareness, exposure, and knowledge levels with respect to:
   a. subject taught (biology, physics, chemistry);
   b. teachers' faculty of graduation;
   c. gender;
   d. occupational seniority;
   e. educational status;
   f. interest in scientific publications, documentaries or programs with scientific content;
   g. school type;
   h. participating in-service training about nanoscience and nanotechnology?
3. Are directly related items of the awareness and knowledge subscales correlated?

Method

Participants

Convenience sampling was used to recruit 624 science teachers (biology 43.8%; physics 30.6%, and chemistry 25.6%) working in three secondary schools. One was a science high school offering a four-year compulsory education and accepting candidates with central examination achievement scores; its organisational goals are to improve students' ability and increase their attainment in science, to increase the number of scientists in academia and industry, and to develop more laboratories in order to support centres of scientific research and development (10.1% of sample). The second was an Anatolian high school offering a four-year compulsory high school level education preparing students both for higher education and for the future according to their interests, expectations and abilities (54.2% of sample). The third was a vocational high school offering a four-year compulsory education preparing students both for higher education as well as for the job market as intermediate professionals (35.7% of sample). The geographical distribution included the cities of Antalya (36.2%), Denizli (34.8%), Burdur (12.7%) and Ankara (16.3%), during 2015/2016 academic year.

Data collection and analysis

The *Nanotechnology Awareness Instrument* (NAI, Dyehouse et al., 2008) was adapted into a Turkish version named *Nanoscience and Nanotechnology Awareness Scale* (NSTAS); validity and reliability of the Turkish version were tested by the authors. The original scale (NAI) assessed changes in higher education student awareness, exposure and motivation for nanotechnology, as well as factual knowledge about nanotechnology. The nanotechnology awareness subscale measures whether respondents "know something about nanotechnology" and whether they "have heard about nanotechnology and its applications". Awareness is supported by exposure, where respondents' previous exposure to nanotechnology may enhance their awareness and knowledge. NAI consisted of two parts: Items in Part A regarding awareness, exposure, and motivation subscales, and Part B regarding factual knowledge about nanotechnology (Dyehouse et al., 2008). Our version, the *Nanoscience and Nanotechnology Awareness Scale,* (NSTAS) has three subscales, the *Awareness* (8 items) and *Exposure* (6 items) subscales adopted from NAI (total of 14 items), and the subscale *Knowledge* developed by us (see Appendix). In developing the knowledge subscale, the initial 10 items were analysed, validated and finalised to 5 items by a group of science, education, and measurement and assessment experts. The knowledge subscale improves reliability of participants' responses to the awareness subscale; helping to confirm that teachers were sincere in their responses. The 5 items in final subscale for knowledge are presented in the Appendix, along with scoring details for all three subscales.

Internal consistency of NSTAS was determined in a pilot study with 71 teachers who were not participants of the actual study. Goodness of fit indexes for construct validity (CFI=.97 and RMSEA=.07 for two factors solution) and Cronbach-alpha reliability coefficient for internal consistency (α=.942) were calculated. Three teachers from Ankara and Antalya provinces participated in the test for item clarity of NSTAS.

Skewness, kurtosis, and Kolmogorov-Smirnov test results were used to determine normality of distribution of the scores. Arithmetic means ($Awareness_{mean}$ = 3.26; $Exposure_{mean}$ = 2.60; $Knowledge_{mean}$ = 2.99) and standard deviations ($Awareness_{S.D}$.= 0.028; $Exposure_{S.D.}$ = .901; $Knowledge_{S.D.}$ = 1.054) were calculated as descriptive statistics. $NSTAS_{mean}$ was created as variable by taking the $Awareness_{mean}$, $Exposure_{mean}$ and $Knowledge_{mean}$ scores as overall subscale scores. Spearman correlation coefficient was used to determine the relationships between item scores of subscales of awareness and knowledge. This correlation coefficient was used to determine responder sincerity of awareness subscale scores. Correlation coefficients between directly related items $Awareness_1$ - $Knowledge_1$; $Awareness_1$ - $Knowledge_2$; $Awareness_5$ - $Knowledge_4$; $Awareness_7$ - $Knowledge_3$; $Awareness_8$ - $Knowledge_5$ were calculated.

Findings

The tests of normal distribution of data are presented in Table 1.

Table 1: Normality test statistics of NSTAS data, N=624

NSTAS	Skew-ness	Skew-ness S_E	t	Kurt-osis	Kurt-osis S_E	t	Kolmogorov -Smirnov statistics
$Awareness_{mean}$	-.132	.098	-1.35	-.870	.195	-4.46*	.080*
$Exposure_{mean}$	.788	.098	8.04*	.126	.195	0.65	.102*
$Knowledge_{mean}$	-.125	.098	-1.28	-1.048	.195	-5.37*	.131*
$NSTAS_{mean}$	.051	.098	0.52	-.836	.195	-4.29*	.044*

*p < .05

The Kolmogorow-Smirnov test demonstrated that the scale and subscales scores were not normally distributed (p<.05). Also, as seen in Table 1, $\text{Awareness}_{\text{mean}}$, $\text{Knowledge}_{\text{mean}}$, and $\text{NSTAS}_{\text{mean}}$ score distributions were not skewed; but they were kurtotic: $\text{Exposure}_{\text{mean}}$ score distribution was skewed. Normal distribution assumptions were not met for score distributions; therefore, non-parametric tests were used to compare groups.

Problem statement 1

The arithmetic means of the $\text{Awareness}_{\text{mean}}$, $\text{Exposure}_{\text{mean}}$, $\text{Knowledge}_{\text{mean}}$, and $\text{NSTAS}_{\text{mean}}$ scores for science teachers were between 2.60 and 3.26, indicating neutral agreement level of awareness. Similar results were obtained for the other two subscale scores and the NSTAS overall, as depicted in Table 2.

Table 2: Descriptive statistics and interpretation of NSTAS and subscale levels of teachers

NSTAS	Mean	SD	Response level
$\text{Awareness}_{\text{mean}}$	3.26	1.03	Neutral
$\text{Exposure}_{\text{mean}}$	2.60	.90	Neutral
$\text{Knowledge}_{\text{mean}}$	3.13	1.86	Neutral
$\text{NSTAS}_{\text{mean}}$	3.00	1.05	Neutral

Problem statement 2

PS2a and PS2b
There were no significant differences in teachers' subject taught and faculty of graduation, in NSTAS and all subscales (p>.05).

PS2c
Mann Whitney-U test results showed that there were no significant differences between genders in terms of medians for $\text{Exposure}_{\text{mean}}$, $\text{Knowledge}_{\text{mean}}$, and $\text{NSTAS}_{\text{mean}}$ (p>.05). However, a significant difference was found in favour of males for $\text{Awareness}_{\text{mean}}$ (p<.05).

PS2d
There was no significant difference between teachers in terms of service years of medians for $\text{Awareness}_{\text{mean}}$ (p>.05) and there were significant differences for $\text{Exposure}_{\text{mean}}$, $\text{Knowledge}_{\text{mean}}$, and $\text{NSTAS}_{\text{mean}}$ (p<.05). In terms of service years, 1-5 years group were significantly higher than the 21-25 years group for the $\text{Exposure}_{\text{mean}}$ (p<.05). Also, there were significant differences in favour of 1-5 years service with respect to 21-25 and over 26 years service groups for the $\text{Knowledge}_{\text{mean}}$ (p<.05) and in favour of 6-10 years with respect to 21-25 and over 26 years for the $\text{NSTAS}_{\text{mean}}$ (p<.05).

PS2e and *PS2f*
With respect to teachers' educational status and following a scientific documentary or program in a scientific field regularly, significant differences were found between the medians of $\text{Awareness}_{\text{mean}}$, $\text{Exposure}_{\text{mean}}$, $\text{Knowledge}_{\text{mean}}$ and $\text{NSTAS}_{\text{mean}}$ (p<.001). Groups in favour of the differences between medians are given in Table 3. Concerning

keeping up to date for developments in NSNT through scientific publications, there was a significant difference in favour of teachers who followed the literature for all NSTAS scores ($p<.05$).

Table 3: Kruskal-Wallis H test statistics for teachers' educational status and following a scientific documentary or program categories and pairwise comparisons

NSTAS variable	Educational Status	p	Significant diffs between groups	Following a scientific documentary or program	p	Significant diffs between groups
Awareness	PhD (4) Masters (3) Undergrad. (2) Associate (1)	***	4>3[a], 4>2, 4>1 3>2, 3>1 2>1	Always (5) Very often (4) Occasionally (3) Rarely (2) Never (1)	***	5>3, 5>2, 5>1 4>3, 4>2, 4>1 3>2, 3>1 2>1
Exposure	PhD (4) Masters (3) Undergrad. (2) Associate (1)	***	4>3, 4>2, 4>1 3>2, 3>1 2>1	Always (5) Very often (4) Occasionally (3) Rarely (2) Never (1)	***	5>3, 5>2, 5>1 4>3, 4>2, 4>1 3>1 2>1
Knowledge	PhD (4) Masters (3) Undergrad. (2) Associate (1)	***	4>3, 4>2, 4>1 3>2, 3>1	Always (5) Very often (4) Occasionally (3) Rarely (2) Never (1)	***	5>3, 5>2, 5>1 4>3, 4>2, 4>1 3>1 2>1
NSTAS (total)	PhD (4) Masters (3) Undergrad. (2) Associate (1)	***	4>3, 4>2, 4>1 3>2, 3>1 2>1	Always (5) Very often (4) Occasionally (3) Rarely (2) Never (1)	***	5>3, 5>2, 5>1 4>3, 4>2, 4>1 3>2, 3>1 2>1

***$p<.001$, a: Awareness level of PhDs significantly higher than that of Masters and so on.

In general, as the teachers' educational status increased, their awareness, exposure, knowledge and NSTAS total scores differed significantly in favour of higher educational status. Similarly, teachers who were following a scientific documentary or program had higher scores than teachers with low following frequency. So, teachers' awareness, exposure, knowledge and NSTAS total scores significantly differed in favour of following a scientific documentary and program often.

PS2g

There were significant differences among school types (science, Anatolian and vocational high schools) in favour of science high school teachers for both NSTAS and in all subscales ($p<.05$).

PS2h

There were significant differences for both NSTAS and all subscales for in-service training or any courses related to NSNT. In-service training participants had higher median values than teachers who did not ($p<.05$).

Problem statement 3

PS3

Significant positive but weak or moderate correlations between $Awareness_1$ and $Knowledge_1$ items (rho=.298, $p<.01$); $Awareness_1$ and $Knowledge_2$ items (rho=.397, $p<.01$); $Awareness_5$ and $Knowledge_4$ (rho=.346, $p<.01$); $Awareness_7$ and $Knowledge_3$ (rho=.445, $p<.01$); and finally $Awareness_8$ and $Knowledge_5$ (rho=.356, $p<.01$) were found.

Discussion

Science teachers' NSNT awareness level was: "Neutral" (PS1). Due to weak background knowledge and teacher perceptions of NSNT; teachers' knowledge was reported to be low to moderate/limited by others in several countries (Ahmed, Imdad, Yaldram & Raza, 2015; Ekli & Şahin, 2010; Schank, Krajcik & Yunker, 2007); those not acquainted with NSNT were unable to engage children meaningfully on the subject matter and were reluctant to introduce it (Ekli & Şahin, 2010; Greenberg, 2009; Jones et al., 2013). Furthermore, the majority of the participants were not aware of nanotechnology; nor its existence, leading to low knowledge of nanotechnology (Cobb & Macoubrie, 2004; Elmarzugi et al., 2014; Farshchi, Sadrnezhaad, Nejad, Mahmoodi & Abadi, 2011; Jones et al., 2013; Kahan, Braman, Slovic, Gastil & Cohen, 2009; Kumar, 2007; Lee, Scheufele & Lewenstein, 2005; Macoubrie, 2005; Schönborn, Höst & Palmerius, 2015; Vandermoere, Blanchmanche, Bieberstein, Marette & Roosen, 2010; Waldron, Spencer & Batt, 2006). These authors are in agreement with our results. Our findings suggest inclusion of NSNT subjects in the biology curriculum and that a sufficient number of hours should be reserved in biology, physics and chemistry curricula to increase NSNT awareness of young people, as well as teachers. A significant proportion of Turkish citizens has never been exposed to or had very limited information in nanotechnology concepts; nanotechnology has been extraneous to the Turkish public (Aydın-Sayılan & Mercan, 2016; Ekli & Şahin, 2010; Enil & Köseoğlu, 2016; Ergün, Ocak & Ergün, 2017; Karataş & Ülker, 2014; Alpat et. al., 2017; Senocak, 2014). However, Güzeloğlu (2015) recently reported increased interest and improvement of awareness in nanotechnology. Uncertainties and risk perceptions have led to some concern in society.

When teachers' subject (*PS2a*) and faculty of graduation (*PS2b*) were evaluated as independent variables, no significant differences between mean scores of their NSNT awareness, exposure, and knowledge were found. Physics teachers' NSNT awareness was slightly higher than others. This may be due to nanotechnology topics being taught in the physics curriculum, but not in the biology and chemistry curricula. Reports of others are diverse on this issue (Aslan & Şenel, 2015; Enil & Köseoğlu, 2016). Low scores of the science teachers may be due to nanotechnology being a new concept. Furthermore, connections between science and technology are not very clear in teachers' conceptions. Awareness and knowledge levels of science teachers were similar; this may be due to their limited appreciation of NSNT developments, similar to results found by others (Desimone, 2009; MoNE, 2014).

Awareness showed a significant difference in favour of males (PS2c). Other reports are conflicting; some are similar to our findings (Ahmed et al., 2015; Cobb & Macoubrie, 2004; Nerlich, Clarke & Ulph, 2007; Senocak, 2014), whilst others are not in complete agreement: Aydın-Sayılan and Mercan (2016), Enil and Köseoğlu (2016) reported no significant differences according to gender. Our results of exposure, knowledge and NSTAS score means showed no significant differences among teacher's subject, taking gender as a independent variable.

Professional service years, seniority, showed no significant differences in teachers' level of awareness (*PS2d*). Young teachers, 1-5 years of professional service, had more exposure and knowledge about NSNT; may have reflected these as excitement/ motivation and idealistic thoughts. This may also be supported with interest in science and technology developments. Therefore, teachers who have gained experience to participate in seminars, conferences, presentations, in-service training activities or courses in the early years of their profession may have more information on NSNT topics. Teachers who have 16-20 years of professional experience are very experienced in their fields, are more confident, have been under inquiry from interested students, had observed more research and experiments; prepared for research, projects, and gaining NSNT knowledge. Teachers of 26 years and over professional service had low knowledge about NSNT. Most of present teachers, especially 15 years and more in service, completed their training before NSNT became prominent. Hence, this group may experience slower adaptation to innovation, and occupational fatigue may exacerbate the situation and lead to low awareness levels.

Overall, teachers' educational status showed teachers with graduate degrees had higher levels of awareness, exposure and knowledge about NSNT (*PS2e*). This could be due to more extensive interaction with academia, faculty members, other graduates and doctoral students in the academic environment. Our results show that as level of teachers' education/training increases, level of NSNT awareness also increases. These results are similar to those of Vandermoere et al. (2010) who examined public attitudes towards and awareness of nanotechnology in Germany. Educational background is positively related to familiarity with nanotechnology. Ahmed et al. (2015) and Karim et al. (2017) studied NSNT awareness levels of undergraduate, graduate, and postdoctoral participants in Malaysia and Pakistan respectively, and concluded that awareness level increases in parallel to educational level. These findings are supported by our results.

Another significant finding of the study was that both the overall NSTAS and the awareness of NSNT increased in line with frequency of following scientific documentaries, publications or programs (*PS2f*). Teachers' access to such media and opportunities to follow developments seems to be expanding with more online offerings, for example Tomasik, Jin, Hamers & Moore (2009). Bektaş-Öztaşkın (2013) reported increased consciousness and awareness of students when documentary film and courses in social fields were used. Alpat et al. (2017) reported benefits of visual media to raise awareness of NSNT and at the same time increase general knowledge. Ahmed et al. (2015) emphasised the importance of Internet, electronic or print (newspapers, etc.) media, and reading technical journals in developing awareness and understanding the subject. Students and teachers with no prior introduction to NSNT either as a subject or even as a chapter in the course contents of higher educational institutions, have accessed information about nanotechnology through individual efforts. Personal efforts evidently play a role in gaining knowledge of science, technology and innovation. Ateş and Üce (2017), Ekli and Şahin (2010), Enil and Köseoğlu (2016), and Ergün et al., (2017) also found Internet and other media resources to be as effective as formal teaching of nanotechnology. In conclusion, Güzeloğlu (2015) also reported invaluable contributions of media for information and appreciation of innovation. These variables may be more influential than gender and school types.

Science high school teachers' NSNT awareness level was higher than Anatolian and vocational high school teachers (*PS2g*). They updated and developed their skills and knowledge to meet high student expectations such as project work, problem solving and analytical thinking. Also, high profile and self-efficacy perceptions of teachers and students in this school type may have contributed. In agreement with our results; positive self-efficacy expectancy increases motivation, enables the teacher to cope with new and difficult tasks become more willing to make efforts (Çapri & Kan, 2006; Yılmaz, Gürçay & Ekici, 2007). Furthermore, Blonder and Mamlok-Naaman (2016) encouraged chemistry teachers to teach nanotechnology with a module they developed and implemented (a topic outside the science curriculum). They found that teaching self-efficacy beliefs and organisational efficacy beliefs contributed to teachers' attaining sustainable changes.

Teachers who undertook in-service training or courses in nanotechnology had significantly higher NSNT awareness (*PS2h*). In support of our results, positive impacts of professional teacher training and educational programs in NSNT teaching, lifelong learning have been reported (Blonder, 2010; Bryan, Sederberg, Daly, Sears & Giordano, 2012; Jahangir, Saheen & Kazmi, 2012; Alpat et al., 2017; Lin et al., 2015; Sgouros & Stavrou, 2017; Tomasik et al., 2009). Online courses designed for promoting teachers' technological development skills were as effective as face to face interactions (Blonder & Mamlok-Naaman, 2016). One of the main challenges for integrating NSNT education in high schools is the necessity to engage in the re-education of K-12 science teachers (Ghattas & Carver, 2012; Planinsic & Kovac, 2008; Ringer, 2014).

Teachers' knowledge and perceived awareness levels were correlated weakly or moderately *(PS3)*, possibly showing teachers with higher level of knowledge were actually unaware of their awareness or vice versa, in NSNT. Weak positive correlations do show somewhat parallel but weak increases in both awareness and knowledge. Logically, teachers with higher knowledge level are expected to have a high level of awareness. Our data did not support this idea; however, at present we cannot further explore this issue by comparing with the work of others owing to a lack of relevant references.

Some universities offer graduate level NSNT education (Aslan & Şenel, 2015; Alpat et al., 2017). Hingant and Albe (2010) argued that there is a shortage of academics in the field and research infrastructure for NSNT training. Despite rapid developments in NSNT, only a few countries offer nanoscience courses at the secondary and undergraduate level (Poteralska, Zielinska & Mazurkiewicz, 2007; Schank et al., 2007). Several barriers related to teachers' limited knowledge, beliefs, self-efficacy and time-constraints regarding their teaching NSNT can be overcome by restructuring the traditional science curriculum, improving teaching resources/materials, tools, and assessment, enriching laboratory equipment, and offering teacher professional development (both pre-service and in-service) (Andina, Rahmawati & Budi, 2019; Ghattas & Carver, 2012; Laherto, 2011; Lin et al., 2015; Sgouros & Stavrou, 2017; Tomasik et al., 2009). The *NanoTeach* project in the U.S. addressed the issue of nanoscience education for high school teachers through a professional development model to support both content knowledge and pedagogical content knowledge, and successfully integrate them into the classroom (Huffman, Ritsrey, Tweed & Palmer, 2015). In addition, attitudes, perceptions, awareness and knowledge about NSNT can influence their teaching approach and behaviours since they play important roles in curriculum innovation; their perspectives must be investigated and considered to facilitate curriculum reform or other changes in school practices. In many countries, school curricula are far from meeting the needs of NSNT education; there are limitations in integrating NSNT into the educational system without making major revisions and radical changes (Laherto, 2011).

However as NSNT is an interdisciplinary field, a high level of integrating into all science fields taught in schools and teaching connections between science and technology should be possible (Ghattas & Carver, 2012; Hadjioluca & Constantinou, 2019; Quirola et al., 2018). Young children are interested in exploring the world; hence, exposing them to science can contribute towards developing a culture of innovation (Ergün et al., 2017; Eshach & Fried, 2005; French, 2004). However, with NSNT some educators find the discipline to be too complex and abstract for young students (Jones et al., 2013). Basic nanotechnology concepts can be taught in secondary schools using advanced technologies in conjunction with student centred active learning pedagogical approaches: game-based learning, learning multimedia, AFM (atomic force microscopy) simple teaching model type, socio critical methods such as project or problem-based learning, storytelling, narratives, etc.

The very first step in nano education at any level is ensuring the awareness of the teachers (Bryan et al., 2012; Enil & Köseoğlu, 2016). If we ensure high-quality professional development for high school physics, chemistry and biology teachers, they will be better prepared to encourage students to view science, technology and innovation as relevant to their daily lives (Huffman et al., 2015; Hingant & Able, 2010; Ringer, 2014). In addition, science centres and museums are very beneficial in enhancing public and students' awareness and helping them to learn about NSNT. Most of these initiatives will boost nano literacy among the public in addition to formal education, and help to overcome barriers to teaching NSNT in the classroom (Chang, 2006; Crone, 2010; Karataş & Ülker, 2014; Murriello et al., 2009). Future scientists are expected to become more conscious and equipped on the fundamentals, applications and prospects of nano disciplines to meet new needs in research, the economy, industry, society and entrepreneurship (Cincera, Medek, Cincera, Lupac & Ticha, 2017; Pas et al., 2019).

Science teacher education should provide training on how to teach NSNT and this pre-service training can be a reference for science teachers to develop in their future classroom teaching (Andina, Rahmawati & Budi, 2019; Bryan et al., 2012; Hingant & Able, 2010; Huffman et al., 2015; Nandiyanto et al., 2018); theoretical and practical training can be planned by close collaboration and coordination between educational authorities, in the case of Turkey, MoNE, the Council of Higher Education, and the universities. STEM education can be used as a new approach in the teaching of NSNT topics. Another way of attracting public attention to importance of NSNT could be inclusion of the topic in the university entrance examinations.

This study is important in the Turkish context for understanding the present level of awareness and knowledge about nanotechnology amongst Turkish high school science teachers and provides a basis for further investigation of strategies to remediate this situation.

Conclusion and recommendations

In conclusion, science teachers' level of awareness, exposure, and knowledge were insufficient; enhancements are needed. Our results show that academic activities such as following scientific articles, documentaries and programs, etc., have positive impacts on knowledge and awareness levels of nanoscience. Another important factor was educational status; teacher graduate education should be encouraged. NSNT subjects should be added to the biology curriculum as well as physics and chemistry curricula. At the institutional level, school support is very important for teachers to implement curriculum reform where schools can provide virtual and simulated laboratories, laboratory equipment, teaching materials, blended learning environments and opportunities for professional development of teachers. There is necessity, at the international level, to update nanotechnology topics in secondary level physics, chemistry and biology curricula to incorporate scientific developments. Weak positive correlations between awareness and knowledge show parallel but weak increases both in awareness and knowledge. Therefore, activities to improve science teachers' awareness level should be considered.

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Appendix: Nanoscience and Nanotechnology Awareness Scale (NSTAS)

Dear Participant,

Items related to nanoscience and nanotechnology are given in the awareness scale below. Five (strongly disagree, disagree, neutral, agree, or strongly agree) response options are provided for each item. Please read each item and indicate the extent to which you agree or disagree (X) to the statement. There are no true or false answers among the responses

Please do not leave any unanswered items. Thank you for your contribution.
Please fill in the following personal information before responding to the awareness scale.

1. Gender: M ( ), F ( ). 2. Years of professional service: 1-5 years: ( ) 6-10 years: ( ) 11-15 years: ( ) 16-20 years: ( ) 25 years and above: ( ) 3. Your subject: Physics ( ), Chemistry ( ), Biology ( ) 4. Higher education institute graduated: Vocational school ( ) Faculty ( ) Teacher education institute ( ) Other ( ) …………………………… 5. Educational status: Associate degree ( ) Bachelor ( ) Masters ( ) Doctorate ( ) 6. School type that you work: Science High School ( ) Anatolian High School ( ) Vocational High School ( )	7. Have you taken any in-service training concerning Nanoscience and Nanotechnology? Yes ( ) No ( ) 8. Do you follow any scientific publication (science and technical journal, etc.)? Yes () No () 9. Frequency of following scientific documentary, media or program? Always ( ) Very often ( ) Sometimes ( ) Rarely ( ) Never ( ) 10. Your city of duty: Antalya ( ) Denizli ( ) Burdur ( ) Ankara ( )

Subscales for awareness and exposure
These were adapted from *Nanotechnology Awareness Instrument (NAS)-Version 2*. Awareness is based on 8 items that used a 5-point (1-5) Likert-style scale. Scores are interpreted as follows: 1.00 ≤ Mean Awareness score < 1.80: Strongly disagree; 1.80 ≤ Mean Awareness score < 2.60: Disagree; 2.60 ≤ Mean Awareness score < 3.40: Neutral; 3.40 ≤ Mean Awareness score < 4.20: Agree; and 4.20 ≤ Mean Awareness score < 5: Strongly agree.

Exposure is based on 6 items that used a 5-point (1-5) Likert-style scale. Scores are interpreted as follows: $1.00 \leq$ Mean exposure score < 1.80: Never; $1.80 \leq$ Mean exposure score < 2.60: Very little; $2.60 \leq$ Mean exposure score < 3.40: Sometimes; $3.40 \leq$ Mean exposure score < 4.20: A fair amount; $4.20 \leq$ Mean exposure score < 5: A great deal. (after Dyehouse, Diefes-Dux, Bennett & Imbrie, 2008).

Subscale for knowledge

The following questions were prepared to measure your level of knowledge in nanoscience and nanotechnology. You are not expected to complete the questions correctly since nanoscience and nanotechnology concepts and applications are relatively new in recent years; the objective is not to test nor assess you. We aim to measure your level of knowledge in nanotechnology, if present. No items/statements in the study are to disclose your identity. We appreciate your participation and sincere responses to the questions. C1, C2, C3, C5 are 5 points each for correct answer; C4 is 0.5 points each correct answer. Maximum 25 points.

1. One nanometre is .... metre.

2. .... can be given as an example of a nanometre size object.

3. An instrument used to measure objects of nanometre scale is ....

4. There are several fields of nanotechnology application. In addition, there are materials and devices developed using nanotechnology. Please provide nanotechnology application fields and materials/devices developed in the space below:

   Field of application *Developed material or device*

   a. ....
   ....…..
   b. ....
   ....…..
   c. ....
   ....…..
   d. ....
   ....…..
   e. ....
   ....…..

5. Can you name a material or device developed using nanotechnology application which are expected to impact humans directly or indirectly?
   ....
   ....
   ....

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