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UAE Elementary Students' Conceptions of Nature of Science

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Abstract: This study was designed to examine the concepts of nature of science (NOS) that elementary grade students bring into the science classroom. A group of 301 boys and girls from elementary schools in United Arab Emirates were sampled. This study investigated two questions related to students conceptions of nature of science: (1) What conceptions of NOS do young students hold?, and (2) What is the relationship between students' conceptions of the nature of science and their gender?. Student's conceptions of NOS were measured with the Nature of Science Questionnaire (NOSQ), a newly developed and piloted instrument. Findings showed that the majority of students in this study held uninformed conceptions about most of the NOS aspects. According to the results, there was a significant difference between female and male students' conceptions about scientific theory, tentativeness of scientific knowledge, and the influence of social and cultural values on scientific knowledge. These findings suggest that today's young students bring to the classroom understandings of the NOS that may serve as the foundation for more effective science education.

Keywords: Nature of Science, Students perceptions, STEM, Science values and cultural values

Introduction

The search for a way to empower students with scientific skills, competencies, and critical thinking skills is an everlasting process. Scientists and science educators have been emphasizing for decades on the importance of NOS aspects, for a successful science education (Tala &Vesterinen, 2015; Wilcox & Lake, 2018; Cofré et al., 2018). Wilcox and Lake (2018) insist on the importance of the accessibility of k-12 students to the aspects of the nature of science to become scientifically literate. The integration of NOS aspects with science content is highly recommended (Hacieminoglu, 2016;Koerber, Osterhaus &Sodian 2015; Michel &Neuman, 2014). Whether it is integrated with science lessons, or it is acquired using an instructional approach, students have to acquire an adequate understanding of NOS aspects. Sadly, a review of extensive literature indicates that students as well as teachers hold an inadequate concepts of the NOS (Abd-El-Khalick& Lederman 2000; Yacoubian and Khishfe, 2018; Torres et al., 2015; Lederman et al., 2002; Vazquez-Alonso et al., 2016).

Historians, scientists, philosophers and science educators do not agree on one single definition for the terminology "Nature of Science" (Karaman, 2016; Hodson& Wong, 2014; Abd-El-Khalick, 2013; Forawi, 2014; Khishfe&Abd-El-Khalick, 2002). Torres et al. (2015) state that nature of science provides a clear description about the dynamics and mechanism of science as a discipline. Establishing a solid understanding of nature of science enlarges the students' scientific curiosity. Torres et al. (2015) consider the understanding of the nature of science as an essential component to achieve scientific knowledge.

Nature of science is characterized by subjectivity, creativity, and tentativeness. Abd-El-Khalick et al.(1998) define nature of science as the epistemology of science and scientific knowledge. NOS is subject to human imagination and creativity. Khishfe and Abd-El-Khalick (2002) state that the definition of nature of science has evolved in the last century due to the complex and dynamic nature of the scientific knowledge. Forawi (2011) states that nature of science is a set of representations and values of scientific knowledge. Accordingly, nature of science represents the values and methods of scientific development (Forawi, 2014).

Nature of science is embedded in social and cultural ethos. Thus, science is considered a way of thinking that leads to the development of scientific knowledge. Besides, nature of science is the developmental process of science. Lederman (2004, p.303) defines Nature of Science as:

"Nature of science is the epistemology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge or the development of scientific knowledge."

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Scientific literacy is a critical component of learning that prepare students to resolve scientific, societal and personal issues (Smith et al., 2012; Praia, Gil-Perez, Vilches, 2007). Science Education focuses on the learning to do science, the learning about science and the learning of science. Hodson (1998) presents the dimensions of the three pillars of science education: (a) learning of science, (b) learning to do science, and (c) learning about science.

Science education is seen as a result of the proper development of scientific literacy and NOS understanding. Understanding NOS permits the development of critical thinking, intellectual excitement and argumentative skills. Students grasp the key features of scientific phenomena through their engagement in deep discussions related to NOS (Khisfe, 2012; Lederman et al., 2002). NOS is neither emphasized in science textbooks (Bell et al., 2003; Abd-El-Khalick 2012), nor integrated with the design of learning activities (Buaraphan, 2012; Reis &Galvao, 2004; Abd-El-Khalick, Bell, Lederman, 1998). While some (Karaman, 2016; Michel &Neuman, 2014; Abd-El-Khalick, 2013; Brase 2014; Jenkins 2013) insist on the need to intentionally integrate NOS aspects as a cognitive instructional outcome, others (Ayvaci, 2007; Abd-El-Khalick, 2013) argue about the impact of an inquiry based science class to develop NOS views.

Scientific theory is a principle derived from rich collective evidence from empirical data. Experimental confirmation makes scientific theories reproducible by other scientists (Park et al. 2014, Louzek 2016). Scientists make predictions about a particular scientific problem based on scientific theories.Science is a subjective theory based discipline based on empirical data, yet, it is objective. Science is an academic discipline having an unquestionable knowledge (Maccaulay, 2015; Curd & Cover, 1998;Louzek, 2016), is hypothesized by scientists (Lederman et al. 2002, Park et al. 2014), and is existent in every culture (Shizha, 2006; Toomey, 2016;Coll et al., 2009;Gondwe and Longnecker, 2015).

Science and scientific knowledge intersect at the tentativeness and changeable point. Science and scientific knowledge are durable (Tanzella-Nitti, 2009; Park et al., 2014), but not permanent or owned by anyone (Forawi, 2014; Kuhn, 1996; Popper, 1963;Louzek, 2016).Scientific knowledge develops over time based on new information that threaten the stability of the existing information. Empirical evidence sets the base for a new discovery (Irzik& Nola, 2011; Curd &Cover, 1998; Toomey, 2016) and is considered an essential requirement to confirm the validity of the new proposed theory (Brase, 2014; Beverly, 2002; Macaulay, 2015).The methodical approach to study the natural world, science, continuously seeks answering questions using logical experimental tests. Various methods are to carry on these scientific investigations. Therefore, scientific method is a rational, incisive and rigor method with which inquiry is carried out (Macaulay, 2015).The scientific method is neither about the steps nor about the sequence of procedures. Scientists try various ways to investigate how nature works rather than pursue one set method (Macaulay, 2015;Wible, 1998; Fang, 2014; Lederman, 2004). At students' level, grappling with issues to find solutions in discussions results in a holistic sense of scientific practices (Allchin, 2014; Rudge &Howe, 2009; Clough, 2006).Scientific inquiry takes place in a variety of ways directed to include NOS questions. Students learn best when they are actively involved in their learning through inquiry process about the process of science and nature of science (Deng et al., 2011; Torres et al., 2015; Oh and Oh, 2011;Giere, 2010; Schwarz et al., 2009).

Students grasp the key features if scientific phenomena through their engagement in deep discussions related to NOS (Khishfe, 2012; Lederman et al., 2002), in modelling activities (Oh and Oh, 2011; Schwarz et al., 2009;Giere, 2010), and in going insightful ideas about nature of science (Ayvaci, 2007;Abd-El-Khalick, 2013; Smith, 2010).Students conceptualize their ideas according to their relevance to context and social parameters. Their understanding of scientific facts is solidified when it is tightly connected with other subject areas (Alfieri et al., 2011;Uchechi, 2013; Burton & Frazier, 2012). Many researchers (Allen, 2007; Burton & Frazier, 2012;Schmoker, 2006;Sheninger&Devereaux, 2012) indicate that connecting the concepts to other disciplines increase students achievements.Cultural and social values affect and are affected by science and the development of human enterprise. Science and culture are uniquely interrelated (Shizha, 2006;Gondwe and Longnecker, 2015). Every culture possesses its own knowledge and beliefs concerning the natural world whereas the boundaries that determine where science ends and where culture starts do not exist.

Girls bring different values to their interest in science as indicated in previous studies (Osborne and Collins, 2001; Kumari and Saraladevi, 2014; Baran, 2016). Students view scientific knowledge as being an important component of their learning process, however boys and girls have developed different articulations for the notion of scientific knowledge and aspects of nature of science. As guided by the Gender Schema Theory (Bam, 1981) individuals become gendered in society according to their gender. Girls look at their ancestors as their role models in all various areas of everyday life experiences. The restrictions exhibited in the society mask the potential of individuals and restrict their creativity based on the displayed strong gender stereotypes. Thus, resulting on various gender differences during their studying journey in particular and in various real world behavior.

Therefore, the purpose of this study was to examine the concepts of NOS that elementary students bring to the classroom. The study investigated two questions: (1) what conceptions of NOS do young students hold?, (2) What is the relationship between students' conceptions of the nature of science and their gender?.

Methodology

This study was focused on examining students' conceptions of nature of science and the relationship between students' conceptions of nature of science and their gender. In this context, the quantitative methodology approach was used. Thus, the numerical data was the only source of data. Theinstrument used was a questionnaire entitled "The Nature of Science Questionnaire" (NOSQ). It is a five-point Likert scale instrument, (strongly agree, agree, don't have an opinion, disagree, strongly disagree), was developed to measure young students' conceptions of science. It constituted of 24 items distributed among the six folds of NOS aspects and illustration of images with use of faces.These images indicated five faces with different levels starting from a very happy to a very sad face to be appropriate to pre-reader participants (**"No Way!"** meaning "I don't agree at all" or "This is definitely not true;" **"Maybe Not"** meaning "I disagree a little" or "This might not be true;" or **"I don't know,"** meaning "I don't agree or disagree" or "I don't know if it's true or not;" **"Maybe Yes"** meaning "I agree a little" or "It might be true;" or **"Yes! Yes!)**.

307 elementary students from various private and public schools in the United Arab Emirates participated in this study. All participants voluntarily participated in this study. Out of the 307 elementary students, 124 were male students and 177 were female students. 40% of students were males and 60% of students were females. The ages of students ranged from 6 to 11 years.

The instrument was reviewed by two experts in the science field to confirm it's valid. Validity of the instrument is of a paramount value. In addition, the instrument was piloted to check its reliability. The reliability coefficient for the pilot data were found to be moderately high at 0.758 using Cronbach's alpha reliability statistics test.

Results

The overall analysis suggests that there is a gender gap where females acquire an adequate understanding of NOS aspects and they outperform male students. The analysis of the results using one sample t test show that elementary students have a thorough understanding of NOS aspects (T=-0.125, p-value=0.901).

On scientific theory, students revealed the same perceptions about scientific theory and the importance of the scientific theory in developing students NOS aspects. Using one sample t-test, the results show that there is no significant difference with the sample size selected (T=-1.885, p-value=0.060). Using independent sample t-test, there is significant different in overall scientific theory ideas by gender, female students are more agreed than male students (t=-3.395, p-value=0.001).

Table 1: Students Perceptions about Scientific Methods

Statement	Mean	Standard deviation	Test
Overall sample	3.91	0.81	One sample t test T = - 1.885 P-value = 0.060
Overall sample by gender	M = 3.73 F = 4.04	M = 0.89 F = 0.73	Independent sample t test T = - 3.395 P-value = 0.001

On scientific knowledge, students revealed suitable ideas about scientific knowledge. Using one sample t test, the results demonstrate that elementary students agreed about scientific knowledge ideas mention in this questionnaire, but there is significant difference with the sample size selected to answer this questionnaire. Using an independent sample t-test, there is no significant different in overall scientific knowledge ideas by gender.

Table 2: Students Perceptions about Scientific Knowledge and its subjectivity

Statement	Mean	Standard deviation	Test
Overall sample	3.80	0.78	One sample t test T = - 4.337 P-value = 0.000
Overall sample by gender	M = 3.77 F = 3.82	M = 0.74 F = 0.82	Independent sample t test T = - 0.551 P-value = 0.582

On scientific inquiry, elementary students have a thorough perception about scientific knowledge in relation with empirical evidence. Using one sample t-test, the results show that there is a significant difference with the sample size selected (t=-5.057, p-value=0.000). Using independent sample t test, the results show that there is a significant difference in overall scientific ideas by gender, female is more agreed than males (t=-3.066, p-value=0.002).

Table 3: Students Perceptions about tentativeness of scientific knowledge

Statement	**Mean**	**Standard deviation**	**Test**
Overall sample	3.76	0.82	One sample t test T = - 5.057 P-value = 0.000
Overall sample by gender	M = 3.59 F = 3.88	M = 0.90 F = 0.72	Independent sample t test T = - 3.066 P-value = 0.002

On science activities, students agree about science activities ideas. Using one sample t-test, the results show that there is significant difference with the sample size (t=5.130, p-value=0.000). Using independent sample t test, the results show that there is no significant different in overall science activities ideas by gender where female students have a slightly better understanding than male (t=-1.369, p-value=0.172).

Table 4: Students Perceptions about scientific knowledge in relation with empirical evidence

Statement	**Mean**	**Standard deviation**	**Test**
Overall sample	4.24	0.82	One sample t test T = 5.130 P-value = 0.000
Overall sample by gender	M = 4.17 F = 4.30	M = 0.87 F = 0.78	Independent sample t test T = - 1.369 P-value = 0.172

On learn science, students have agreed about learn science ideas. Using one sample t-test, the results show that there is no significant difference with the sample size selected (t=0.000, p-value=1.000). Using independent sample t test, the results show that there is no significant different in overall learn science ideas by gender (t=-0.784 p-value=0.434).

Table 5: Students Perceptions about real life integration to scientific knowledge

Statement	**Mean**	**Standard deviation**	**Test**
Overall sample	4.00	0.90	One sample t test T = 0.000 P-value = 1.000
Overall sample by gender	M = 3.95 F = 4.03	M = 0.90 F = 0.89	Independent sample t test T = - 0.784 P-value = 0.434

On social and cultural value, students agree about the social and cultural values related to NOS aspects. Using one sample t-test, the results show that there is significant difference with the sample size (t=-6.143, p-value=0.000).Using independent sample t test, the results show that there is significant different in overall cultures ideas by gender, female is more agreed than male (t=-2.236, p-value=0.026).

Table 6: Students Perceptions about the relation between science and social and cultural values

Statement	**Mean**	**Standard deviation**	**Test**
Overall sample	3.70	0.84	One sample t test T = - 6.143 P-value = 0.000
Overall sample by gender	M = 3.58 F = 3.79	M = 0.81 F = 0.84	Independent sample t test T = - 2.236 P-value = 0.026

Discussion and Conclusion

The study indicates that elementary students had uninformed views of NOS aspects. This parallels findings reported in other international studies (BouJaoude, 2003; BouJaoude, Abd-El-Khalick& El-Hage, 2009; BouJaoude et al., 2011 Torres et al., 2015). Students possess inadequate understanding of the aspects of NOS. The results indicated a gender difference. Females are more agreed than males about scientific theory, tentativeness of scientific knowledge, and the influence of social and cultural values on scientific knowledge. However, there were a gender equity with regards to the subjectivity of scientific knowledge, empirical evidence of scientific knowledge, and the real life application of scientific knowledge. The experimentation that students were experiencing during science learning allowed them to understand the content and the processes of science. Both males and females were convinced that the empirical evidence obtained from observations has a direct impact on the formation of scientific knowledge.

The gender differences might be the result of different views of the role of science by girls and boys (Khishfe and BouJaoude, 2016). Elementary girls consider science as a live discipline which continuously develop based on new evidence obtained from collected data. For them, science concepts are established once observations and experiments are conducted. It seems that males and females share similar interests in discovering scientific topics through taking part in various activities that demonstrate the logical systems that regulate the natural phenomena of the real world they live in. Students across the elementary grade levels understand the practical implications of science topics in their daily life.

The findings of this study highlight the fact that better perceptions for future is required to enable students to envision the true value of learning science content. Students need to become scientifically literate (Sandoval, 2005; National Research Council, 2013) to be able to solve global issues. The development of scientific literacy skills can only be achieved if they possess adequate understanding of NOS aspects (Hwang, 2015; Ramnarain&Chanetsa, 2016; Leung et al., 2015). Acquisition of NOS understanding empowers students to be scientifically educated, to understand the role of science in their own societies and cultures, and to increase their ability to acquire science content material (Bloom, Binns& Koehler, 2015). Educators are calling for science reformation to develop appropriate understanding of NOS aspects (Fouad et al., 2015; Smith &Scharmon, 2008; Tala &Vesterinen, 2015; Wilcox & Lake, 2018; Cofré et al., 2018) and to enable citizens to be scientifically literate (Çil&Çepni, 2016; Leung, Wong & Yung, 2015; National Research Council, 2013; Sandoval & Morrison, 2003).

Another finding calls for the need to focus the attention of students on specific procedures to learn science and take decisions based on experimental choices. Such a recommendation is consistent with science education reforms that call for a holistic restructure for the science curricula and instructional approaches used in schools (Wilcox and Lake, 2018; McComas and Nouri, 2016; Ramnarian and Chanesta, 2016).

Based on the findings of this study, the following implications are suggested to develop an informed conceptions of NOS and to minimize the gender gap between females and males. First, there is a need to develop learning opportunities that allow students to understand the process and content of science. Second, there is an urgency to design experimentations and activities that are appealing for both genders to allow both, males and females, to develop their abilities and skill sets to become well-rounded global citizens.

The results of this study suggest that further research is required to better understand how elementary students develop their conceptions about NOS aspects in their classes and how the teaching pedagogies inform those conceptions. Moreover, a school wide study could provide better insights about students' conceptions to understand the development of the students' understanding in elementary, middle and high school phases

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