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University and High School Students' Perceptions of the Nature of Science: The Effect of Gender, Class, Specialty, and Reported Ability in Science

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Abstract: Students' ideas of the nature of science (NOS) influence their learning processes and understanding of science. This influence has attracted researchers' attention to this area for decades. What mainly differentiates the current study from previous studies is the comparison that it makes between ideas about NOS that university students hold vs. those held by high school students, in addition to comparisons between NOS ideas related to other background variables: gender, specialty, and scientific ability. The participants were 421 secondary and university students: 226 high school students and 195 university students. The students were asked to complete a questionnaire developed by McComas and Olson and which examines four aspects of NOS ideas: philosophical insights, sociological insights, psychological insights and historical statements and assumptions. Computing t-test and f-test values, we found significant differences between students' NOS ideas that could be attributed to the class in the philosophical and sociological insights, where university students had higher averages in NOS ideas than high school students. The current study also found significant differences between students' NOS ideas attributed to their specialty in three of the four aspects of the NOS: the philosophic, the psychological, and the sociological, whereas the difference was not significant in the historical aspect. Further, the results indicated a significant difference between students' NOS ideas that could be attributed to their reported ability in science in the philosophical aspect and the whole NOS ideas.

Keywords: Conceptions of Science, University Students, High School Students, Gender, Speciality, Class, Ability

Introduction

Associations for science education call for educational practices that focus on scientific literacy in general and on understanding the nature of science in particular (American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC], 1996; National Science Teachers Association [NSTA], 1993). This call for new and different educational practices came as a response to the poor results that students had in science and to students' misconceptions about scientific concepts and ideas. This situation also started a rich research that examined scientific literacy in the classrooms as well as students' ideas about the nature of science (NOS). This situation has not changed much in the past two decades, at least in developing countries. For example, Sarkar (2010) found that the majority of the teachers participating in the research held uninformed conceptions about most of the NOS aspects. Also, an inconsistent response pattern was revealed in teachers' responses to the aspects directly related to NOS. These findings of Sarkar (ibid) make it necessary to examine teachers' and students' ideas about NOS in different countries to find if the reported findings still prevail in the classrooms. Our study does this, but it takes into consideration two populations: high school students and university students, where both populations include science majors and non-science majors. This constitutes the uniqueness of the current study.

Literature Review

According to Parker et al. (2008), past research examined NOS ideas of in-service teachers and their students in order to understand how ideas about science are learned in schools, but more recently the majority of research focused on undergraduate students in pre-service teaching programs to understand how the undergraduate students will communicate the NOS ideas to the next generation of school students.

Less research has been done on school students' views of NOS ideas. One of the studies done in this field is that of Bektas, and Geban (2010) who found that Turkish high school students had some deficiencies related to these ideas, and they still held naive ideas about what scientific data is constituted of.

Regarding research which examined the NOS ideas held by undergraduate science majors, Bezzi (1999) found that undergraduate geography majors considered field-based disciplines to be less scientific than experimental or laboratory-based disciplines. Ryder and Leach (1999) found that students believe all claims in science can be proved or disproved empirically, while a minority of students pointed at creativity and imagination as important characteristics for scientists.

Parker et al. (2008) explored the NOS ideas of atmospheric science students and found that students had the following ideas: (1) Science is empirically based (with emphasis on proving, finding facts, or arriving at right or wrong answers); (2) experiments serve the role of testing or confirming scientific ideas; (3) a hierarchical relationship exists between laws and theories; and (4) creativity is an important aspect of science.

Some researchers attempted to examine the difference between NOS ideas held by undergraduate, graduate and faculty. For example, Mercan (2007) found that undergraduates expressed authoritative beliefs about knowledge more than graduate students, while faculty did not express authoritative beliefs. Further, faculty expressed modeling – based beliefs about knowledge more than graduate students, while undergraduates did not express such beliefs. Moreover, there were no differences in rational, empirical, experiential, relativistic, and religious beliefs about knowledge among the expertise level groups. As the expertise level increased the number of participants who expressed authoritative beliefs about knowledge decreased and the number of participants who expressed modeling - based beliefs about knowledge increased.

The study of Liu and Tsai (2008) examined the difference between NOS ideas held by science majors vs. other disciplines majors. They found that undergraduates' epistemological views of science did not differ significantly between science majors and non-science majors. In general, the sophistication of the two populations' views was equivalent; however, non-science majors' views were more sophisticated than science majors' views regarding theory-laden and culturally dependent aspects of science. The authors explained their findings by saying that science majors might be involved longer in an epistemic environment that emphasized scientific knowledge as objective and universal. The authors noted that science majors' beliefs about certainty and objectivity probably led them to select science as their major study. Another study which compared between NOS ideas of science majors to others is the study of Johnson and Pigliucci (2004) that compared between groups of science and non-science majors regarding: knowledge of science, knowledge of the conceptual foundations of science, and belief in a series of paranormal phenomena. The results showed that there were significant differences between science and non-science majors in their degree of factual knowledge of science (with science majors having more), however, there were essentially no differences (only one out of ten comparisons being statistically significant) between science majors and non-science majors in their understanding of the conceptual foundations of science. Moreover, there were no measurable differences between science majors and non-science majors in their degree of acceptance of a series of pseudoscientific claims. The authors concluded that there was little

evidence that better knowledge of scientific facts leads to better understanding of the nature of science, or to a lower degree of belief in the paranormal.

Dogan (2011) investigated science-math and literate-math high school students' views about the nature of science. The study findings showed that both groups of students had naive views about creativity and imagination, as well as about the social and cultural aspects of NOS, but compared to science-math students, the literature-math students seemed to be more informed about the following aspects of NOS ideas: tentativeness of scientific knowledge, arriving at scientific knowledge, differences in scientific knowledge and scientific opinion. The author explained these findings by the fact that the science curriculum contained many facts and formulas and as a result of the pressure on teachers to prepare students for the university entrance examination while also teaching the regular curriculum. This situation might have made the teachers not pay attention to the big ideas of science.

Regarding the difference of NOS ideas that could be attributed to gender, Conley et al. (2004) used self-report questionnaires administered in class to examine fifth grade students' NOS ideas. They found no significant difference of NOS ideas that could be attributed to gender. Other researches confirmed the previous findings, for example, Osborne (2003). On the other hand, some researchers found the opposite: gender influences students' ideas about NOS (for example, Kılıç, Sungur, Çakıroğlu & Tekkaya, 2005; Çelikdemir, 2006).

Researchers also tried to influence students' views on NOS by different interventions, for example Akerson, Abd-El-Khalick and Lederman (2000) examined the influence of a reflective, explicit, activity-based approach to the instruction of NOS in an elementary science methods course on pre-service teachers' views of some aspects of NOS: the empirical, tentative, subjective (theory-laden), imaginative and creative, and social and cultural NOS ideas. Two additional aspects were the distinction between observation and inference, and the functions of and relationship between scientific theories and laws. The study findings showed the effectiveness of explicit, reflective NOS instruction, where the authors concluded that such instruction might turn more effective when integrated within a conceptual change approach.

Further, Schwartz, Lederman and Crawford (2004) studied developments in NOS ideas during a science research internship course for pre-service secondary science teachers. Their findings indicated that most interns showed substantial development in NOS knowledge. The findings identified three factors as important for NOS development during the internship: (1) reflection, (2) context, and (3) perspective, where reflective practice during journal writing and seminars had the greatest impact on NOS ideas. In addition, the science research component provided a context for the pre-service teachers' reflection. Further, the perspective of the interns' role appeared to impact their abilities to effectively do the reflection. The study of Gess-Newsome (2002) supports the previous study findings that ideas about NOS could be changed. Gess-Newsome (ibid) found that explicit teaching methods for introducing elementary pre-service teachers to NOS ideas within the context of a science methods course were successful in facilitating a shift from defining science in terms of a body of knowledge or product to a conception that accurately blends scientific products and processes. In addition, students' definitions of science became more sophisticated and elaborated as a result of the course.

Research Rationale

Parker et al. (2008) say that little research has been done about the NOS ideas that students hold after they have chosen science as their undergraduate major. They elaborate that this is unfortunate because undergraduate science majors will have careers in science and will be communicating with the public about science in both formal and informal settings. It is the intention of this research to examine NOS ideas that university science majors have, but this research goes beyond that to differentiate between science students and find out if students' NOS

ideas differ among different science subjects (chemistry, physics, biology). We are also interested in NOS ideas that high school students hold, whether they are science majors or not.

Lederman (1998) stated that providing teachers with a functional understanding of the nature of science (NOS) and scientific inquiry (SI) is "prerequisite to any hope of achieving the vision of science teaching and learning specified in the various reform efforts" (p. 2). This research will contribute to our understanding regarding NOS ideas that high school and university students hold, and particularly help teachers have a clear picture of students NOS ideas, thus they can attempt to change the ideas which contradict the new approach to NOS. The focus on influencing positively students' NOS ideas will improve students' learning processes and the ways of their construction of knowledge in science (Huang, Tsai & Chang, 2005).

The Research Questions

Is there a significant difference between students' NOS ideas that could be attributed to gender?

Is there a significant difference between students' NOS ideas that could be attributed to class?

Is there a significant difference between students' NOS ideas that could be attributed to specialty?

Is there a significant difference between students' NOS ideas that could be attributed to reported ability in science?

The Research Hypotheses

We adopt the null hypotheses for the four research questions and want to verify these hypotheses using quantitative methodology.

Methodology

Researchers have used a number of methods to study conceptions about the NOS (Shah, 2009). These methods include: the use of critical incidents, open-ended questionnaires, multi-choice questionnaires, life history framework, and combination of interview and classroom observation. In the current research we used a multi-choice questionnaire for we wanted to examine NOS ideas in large samples of university and high school students.

Research Setting and Participants

The research was conducted in An-Najah National University in Nablus, Palestine, and in four high schools in Nablus. We chose the students to meet different conditions related to gender, class, specialty and ability level.

The participants were 421 secondary and university students: 160 male students and 261 female students. The university students were second year and third year students. Table 1 shows the distribution of the participants among the different classes.

Table 1: The Participants' Class

Class	Frequency	Percent
eleventh class	226	53.7
second year university	87	20.7
third year university	108	25.7
Total	421	100.0

The participants were from different specialties. Table 2 shows the distribution of the participants along specialty in the secondary school or university .

Table 2: The Participants' Specialty

Specialty	Frequency	Percent
Secondary scientific	118	28.0
Secondary humanistic	108	25.7
Chemistry	41	9.7
Physics	40	9.5
Biology	37	8.8
Education	77	18.3
Total	421	100.0

The participants had different abilities in science. Table 3 shows the distribution of the participants according to their reported ability in science.

Table 3: The Participant's Reported Ability Level

Ability level	Frequency	Percent
poor	5	1.2
middle	169	40.1
strong	247	58.7
Total	421	100.0

Data Collecting Tools

We used a multi-choice items questionnaire. This questionnaire has two parts. The first part collects background information about the participant: gender, class, specialty and ability level in science, while the second part collects data about the participant's nature of science ideas.

Regarding the second part, we used the questionnaire developed by McComas and Olson (1998) based ons a number of leading science education standard documents. In this questionnaire, NOS includes four aspects: philosophical insights, sociological insights, psychological insights and historical statements and assumptions. This questionnaire was used in the current research due to its coverage of important and overwhelming aspects of NOS ideas (McComas & Olson, ibid).

Validity of the Questionnaire

After translating the questionnaire items to Arabic we asked 2 university instructors and 3 high school teachers to judge the clarity of the translation, and as a result of their comments we changed the statements of 5 items .

Reliability of the Questionnaire

Computing alpha of Cronbach for the whole NOS questionnaire, we got the value 0.845 which is a good reliability value. Table 4 shows the reliability values of the four aspects of NOS.

Table 4: Reliability of the Different Aspects of the Nature of Science

The category	Cronbach's Alpha
The philosophical insights	0.770
The sociological insights	0.694
The psychological insights	0.674
The historical insights	0.634

All the values are acceptable reliability values, while the philosophical insights reliability is a good one.

Data Analysis Tools

We used SPSS 17 pckage to analyze the data collected from university and high school students. Doing so, we computed means, standard deviations, and ran t and F tests. We ran t and F tests to compare the averages of students' NOS and its aspects regarding the four independent variables of the study: gender, class, specialty and reported ability in science.

We also computed alpha of Chronbach to find the reliability of the whole questionnaire and its four categories: the philosophical NOS aspect, the sociological NOS aspect, the psychological NOS aspect and the historical NOS aspect.

Findings and Discussion

Table 5 gives a general picture regarding the participants' views on NOS ideas. It shows the means of the four aspects of the nature of science and the mean of the nature of science itself.

Table 5: Means and Standard Deviation

Aspect	Mean	Std. Deviation
Philosophical insights	3.92	0.36
sociological insights	4.22	0.48
psychological insights	3.95	0.68
historical insights	3.74	0.47
Nature of Science	3.94	0.33

We see from Table 5 that the participants had lower scores in the historical statements than in the other aspects of the nature of science. At the same time, they had the highest scores in the sociological insights. The lower scores in the history of science could be attributed to the little reference to science history in school science textbooks (Monk & Osborne, 1997). Integrating more history of science in the curriculum and thus in the science classroom would make students aware of this history, thus understand more deeply NOS ideas, and as a result improve their learning (Lin, Hung & Hung, 2002).

Tables 6-9 show the means of the four aspects across gender, class, specialty, ability level and achievement level.

Table 6 shows the means of the four aspects across gender, together with t values between the means of males and females, and the significance of these values.

Table 6: Means of the NOS aspects across gender

Aspect	Gender	Mean	t	sig
Philosophical insights	male	3.88	1.779	0.076
	female	3.95		
sociological insights	male	4.22	1.333	0.184
	female	4.29		
psychological insights	male	3.93	0.489	0.625
	female	3.97		
historical insights	male	3.73	0.507	0.613
	female	3.76		
Nature of Science	male	3.91	1.199	0.231
	female	3.96		

Table 6 shows that there is no significant differences at the level of 0.05 or less that could be attributed to gender. These findings agree with other findings regarding the insignificant difference between students' NOS ideas that could be attributed to gender (as in Conley et al., 2004 and Osborne, 2003), but they disagree with findings which showed significant difference between students' NOS ideas that could be attributed to gender (as in Kılıç et. al., 2005 and Çelikdemir, 2006). Our findings could be a result of parents' and teachers' modern perceptions of science as an endeavor appropriate equally for student males and student females.

Table 7 shows the means of the four NOS aspects across class, together with F values between the means of the different classes, and the significance of the F values.

Table 7: Means of the NOS Aspects Across Class

Aspect	Class	Mean	Std. Deviation	F	sig
Philosophical insights	eleventh class	3.87	0.41	5.17	0.006
	second year university	3.98	0.30		
	third year university	3.99	0.28		
sociological insights	eleventh class	4.2	0.52	4.28	0.014
	second year university	4.34	0.42		
	third year university	4.33	0.43		
psychological insights	eleventh class	3.9	0.76	1.79	0.169
	second year university	4.06	0.61		
	third year university	3.99	0.55		
historical insights	eleventh class	3.75	0.51	0.2	0.82
	second year university	3.74	0.42		
	third year university	3.72	0.44		
Nature of Science	eleventh class	3.9	0.38	3.04	0.049
	second year university	3.98	0.25		
	third year university	3.98	0.26		

Table 7 shows that there is a significant difference at the 0.01 level between students' NOS ideas that could be attributed to the class in the philosophical insights. In addition, there are significant differences at the 0.05 level between students' NOS ideas that could be attributed to the class in the sociological insights as well as the whole NOS ideas. The results regarding the significant differences in students' NOS ideas that could be attributed to the class agree with other researches' findings, for example Mercan (2007) found that undergraduates expressed authoritative beliefs about knowledge more than graduate students, while faculty did not express authoritative beliefs. In addition, Aisawi (1983) found that Egyptian university students believe in paranormal phenomena less than others. At the same time, some researchers found that the grade level had no significant relationship with students' NOS ideas (for example Yaman and Nuhoglu, 2010).

The insignificant relationship in students' NOS ideas in the historical aspect could be explained by the little integration of history in science textbook in the different grade levels. The insignificant relationship in students' NOS ideas in the psychological aspect could point that science textbooks or teachers do not emphasize the importance of being open to new ideas, being creative, or intellectually honest (three of four items in the psychological aspect). The absence of emphasis on new ideas for example explains why "new ideas in science are often received with a degree of skepticism, especially if they are contrary to well-established scientific concepts" (Bell, 2009, p. 2).

Table 8 shows the means of the four aspects across specialty, together with F values between the means of the different specialties, and the significance of these values.

Table 8: Means of the NOS aspects across specialty

Aspect	Specialty	Mean	Std. Deviation	F	sig
Philosophical insights	secondary scientific	3.86	0.37	3.196	0.008
	secondary humanistic	3.88	0.45		
	chemistry	4.03	0.30		
	physics	4.03	0.32		
	biology	3.98	0.31		
	education	3.92	0.24		
sociological insights	secondary scientific	4.21	0.55	2.330	0.042
	secondary humanistic	4.18	0.50		
	chemistry	4.39	0.42		
	physics	4.41	0.45		
	biology	4.32	0.41		
	education	4.27	0.41		
psychological insights	secondary scientific	3.78	0.79	3.509	0.004
	secondary humanistic	4.03	0.71		
	chemistry	4.02	0.41		
	physics	4.24	0.62		
	biology	3.96	0.61		
	education	3.92	0.60		
historical insights	secondary scientific	3.71	0.48	1.270	0.276
	secondary humanistic	3.80	0.54		
	chemistry	3.63	0.37		
	physics	3.80	0.45		
	biology	3.82	0.46		
	education	3.71	0.42		
Nature of Science	secondary scientific	3.88	0.35	2.422	0.035
	secondary humanistic	3.92	0.41		
	chemistry	3.99	0.24		
	physics	4.08	0.25		
	biology	4	0.28		
	education	3.93	0.24		

Table 8 shows that there is significant difference at the 0.01 level between students' NOS ideas that could be attributed to their specialty in the philosophical as well as in the psychological insights. In addition, there are significant differences at the 0.05 level between students' NOS ideas that could be attributed to students' specialty in the sociological insights as well as the whole NOS ideas. These results agree with some earlier researcher regarding the influence of specialty on the NOS ideas. Chen (2001) for example found that pre-service teachers specializing in different science disciplines varied in their views regarding NOS and the teaching of NOS ideas. In addition, Aisawi (1983) found that students majoring in humanistic subjects believed paranormal phenomena more than students majoring in scientific subjects. The research results do not agree with other researches' findings that there are no significant differences between students' NOS ideas that could be attributed to specialty (for example, Karakas, 2008). Our results could be explained by the positive influence of deeper understanding of science on the ideas held about NOS. They also can indicate to science teachers how to lead their students to more elaborated ideas about NOS.

The participants did not have significant difference in the historical aspect of NOS which could be attributed to specialty. Here too, it seems that this insignificant difference exits because of little the involvement with the history of science of science textbooks for science majors or non-science majors.

Table 9 shows the means of the four aspects across reported ability level, together with F values between the means of poor, middle and strong abilities, and the significance of these values.

Table 9: Means of the NOS Aspects Across Ability Level

Aspects	Ability level	Mean	Std. Deviation	F	sig
Philosophical insights	poor	3.57	4	5.561	0.004
	middle	3.87	0.38		
	strong	3.96	0.34		
sociological insights	poor	3.89	0.44	2.429	0.089
	middle	4.23	0.48		
	strong	4.30	0.48		
psychological insights	poor	3.85	0.78	0.260	0.771
	middle	3.98	0.63		
	strong	3.94	0.72		
historical insights	poor	3.63	0.43	0.673	0.511
	middle	3.71	0.48		
	strong	3.76	0.46		
Nature of Science	poor	3.67	0.37	3.251	0.040
	middle	3.91	0.33		
	strong	3.97	0.32		

Table 9 shows that there is difference at the 0.01 level between students' NOS ideas that could be attributed to the reported ability in science in the philosophical insights. In addition, there are differences at the 0.05 level between students' NOS ideas that could be attributed to students' ability in the whole NOS ideas. The significant difference in students' NOS ideas attributed to students' ability is reported also in Aisawi (1983) who found that the academically outstanding students' believe in paranormal phenomena less than other students. Some of the differences found in this research are not significant at the statistical level of 0.05 or less (the sociological insights, the psychological insights, and the historical insights). The insignificance of differences could be attributed to the same way of teaching which is used in the whole classroom, so students of different abilities learn in the same way, and thus these students would not have significant differences in NOS ideas (here in three of the four aspects of NOS).

Conclusions and Recommendations

Possessing accurate views about NOS and scientific knowledge is believed to contribute to one's scientific literacy. In this research we wanted to examine students' NOS ideas in various populations, and to examine the relationships between students' NOS ideas in different populations. We found that that the participants had lower scores in the historical statements than in the other aspects of the nature of science. This implies that textbooks' writers should integrate science history in science books as an educational motive to deepen students' learning. Further, teachers should refer to this history in the science classrooms, which would help students pay more attention to big NOS ideas. Our findings showed no significant differences that could be attributed to gender, which is a good sign that implies that science education probably does not still suffer from a long injustice regarding the female students as science learners.

The findings showed significant difference between students' NOS ideas that could be attributed to the class in the philosophical and sociological insights, where university students had higher averages in NOS ideas than high school student. It is recommended to examine the differences of science teaching and science learning in the university and school to discover the differences between teachers' methods and students' learning methods in the university and the schools. We can use the findings to enrich and complement school science teachers' methods and students learning methods of science .

The research also found that there was significant difference between students' NOS ideas that could be attributed to their specialty in three of the four aspects of the NOS (the philosophic, the psychological, and the sociological), whereas the difference was not significant in the historical aspect .

The results indicated significant difference between students' NOS ideas that could be attributed to the reported ability in science in the philosophical aspect and the whole NOS ideas. The insignificance of the other NOS aspects implies that we can change positively the NOS ideas of students of various ability levels, which can be done by emphasizing the NOS ideas in the science classes.

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