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Using Video Vignettes of Historical Episodes for Promoting Pre-service Teachers' Ideas about the Nature of Science

GULTEKIN CAKMAKCI*†

ABSTRACT: This study used video vignettes of historical episodes from documentary films as a context and instructional tool to promote pre-service science teachers' (PSTs) conceptions of the nature of science (NOS). The participants received explicit-reflective NOS instruction, and were introduced to techniques to be able to use scenes from documentary films to illustrate and discuss scientific concepts, principles, processes and ideas about science. In addition, the participants were asked to critically evaluate a documentary film, select scenes from the film to illustrate and discuss ideas about science and its nature, make a presentation to their peers, and afterwards write a reflective report about their classroom teaching. A modified version of the *Views on Science-Technology-Society* (VOSTS) questionnaire was used to assess PSTs' ideas about NOS. The results indicated that compared to their ideas at the beginning of the course, many PSTs developed informed ideas about NOS during the course. Nonetheless, the instruction was not equally effective in all aspects of NOS.

KEY WORDS: Nature of science, situated cognition, documentary film, effects of media on science learning, science communication.

INTRODUCTION

This study discusses the examples of using documentary films in science teaching to promote PSTs' ideas about NOS, as well as the effectiveness of and how to integrate video vignettes into the science curriculum. Understanding the nature of science (NOS) as a part of scientific literacy is an important feature in the public engagement with science and technology (Driver Leach, Millar & Scott, 1996; Millar, 2006). The phrase, the nature of science, usually refers to "the epistemology and sociology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development" (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002, p.498). It is, however, interpreted in different ways by researchers in different disciplines (e.g. Allchin, 2011; Yalaki & Cakmakci, 2010). The researcher's position on

* Corresponding Author: cakmakci@hacettepe.edu.tr
†Hacettepe University, Faculty of Education, TURKEY

NOS, which serves as a theoretical framework for the present study, is discussed in the methodology section of this paper and further elaborated in the results section. One approach to NOS instruction is via explicit-reflective approaches (Abd-El-Khalick, 2005; Akerson, Abd-El-Khalick & Lederman, 2000) through a pedagogical framework in the context of documentary films. This facilitates discussion on aspects of NOS within science content and historical episodes (Irwin, 2000).

REVIEW OF RELEVANT LITERATURE

Documentary films usually present the context of a discovery in its social context, rather than only interpreting the past event in terms of presenting ideas and values. This humanistic approach in science education attracts more students to science and facilitates the learning of science (Stinner, 1995). Accordingly, some researchers have used movies (Seckin Kapucu, Cakmakci, & Aydogdu, 2015; Aduríz-Bravo & Izquierdo-Aymerich, 2009; Hadzigeorgiou & Garganourakis, 2010; Hadzigeorgiou, Kodakos & Garganourakis, 2010; Park & Lamb 1992), science fiction films (Dark, 2005; Dennis, 2002; Efthimiou & Llewellyn, 2006, 2007; Freudenrich, 2000; Rose, 2003; Smith, 2009) and animated movies (Barak & Dori, 2011; Barak, Ashkar & Dori, 2011) to address the relevance of science to students. For example, Efthimiou and Llewellyn (2006) designed *a Physics in Film* course to provide undergraduate students with an engaging introduction to the physical sciences as well as to complement and support their understanding of scientific concepts. The results showed that using scenes from popular films (e.g. *Contact*, 1997) to illustrate scientific concepts, positively influenced students' interest in science and also improved their performance (Efthimiou & Llewellyn, 2006).

Several curriculum reform initiatives have aimed at humanizing science education by taking into account the human element of science (Donnelly, 2004; Millar, 2006). Presenting human aspects of science through popular media can facilitate students' individual interest in science (Krap, 2002) and help them to appreciate science as a human activity (Matthews, 2009). Exposing students to not only scientists' research, but also their life experiences and everyday lives, can promote appropriate and realistic images of science and scientists among students (Cakmakci et al., 2011; Eshach, 2009). Research also shows that interest-driven activities can improve students' understanding in science (Barak et al., 2011; Krapp, 2002; Piliouras, Siakas & Seroglou, 2011).

It is noteworthy that several textbooks present science as a final form or product (Duschl, 1994) and neglect methodological and interpretative components of the epistemology of science (Monk & Osborne, 1997). Science is a process and students have difficulties in understanding this process through traditional instructional methods. However, some media such as movies and animations provide more engaging and thought-provoking entertainment than the traditional teaching environment can offer. Such mediums (e.g. case studies of authentic science from documentary films) create opportunities to interpret the past in terms of economical, political and social contexts and the contingent factors in its production. These mediums are well suited for engaging learners in the process of science (Bell et al., 2009).

Influenced by previous studies (e.g. Aduríz-Bravo & Izquierdo-Aymerich, 2009; Dark, 2005; Dennis, 2002; Efthimiou & Llewellyn, 2006, 2007; Rose, 2003; Smith, 2009), this study investigates how scenes from documentary films (video vignettes) could lead to the improvements of PSTs' ideas about NOS. Video vignettes are excerpts selected from movies (Park & Lamb, 1992) and their length may vary (e.g. from 1 minute to 10-15 minutes). The preference for using documentary films as an instructional tool is compared to science fiction films. Documentary films are less likely to have scenes that contain scientifically incorrect information or concepts. There are several scientifically flawed movies and documentaries; however, students may not have the capacity to notice (Allday, 2003). Although science fiction films can be a good way of enhancing students' interest in science, without explicit teaching and discussing some of the information presented in them, this may lead to students' misunderstanding scientific concepts (Allday, 2003).

RESEARCH QUESTION

Reflecting upon previous research, this study aims to explore the influence of a course, which uses video vignettes of historical episodes as a context to address aspects of NOS with integration of an explicit-reflective NOS instruction on PSTs' NOS views. Accordingly, the present study addresses the following research question:

1. How effective is the use of video vignettes of historical episodes on PSTs' conceptions of NOS?

METHODOLOGY

Data Collection and Instruments

A modified version of the *Views on Science-Technology-Society* (VOSTS) questionnaire was used to assess PSTs' ideas about NOS. Data sources included PSTs' responses to written questions. The VOSTS (Form CDN.mc.5) questionnaire was originally developed by Aikenhead and his colleagues (Aikenhead, Ryan & Fleming, 1989; Aikenhead & Ryan, 1992) and has been used by other researchers (e.g. Botton & Brown, 1998). Dogan and Abd-El-Khalick (2008) employed a modified version of VOSTS to assess Turkish secondary school students' and teachers' views about NOS. For this study, 14 modified VOSTS items were used, which were validated and tested in the Turkish context (Dogan & Abd-El-Khalick, 2008). The following twelve NOS aspects were targeted in these modified VOSTS items and served as the theoretical framework for the study:

NOS-1: The theory-driven nature of observations (item 90111);
NOS-2: Tentative nature of scientific knowledge (item 90411);
NOS-3: Precision and uncertainty in scientific knowledge - probabilistic reasoning (item 90711):
NOS-4: Coherence of concepts across disciplines (item 91111);
NOS-5: Relationship between scientific models and reality (item 90211);
NOS-6: Relationship between classification schemes and reality (item 90311);
NOS-7: Relationships between hypotheses, theories and laws (item 90511);
NOS-8: Epistemological statues of hypotheses, theories and laws- "Inventions" vs. "discovery" (items 91011, 91012, and 91013);
NOS-9: Assumptions underlying theories and laws (item 90521);
NOS-10: Nature of scientific theories (simple vs. complex) (item 90541);
NOS-11: Rejection of step-wise procedures - myth of the "scientific method" (item 90621);
NOS-12: Nonlinearity of scientific investigations- the role of error (item 90651).

The VOSTS questionnaire was administered to 34 PSTs at the beginning and 39 at the end of the course.

Context and Instructional Strategies

A NoSHoS course, taught by the author, occupied 14 weeks (three-hour blocks per week). The course aimed to help PSTs:

(a) to contextualize the target aspects of NOS,

(b) to encounter scientific concepts, principles, processes and characteristics of scientific knowledge within narratives in documentary films,

(c) to analyse a documentary film, select scenes from the film to illustrate, discuss scientific concepts and aspects of NOS and make a presentation to their peers in the classroom, and

(d) to write a reflective report about their classroom teaching.

The instruction included these four crucial parts (hereafter called strategies a-d), which complement each other in the teaching of NOS.

Course operation

During the first two weeks of the course, participants were shown a documentary film called *Einstein's Big Idea* (Johnstone, 2005). The film was divided into 5 parts (i-v). In each part, relevant scientists as well as their contributions to science and ideas about NOS were discussed. These scientists were:

(i) Michael Faraday, James Clerk Maxwell,
(ii) Antoine-Laurent and Marie Anne Lavoisier,
(iii) Emilie du Châtelet,
(iv) Albert Einstein,
(v) Otto Hahn, Lise Meitner and Otto Robert Frisch.

During the activity, the instructor encouraged PSTs to raise questions related to the documentary film and to use these questions to develop scientific ideas or ideas about NOS. The instructor assigned PSTs a task for the coming weeks. The task was finding a documentary film, selecting scenes from it, presenting them in the classroom and writing a reflective report about their classroom teaching. PSTs were asked to work on the task in groups of 4-6. PSTs formed their own groups and they were guided to consult with the instructor about their documentary films and agenda. The documentary films chosen to address aspects of NOS are presented in Table 1.

Some researchers (e.g. Hanuscin, Lee & Akerson, 2011) have expressed a demand for courses and curriculum materials that focus on developing teachers' pedagogical content knowledge for NOS. Accordingly, PSTs, in groups of 4-6, were asked to analyse a documentary film, select scenes from the film to illustrate and discuss ideas about science as well as its nature, and make a presentation to their peers in the classroom. One of the aims of this activity was to improve PSTs' pedagogical content knowledge with regard to NOS. The documentary films were chosen by the participants. The choices probably reflected the interests and aspirations of the PSTs. Each group of PSTs presented their work in a class hour. The PSTs selected short video vignettes (usually around 25-30 minutes in total) from a documentary film as the basis for discussions and for addressing ideas about NOS. Most PSTs knew how to extract usable scenes from the documentary films. For those who did not know this, technical support was provided. Several free video-editing software packages were used. During their classroom presentations, PSTs usually showed 4-6 short video vignettes. After showing each part, the presenters asked their peers questions to provoke discussion: "If you were presenting this part of the documentary, what aspects of science and NOS would you discuss and how?" In some cases, a discussion was held both before and after the video vignette. For example, before a video vignette was shown, participants were asked to make a comment on the issues presented in Figure 1. Then, the video vignette (related to the issues discussed) was shown. The written synopsis of the video is presented in Table 2 to provide basic ideas about what happened on during teaching. Afterwards, the participants were asked again about their views on the same issues as presented in Figure 1. In other words, cases related to the target aspects of NOS and scientific concepts were shown and discussed within the context of the documentary film. The aim of this activity was to encourage the participants to reflect on several aspects of NOS in different historical episodes. The presentation was mostly interactive between the presenters and audience: PSTs were encouraged to address all questions and comments arising throughout their presentation. After the presentation (in the following class hours), the presenters' pedagogical content knowledge for NOS was also discussed and the audience was encouraged to provide feedback and state the strongest aspects, as well as areas for improvement of that presentation, and to make suggestions constructively. The aim was to empower PSTs to teach in a way that fosters students' understanding about NOS.

It should be emphasised that in some cases video vignettes were used to introduce or develop some science concepts as well as conceptions of NOS. For instance, a video vignette was shown to the participants to introduce Kepler's three laws of planetary motion that describes and makes predictive inferences about planets' motion (see Table 2).

Supervision meetings: The participants had supervision meetings while preparing their video vignettes, presentations and written report. Each group had two compulsory meetings.

Table 1. Documentary films chosen by PSTs to address scientific concepts and aspects of NOS

Group (number of PSTs)	**Visual Media/Film**	**Targeted aspects of NOS**	**Targeted aspects of scientific concepts/ideas**	**Title of the written report**
A(5)	Andorfer, G. and McCain, R. (Producers), and Malone, A. (Director). (1980) *Cosmos: A Personal Voyage. Episode 3: The Harmony of the Worlds* [DVD]. USA: PBS	NOS-1-7-8-9-10	Kepler's three laws of planetary motion.	Johannes Kepler and the relationships between theory and law
B(5)	BBC Earth (Producer), Attenborough, D. (Director). (2009). *Charles Darwin and the Tree of Life* [DVD]. UK: BBC Warner.	N0S-2-4-6-7-8-10	Darwin's theory of evolution: natural selection, adaptation and mutation.	Under the lens of nature of science; Charles Darwin and the theory of evolution
C(5)	Devine, D. (Producer and Director). (2000). *Galileo: On the shoulder of giants* [DVD]. USA: Devine Entertainment.	NOS-2-3-5-6-11-12	The notion of free fall: When objects fall towards the Earth their acceleration is independent of the object's mass.	Teaching nature of science through the documentary film "Galileo Galilei"
D(5)	MGM (Producer), and Lewin, A. Tourneur, J. and LeRoy, M. (Directors). (1943). *Madame Curie.* [DVD]. USA: Warner Home Video.	NOS-6-11-12	Radioactivity, the radioactive half-life of the substance	For teaching nature of science: Madame Curie documentary
E(4)	Lambert, T. and Harrison, C. (Producer and Director). (2005). *Guns, Germs and Steel* [DVD]. USA: National Geographic & PBS.	N0S-1-3-4	Immune system, viruses and bacteria, differences between vaccine and serous fluid	Nature of science with the documentary of Guns, Germs and Steel
F(5)	Uth, R. (Producer), and Stefanovic-Ravasi, S. (Director) (2000). *Tesla: Master of Lightning* [DVD]. USA: PBS Home Video.	NOS-5-11-12	The process of conversion of electrical energy into mechanical energy and vice versa*, direct current (DC), alternating current (AC), showing differences between AC and DC in experiments. (Some exemplar lessons plans for teachers are available at: http://www.pbs.org/tesla/tt/index.html)	Nature of science with the use of visual media: Nikola Tesla
G(5)	Marconi, L. (Producer and Director) (2009). *Mystery Files: Leonardo Da Vinci* [TV, National Geographic]. UK: Parthenon Entertainment Ltd.	NOS-4-5-11-12	Air pressure, golden ratio (mathematics)	Leonardo da Vinci
H(5)	Martin, K.D. (Producer), and Rich, R. (Director). (1995). *The Animated Hero Classics: Louis Pasteur* [DVD]. USA: Nest Family Entertainment.	NOS-1-2-10-11	The germ theory, the notion of vaccination and immunisation, and fair testing.	Teaching nature of science through visual media on the studies of Louis Pasteur.

Table 2. Introductory narrative of a video vignette (in total 4 minutes 69 seconds)

Source: Andorfer, G. & McCain, R. (Producers) & Malone, A. (Director). (1980) *Cosmos: A Personal Voyage. Episode 3: The Harmony of the Worlds* [DVD]. USA: PBS	
Time frame: 00:45:52,197 - 00:50:21,199	… He tried various oval-like curves, calculated away...made some arithmetical mistakes, which caused him to reject the correct answer. Months later, in some desperation, he tried the formula for the first time for an ellipse. The ellipse matched the observations of Tycho beautifully. In such an orbit, the sun isn't at the centre. It is offset. It's at one focus of the ellipse. When a given planet is at the far point in its orbit from the sun, it goes more slowly. As it approaches the near point, it speeds up. Such motion is why we describe the planets as forever falling towards the sun, but never reaching it. **Kepler's first law of planetary motion is simply this: A planet moves in an ellipse with the sun at one focus [emphasis added].** As a planet moves along its orbit, it sweeps out in a given period of time, an imaginary wedge-shaped area. When the planet's far from the sun, the area's long and thin. When the planet is close to the sun, the area is short and squat. Though the shapes of the wedges are different, Kepler found that their areas are exactly the same. This provided a precise description of how a planet changes its speed in relation to its distance from the sun. Now, for the first time astronomers could predict where a planet would be in accordance with a simple and invariable law. **Kepler's second law is this: A planet sweeps out equal areas in equal times [emphasis added].** Kepler's first two laws of planetary motion may seem a little remote and abstract. Planets move in ellipses and they sweep out equal areas in equal times. So what? It's not as easy to grasp as circular motion. We might have a tendency to dismiss it to say it's a mere mathematical tinkering; something removed from everyday life. But these are the laws our planet itself obeys. As we, glued by gravity to the surface of the Earth, hurtle through space, we move in accord with laws of nature, which Kepler first discovered. When we send spacecraft to the planets, when we observe double stars, when we examine the motion of distant galaxies, we find that all over the universe, Kepler's laws are obeyed. Many years later, Kepler came upon his third and last law of planetary motion. A law, which relates the motion of the various planets to each other, which lays out correctly the clockwork of the solar system. He discovered a mathematical relationship between the size of a planet's orbit and the average speed at which it travels around the sun. This confirmed his long-held belief that there must be a force in the sun that drives the planets. A force stronger for the inner, fast-moving planets and weaker for the outer, slow-moving planets. Isaac Newton later identified that force as gravity. Answering at last the fundamental question: What makes the planets go? **Kepler's third or Harmonic Law states that the squares of the periods of the planets - the time for them to make one orbit (T) are proportional to the cubes - the third power - of their average distances from the sun (A). $[(T_1/T_2)^2 = (A_1/A_2)^3]$. [emphasis added].** So the further away a planet is from the sun, the slower it moves but according to a precise mathematical law. Kepler was the first person in the history of the human species to understand correctly and quantitatively how the planets move, how the solar system works. The man who sought harmony in the cosmos was fated to live at a time of exceptional discord on Earth.

Writing a reflective report: After completing their classroom presentation, PSTs were asked to write a report on their classroom teaching by the end of the semester. PSTs were asked to be reflective about their teaching through analysing their experiences, defining any problems they encountered during their teaching and making suggestion on the use of visual media in science teaching.

What is novel in this study is that video vignettes were not only used by the instructor, but also by the PSTs. The intention was to enhance PSTs' pedagogical content knowledge and to empower them to teach in ways that foster students' understanding about NOS. However, the effect of the course on participants' pedagogical content knowledge of NOS is not the focus of this paper.

Figure 1. Same questions raised in the classroom both before and after the video vignette.

FINDINGS AND DISCUSSION

Changes of Participants' Views of NOS

A chi-square test was used to compare the percentages of participants' "naïve", "has merit" and "informed" views from pre- to post-instruction testing on each NOS aspect (see Table 3). The researcher first separated the cases with *df*=1. Thus, these cases were tested using a Chi-squared test with two categories (naïve and informed views). Even though there were cases with an observed cell value less than 5, the calculations on the expected cell values did not reveal any assumption violation due to cell size (McHugh, 2013). There were, in total, 5 cases with an observed cell frequency lower than 5; namely, 90651, 90621, 90541, 91013 and 90411 (see Table 3). However, the chi-square test assumes that at least 80% of the expected values should not be lower than 5 and each expected value should be larger than 1 (McHugh, 2013). The expected cell values for these cases (90411 naïve post-test cell's expected value = 7.2; 91013 has-merit pre-test cell's expected value = 12.8; 90541 has merit post-test cell's expected value = 5.9; 90621 naïve post-test cell's expected value = 22.05; 90651 informed post-test cell's expected value = 3.5) were calculated. The results suggested that the assumption of chi-squared test related to expected cell values were not violated.

NOS-1-The theory-driven nature of observations (item 90111)

It is often assumed that science is objective; however, scientists are people who view the world through theoretical lenses created by prior knowledge and experience. Scientists' disciplinary training and educational backgrounds, personal experiences and values, social commitments, preferences, opinions, and basic guiding assumptions, as well as other human elements, influence the ways in which scientists interpret any (empirical) evidence, as well as generate and support scientific claims (Abd-El-Khalick & Lederman, 2000). Therefore, scientific knowledge is subjective and/or theory-laden, in that theories strongly influence how science is done and how the data is interpreted. Our results showed that prior to the instruction, about 41% and at the end, about 13% of the PSTs held naïve views of the theory-driven nature of observations. When a chi-square test was calculated to compare the percentage of PSTs' naive, has merit and informed views from pre- to post-instruction for the theory-laden nature of scientific knowledge, it revealed statistically significant changes from pre- to post-instruction in participants' views (χ^2=8.49, n=73, *df*=2, $p<0.05$) (see Table 3). By comparison, at the beginning, about 27% and at the end of the study, about 51% of PSTs ascribed "informed" views to themselves about the theory-driven nature of observations. These participants might believe "scientific observations made by competent scientists will usually be different if the scientists believe different theories" (Aikenhead et al., 1989). That may happen "because scientists will think differently and this will alter their observations" (B). In addition, at the beginning of the study 32% of the PSTs and at the end of the study about 36% of PSTs claimed, "scientists will experiment in different ways and will notice different things" (A).

NOS-2-Tentative nature of scientific knowledge (item 90411)

Although scientific knowledge including "facts," "theories," and "laws" is reliable and durable, it is never absolute and totally certain (Abd-El-Khalick & Lederman 2000). Scientific knowledge is tentative. The results showed that the majority of the PSTs held informed views of the tentative NOS. Although PSTs' informed views on the tentative NOS increased from pre- (88%) to post-instruction (97%), no statistically significant changes were identified from pre- to post-instruction in their views (χ^2=2.41, n=73, *df*=1, p=0.121). It is believed that scientific knowledge is subject to change in light of new evidence or reinterpretation of present evidence (Abd-El-Khalick & Lederman, 2000; Ryan & Aikenhead, 1992). Nevertheless, before the instruction about 12% and after the instruction 3% of the PSTs believed that "correctly done experiments yield unchangeable facts" (C) or they believed that "new knowledge is added to old knowledge; the old knowledge doesn't change" (D).

NOS-3-Precision and uncertainty in scientific knowledge - probabilistic reasoning (item 90711)

Scientific knowledge is based on and/or derived from observations of the natural world. When making predictions based on scientific knowledge, we can only tell what will probably happen. We cannot tell what will happen for certain, because scientific knowledge changes as new discoveries are made or the current evidence is interpreted with a different theoretical framework. Therefore, predictions are likely to change and are not totally infallible due to the limitations of data and theoretical bases.

According to the present research, there was no statistically significant change identified from pre- to post instruction in participants' views of probabilistic reasoning (χ^2=0.75, n=73, df=2, p=0.685). At the beginning of the study, 35% and at the conclusion of the study, 28% of the PSTs had naïve views on the role of probabilistic reasoning in scientific investigation (C and E). Before the instruction about 9% and after the instruction 15% of the PSTs had "merit views" on the role of probabilistic reasoning in scientific investigation (D). PSTs' informed views about the probabilistic reasoning were 59% before and 56% after the instruction (A-B).

NOS-4-Coherence of concepts across disciplines (item 91111)

Scientists in different fields may interpret the same thing or data differently. For example, H+ may causes chemists to think of acidity and physicists to think of protons (Aikenhead et al., 1989). Furthermore, while some physicists and geologists claim that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction of dinosaurs (the asteroid-impact theory), some palaeontologists believe that massive and violent volcanic eruptions were responsible for the extinction of dinosaurs (the volcanic theory) (Lederman et al., 2002; Mason, 2001).

A chi-square analysis indicated a statistically significant change from pre- to post-instruction in participants' views about coherence of concepts across disciplines (χ^2=16.09, n=73, df=2, p<0.001). 56% of the PSTs at the beginning, and 23% of the PSTs at the end of the study had naïve views about the coherence of concepts across disciplines (C-E). However, before the instruction 18% and after the instruction 64% of the participants believed that "it is difficult for scientists in different fields to understand each other because scientific ideas depend on the scientist's viewpoint or on what the scientist is used to" (A).

Indeed, the number of students agreeing "scientists must make an effort to understand the language of other fields that overlap with their own field" (B) dropped from 27% before the instruction to 13% afterward.

NOS-5-Relationship between scientific models and reality (item 90211)

Scientific models (e.g., the model of atom, DNA model) are not copies of reality. Rather, these models are theoretical entities used to explain natural phenomena. Before the instruction 47% and after the instruction 33% of the PSTs believed that "models are copies of reality" (A-C) or "come close to being copies of reality" (D) or that "scientific models are NOT copies of reality because these models must be ideas or educated guesses, since we can't actually see the real thing" (G). Although there was no statistically significant change in participant views from pre- to post-test (χ^2=1.43, n=73, *df*=1, *p*=0.232), their informed views on the relationship between scientific models and reality (E-F) increased from pre- (53%) to post-instruction (67%).

NOS-6-Relationship between classification schemes and reality (item 90311)

Classification is an important aspect of science. For example, Dimitri Ivanovich Mendeleev (1834-1907) classified chemical elements and proposed the periodic law. Mendeleev arranged the elements in order of increasing relative atomic mass and his periodic law stated "the properties of the elements are a periodic function of their relative atomic masses". Mendeleev contributed to science much more than mere classification; he used his classification scheme (periodic table) to predict the existence of as-yet-undiscovered elements and predicted their properties.

The present study showed that most of the participants had informed views toward the classification schemes and reality; however, there was no statistically significant change in participant views from pre- to post-test (χ^2=1.06, n=73, *df*=1, *p*=0.303). Before the instruction 12% and after the instruction 5% of the PSTs had a naïve realism viewpoint (i.e. "classifications match the way nature really is") on the classification schemes and reality (A-B). The participants' informed views changed from pre- (88%) to post-instruction (95%) when they considered the human inventive character of scientific classification schemes (C-F).

Table 3. Percentage of participants with naïve, has merit and informed views of NOS and summary of a chi-square test (χ^2)

VOSTS item		Percentage of participants in the category									
		Naïve		Has merit		Informed		χ^2test			
No#	**Focus**	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	χ^2	*df*	N	*p*
90111	The theory-driven nature of observations	41.2	12.8	32.4	35.9	26.5	51.3	8.49	2	73	0.014*
90411	Tentative nature of scientific knowledge	11.8	2.6	0.0	0.0	88.2	97.4	2.41	1	73	0.121
90711	Precision and uncertainty in scientific knowledge - probabilistic reasoning	32.4	28.2	8.8	15.4	58.8	56.4	0.756	2	73	0.685
91111	Coherence of concepts across disciplines	55.9	23.1	17.6	64.1	26.5	12.8	16.09	2	73	0.000**
90211	Relationship between scientific models and reality	47.1	33.3	0.0	0.0	52.9	66.7	1.43	1	73	0.232
90311	Relationship between classification schemes and reality	11.8	5.1	0.0	0.0	88.2	94.9	1.06	1	73	0.303
90511	Relationships between hypotheses, theories and laws	61.8	7.7	0.0	0.0	38.2	92.3	24.06	1	73	0.000**
91011	Epistemological statues of laws: "Inventions" vs. "discovery"	55.9	76.9	0.0	0.0	44.1	23.1	3.64	1	73	0.056
91012	Epistemological statues of hypotheses: "Inventions" vs. "discovery"	50.0	43.6	26.5	46.2	23.5	10.3	4.01	2	73	0.135
91013	Epistemological statues of theories: "Inventions" vs. "discovery"	50.0	30.8	0.0	25.6	50.0	43.6	10.56	2	73	0.005**
90521	Assumptions underlying theories and laws	52.9	69.2	0.0	0.0	47.1	30.8	2.03	1	73	0.153
90541	Nature of scientific theories (simple vs. complex)	76.5	69.2	11.8	0.0	11.8	30.8	7.71	2	73	0.021*
90621	Rejection of step-wise procedures: Myth of the "scientific method"	44.1	0.0	50.0	59.0	5.9	41.0	26.57	2	73	0.000**
90651	Nonlinearity of scientific investigations: the role of error	23.5	25.6	70.6	74.4	5.9	1.1	2.36	2	73	0.307

Notes: Chi-square test (χ^2) compares the percentages of participants' views from pre- to post-instruction. * Significant at $p<0.05$, ** Significant at $p<0.001$.
The reference number to the VOSTS item corresponds to those in the complete VOSTS questionnaire (Aikenhead et al., 1989)

NOS-7-Relationships between hypotheses, theories and laws (item 90511)

Scientific theories and laws represent different kinds of knowledge and serve different functions. Therefore, one does not become the other. Generally speaking, theories propose underlying processes that result in the observations we have made and are inferred explanations for observable phenomena, whereas laws are general descriptions of the relationships among observable phenomena (Lederman & Abd-El-Khalick, 1998). A hypothesis is a tentative description of the relationship between a set of observable phenomena and inferred explanation for those phenomena and it guides investigations. With supporting evidence, a hypothesis, or set of hypotheses, may develop a theory or a law.

A chi-square analysis indicated statistically significant changes from pre- to post-instruction in participants' views on the relationships between hypotheses, theories and laws (χ^2=24.06, n=73, *df*=1, *p*<0.001). Before the instruction around two-third of the PSTs compared to after the instruction only 8% of the PSTs had naïve views on this aspect (A-D). Most of these participants believed that there is a hierarchical relationship among hypotheses, scientific theories and laws (A-B). The results indicated that compared to their ideas at the beginning of the course (38%), throughout the course PSTs developed informed ideas about the relationships between hypotheses, theories and laws (92%) (E). After the instruction, most of the participants believed that "theories cannot become laws because they both are different types of ideas" (E).

NOS-8-Epistemological statues of hypotheses, theories and laws-"Inventions" vs. "discovery" (items 91011, 91012, and 91013)

In general, significant academic consensus has been achieved on the aspects of NOS and how it should be taught in schools. Nevertheless, there are different views on some aspects. For instance, while Dogan and Abd-El-Khalick (2008, p. 1111) argue that "scientists invent theories, hypothesis and laws, because scientists interpret the experimental facts that they discover", McComas (2003, p.144) claims that "scientific laws are generally considered to be discovered rather than invented" whereas some others state that some theories have characteristics of invention or discovery (Yildirim, 2005, p. 146). During teaching, PSTs were informed about these different views on the epistemological statues of hypotheses, theories and laws (Yildirim, 2005, p.145-146).

Scientific knowledge is not out there in the universe, which scientists discover; rather scientists invent theories, hypotheses and laws (Dogan & Abd-El-Khalick, 2008; Ryan & Aikenhead, 1992). As Ryan and Aikenhead (1992) emphasised, "scientists do not invent what nature does, but they invent the laws that describe what nature does, the theories that explain what nature does and the hypotheses that describe or explain what nature does." The results showed that before the instruction, around half of the PSTs expressed an ontological perspective consistent with logical positivism (A-D) and others expressed an epistemological views consistent with contemporary views (E-F) (Dogan & Abd-El-Khalick, 2008; Ryan & Aikenhead, 1992). After the instruction, many PSTs believed that while theories (69%) and hypotheses (57%) are invented (E-F), laws are discovered (77%) (A-D). Many PSTs expressed that scientists discover scientific laws "because the laws are out there in nature and scientists just have to find them" (A) or that "some scientists may stumble onto a law by chance, thus discovering it. But other scientists may invent the law from facts they already know" (D). One of the reasons for PSTs' difficulties would be that they misinterpreted definitions of laws and theories. As quoted below, they believed that since laws are descriptions of phenomena, they must be discovered; however, as theories are explanations of phenomena, they must be invented:

> Laws are descriptions. For this reason scientists discover scientific laws. [A student's written response to item 91011] [Post-test-PST-03]
>
> Scientists invent a theory, because theories are the explanations and interpretations of existing beings. Since this matter includes mind, imagination, creativity and several inferences, we create them. [The same student's written response to item 91013] [Post-test-PST-03]

Another reason for PSTs' difficulties might be that PSTs found the views expressed in a book section (Yildirim, 2005, p.145-146, which was given to them as a reading paper) more convincing and closer to their point of view. During teaching, it should have been made clearer that such ideas do not represent contemporary views and more attention ought to have been given on this aspect of NOS.

NOS-9-Assumptions underlying theories and laws (item 90521)

There was not a significant change in the participants' views on the role of assumptions in scientific investigations (χ^2=2.03, n=73, df=1, p=0.153); however, at the beginning of the study about half of the PSTs and at the conclusion of the study 69% of the PSTs had naïve views on this aspect of NOS (A-D and F). Interestingly, the number of PSTs who had an informed view (E) decreased from pre- (47%) to post-instruction (31%). These participants believed that when developing new theories or laws, scientists need to make certain assumptions about nature and that "history has shown that great discoveries have been made by disproving a theory and learning from its false assumptions" (E). It seems that the instruction has not been effective in challenging participants' views on this aspect of NOS.

NOS-10-Nature of scientific theories (simple vs. complex) (item 90541)

Scientific theories explain natural phenomena and several theories may explain the same phenomenon. Simplicity is one of the factors that we consider while choosing a theory among competing theories. William of Occam (1288-1348) argued that a scientific phenomenon should be explained in the most economical way possible. When two theories explain a phenomenon equally well, we prefer the simpler theory to the more complex one because the simple one is better testable and more easily falsifiable than the complex one (Popper, 1959).

The present study indicated that participants' views on the nature of scientific theories significantly improved from the pre- to post-instruction (χ^2=7.71, n=73, df=2, p<0.05); however, even after the instruction around two-third of the PSTs had a naïve view on this aspect of NOS (69%) (A-B). They might confuse the simplicity of theories with criteria for theory choice. Values in science also function as criteria for theory choice (Irzik & Nola, 2011). For instance, given two rival theories, other things being equal, scientists choose the simpler theory rather than more complex one. Scientists also judge theories based on their explanatory value and fruitfulness.

NOS-11-Rejection of step-wise procedures - myth of the "scientific method" (item 90621)

Scientific knowledge is empirically based; however, there is no single, universal scientific method in science; rather various approaches and varieties of different methods might be used during an investigation (Lederman & Abd-El-Khalick, 1998). However, before the instruction nearly half of the PSTs (44%) expressed that "most scientists follow the steps of the scientific method" (A) or that "the scientific method should work well for most scientists; based on what we learned in school" (B). It seems that they have a common misconception, which has been commonly reported in other studies as well (McComas, 1998). Before the instruction, half of the participants believed not only in the usefulness of the scientific method but also the creativity of the scientists (C) or the role of accidental discoveries (E). Before the instruction, only 6% of the PSTs had informed views on the nature of scientific methods (D). Participants' views on the scientific methods were significantly enhanced from pre- to post-instruction (χ^2=26.57, n=73, *df*=2, *p*<0.001). After the instruction, none of the participants had naïve views, 59% of the PSTs were aware of the complexity and diversity of scientific investigation (C and E) and 41% of the PSTs argued "the best scientists are those who use any method that might get favourable results (including the method of imagination and creativity)" (D).

NOS-12-Nonlinearity of scientific investigations- the role of error (item 90651)

There was not a significant change in the participants' views from pre- to post-instruction on the role of error in scientific investigation (χ^2=2.36, n=73, *df*=2, *p*=0.307). At the beginning of the study, 24% and at the conclusion of the study, 26% of the PSTs had naïve views on the role of error in scientific investigation (A and E). Before the instruction about 71% and after the instruction 75% of the PSTs had "merit views" on the role of error in scientific investigation (B and D). Only 6% of the PSTs before and 1% of the PSTs after the instruction expressed that "scientists reduce errors by checking each other's results until agreement is reached" (C). It seems that the instruction has not been effective in challenging participants' views on this aspect of NOS.

CONCLUSIONS

This paper reflects on outcomes of a course in which video vignettes of historical episodes were used as a mediating artefact for promoting PSTs' conceptions of NOS. The proposed teaching had four crucial parts (see section 2.2, strategies a-d), which were intended to complement each other in the teaching of NOS aspects. The results indicate that the combination of these four strategies, as a whole, caused desirable changes in many participants' NOS views. As evident in Table 3, these changes were mostly substantial and in the case of 6 out of the 14 items significant statistically significant differences were observed. These six items were related to the theory-driven nature of observations (item 90111), relationships between hypotheses, theories and laws (item 90511), the nature of scientific theories (simple vs. complex) (item 90541), the rejection of step-wise procedures (item 90621), the epistemological statues of theories (item 91013) and the coherence of concepts across disciplines (item 91111). Although desirable changes were observed from pre- to post-instruction in participants' views of the following NOS aspects, no statistically significant changes were identified about these views: the relationship between scientific models and reality (item 90211), the relationship between classification schemes and reality (item 90311) and the tentative nature of scientific knowledge (item 90411). However, participants' views on the following aspects of NOS changed in an undesirable way in that compared to their pre-instructional views, they developed more "naïve views" on the following aspects of NOS: assumptions underlying theories and laws (item 90521), the nonlinearity of scientific investigations (item 90651) and the epistemological statues of laws: "inventions" vs. "discovery" (item 91011). In particular, assumptions underlying theories and laws as well as the epistemological statues of laws were the most confusing aspects for the participants both before and after the instruction. It seems that during teaching contemporary views on these aspects of NOS need more attention.

There are many ways in which popular media can be used in the science classroom. The results of the present study suggest that using documentary films as a medium seems to be a promising avenue to improve PSTs' conceptions of NOS. In this respect, this approach can be employed by other researchers and teachers to enhance students' understanding of science and its nature. Teachers need to see examples of how to use documentary films in science teaching and how to integrate them into their science curriculum. Therefore, this type of research is further required. The results of this type of research can inform the producers and editors of mass media, in particular of popular educational TV programs and documentary film producers. They may deliver the ideas in a way that enhance public understanding of science and its nature. Strategies that encourage the public to become scientifically literate citizens are desirable.

Limitations of the Study/Approach

Since most of the participants had difficulties in understanding films in English, the selection of documentary films was constrained by those available in Turkish. It should be emphasized that selecting usable video vignettes from documentary films might be challenging and demanding for PSTs. Technical guidance and support should be also provided to PSTs. There are several software packages for this purpose.

In this study, 14 modified VOSTS items (Dogan and Abd-El-Khalick 2008) were used for assessing participants' views about NOS. However, this study suggests that students' understanding of NOS can also be assessed with more open-ended contextualised probes, such as within the context of historical episodes or vignettes of popular media reports (Cakmakci & Yalaki, 2012; Murcia and Schibeci, 1999). During teaching it appeared that probing PSTs' NOS views, based on these concrete examples, encouraged them to elaborate their ideas further.

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