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In-service science teachers' purposes for integrating the history of science: the role of their science teaching orientation

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ABSTRACT

This qualitative study examined teachers' science teaching orientations (STO) and their purposes for integrating the history of science (HOS) into their teaching using newly developed instructional materials. The HOS may be used as an effective instructional tool for achieving scientific literacy; however, science teachers utilise it in various ways for very different purposes. Data was collected from nine in-service high school science teachers using an orientation interview protocol, reflective journals and semi-structured interviews. Data collection focused on the experiences of participating teachers who implemented instructional materials based on HOS over the course of two years. Participants' STO profiles were classified into three groups: traditional, transitional and reformist. Data analysis revealed 13 distinct purposes for integrating HOS, which fell under four overarching domains: namely, pedagogical, conceptual, affective and epistemological. The results of the study revealed that teachers failed to relate HOS with the tenets of nature of science (NOS) in their teaching. They were not able to identify the potential NOS aspects within the HOS materials. Only the reformist teachers integrated HOS for epistemological purposes, whereas the traditional teachers relied on HOS simply as an interesting life and work stories of well-known scientists. Teachers could use HOS instructional materials for a variety of reasons by utilising different aspects of HOS as their views on science and teaching shift from traditional to reformist.

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History of science; science teachers; science teaching orientation; using the history of science

Introduction

Since scientific literacy was coined as a term by the American Association for the Advancement of Science (AAAS, 1991), teaching about the nature of science (NOS) has become one of the main goals of science education and is included in many national standards (Lederman & Lederman, 2014; Osborne et al., 2003). Despite the importance of NOS for achieving the goal of scientific literacy, methods of incorporating it into teaching have been the subject of ongoing debate for the last 50 years. The history of

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science (HOS) can serve as a bridge between subject knowledge and the scientific research process (Matthews, 1994). HOS may not only help to teach about NOS (Abd-el-Khalick & Lederman, 2000; de Hosson & Décamp, 2014) but also provide an opportunity to humanise scientists for students by focusing their attention on scientists' experiences as people (Guney & Seker, 2012; Hadzigeorgiou, 2006) and besides provide opportunities for aesthetic experiences (Guney, forthcoming). Historical narratives can function as settings that give meaning to epistemological ideas, thus promoting their transferability to other situations (Irwin, 2000). Numerous international initiatives such as The MAP Project, STeT Project, HIPST Project and SHINE Project have developed instructional materials to this end (Clough, 2006; Klopfer & Cooley, 1963; Kokkotas et al., 2007; Tolvanen et al., 2014). Besides supporting conceptual learning, these materials include activities that are designed to encourage views about NOS (Henke et al., 2009), animations that illuminate the procedural and socio-cultural structure of science (Piliouras et al., 2011) and historical experiments (Cavicchi, 2008; Mäntylä, 2013). The success of all these resources depends on the ability of teachers to implement them effectively. Understanding the history of science is necessary to develop the informed views of the nature of science that are identified in curricular standards (NRC, 2000). For this reason, teachers should not only have extensive knowledge of HOS – they should also be pedagogically prepared for how and when to use such historical materials in their teaching. Despite recommendations for and encouraging attempts at incorporating HOS into the curriculum, the concept is new and unfamiliar for some science teachers. Studies have indicated that teachers are often ineffective in integrating HOS into their classroom practices (King, 1991; Wang, 1999).

Moreover, many researchers highlight that teachers' belief systems significantly impact their practice. They claim, for example, that experiences that are incompatible with a teacher's belief system are given relatively little consideration or even ignored entirely (Nespor, 1987; Pajares, 1992). When the understanding of science represented through HOS differs from teachers' pre-existing beliefs about teaching, learning, or science, teachers may implement it in more limited ways. Teachers' epistemological and pedagogical beliefs, thus, seem to the main obstacles for this integration process. Höttecke and Silva (2011) approach the issue from a similar perspective, explaining that despite the tremendous potential benefits of using HOS in the classroom on students' understandings of science, science teachers' incompatible epistemological beliefs, skills and knowledge (or lack of adequate epistemological beliefs, skills and knowledge) form potential obstacles to the effective use of HOS.

All these obstacles are included under the definition of teachers' science teaching orientation. The term orientation was first operationalised in education by Anderson and Smith (1986), who defined it as the general pattern of thoughts and actions of the teacher related to the science teaching process, explaining why teachers use different approaches in their practices despite a uniform curriculum. A teacher is a person who not only possesses certain subject-matter knowledge but also converts this knowledge into educational practices through their pedagogical filter to benefit learners (Shulman, 1987). The literature shows that teachers' beliefs about teaching and learning, which are considered under the concept of orientation, shape their practices in a transformative process (Friedrichsen et al., 2009; Käpylä et al., 2009; Newton et al., 2020; Subramaniam, 2013; Van Driel et al., 2002; Yehya et al., 2018). Two dimensions of teaching orientation separate science teachers from other individuals who have subject matter knowledge, such as engineers or scientists: their views on learning and teaching, and views about science (Bartholomew et al., 2004). Our study argues that teachers' orientations toward science teaching can shape their purposes for and implementations of HOS into classroom practices.

Teaching orientation has been defined in many ways in science education literature, therefore, Friedrichsen et al. (2011) advised establishing a solid theoretical basis before using the concept. According to the most cited definition which was proposed by Magnusson et al. (1999), science teaching orientation is 'teachers' belief in what is important and most effective in the teaching process'. It is accepted that teachers' beliefs about teaching and learning directly influence their teaching practices (Hashweh, 1996). Moreover, researchers have illustrated the possible impacts of teachers' views of science on their teaching practices (Abd-El-Khalick et al., 1998; Gallagher, 1991; Lederman, 1992). Tsai (2002), for example, showed that teachers' beliefs about teaching and learning have a relationship with their views of science, and that their belief systems affect their practices as well. Given the results of these studies demonstrating that views on science also affect classroom practices, teachers' orientation should be re-conceptualized to include two dimensions – namely, beliefs about the nature of science, and beliefs about science teaching and learning (Friedrichsen et al., 2011). As a result, considering the dimensions outlined by Friedrichsen et al. (2011, p. 372), this study uses the following definition of teaching orientation: 'the belief system which depends on the view of science and belief on teaching, and learning which shapes teaching practices'.

Understanding teachers' orientations will help us to evaluate their usage of HOS in their classrooms. Implementing the history of science in teaching has an effect on achieving the goal of scientific literacy, but nevertheless, the teacher factor is one of the most important aspects of successful implementation for achieving desired results. Teachers' orientation reflects their ability to make judgments about the context and situations that influence their teaching, especially when curriculum innovation is necessary. In cases of new educational perspectives, teachers use their orientation to evaluate information and make decisions (e.g. traditional versus constructive – Mansour, 2009), even when complying with established curriculum or other policies. The implementation of HOS-based science teaching represents one such new perspective. Therefore, understanding teachers' science teaching orientation helps researchers to evaluate their usage of the history of science in classroom settings.

Purpose and research questions

This study investigated in-service science teachers' implementation of the HOS, alongside their science teaching orientation profiles. Initially, various instructional HOS materials were developed based on the Turkish High School curriculum. This study uses these resources to assess the relationship between teachers' science teaching orientations and their experiences of using HOS in their classroom practices. The research questions guiding this investigation included:

1. What are the aims of science teachers who integrate HOS into classroom teaching?

2. What is the relationship between these teachers' science teaching orientations and their purposes for integrating HOS?

Methodology

Research design

This study utilised a qualitative research method. A phenomenological study was deemed appropriate for two reasons. First, there is not an existing model for the relationship between science teachers' science teaching orientations and their purposes for using HOS in the classroom. Secondly, phenomenological designs are used when little has been discovered or published about a phenomenon. In such a study, data are collected from practitioners or knowledgeable people who describe and explain their perspectives on the phenomenon. As Creswell and Poth (2016, p. 15) put it, 'qualitative research is multi-method in focus, involving an interpretive, naturalistic approach in which the researcher attempts to make sense of or interpret phenomena in terms of the meanings people bring to them'. In-depth experiential qualitative data were collected from a selected group of science teachers and analyzed in order to describe and interpret their perspectives on using HOS in science classrooms (Bogdan & Biklen, 1997).

Participants

Data for this study were collected during a three-year-long project aimed to develop the pedagogical history of science materials that are consistent with the high school national curriculum. Detailed accounts of the project's theoretical background and material development process of have been published (Seker, 2012). In summary, the project materials developed according to the model (Seker, 2007) consisted of historical stories divided into four main categories – conceptual, epistemological, socio-cultural and interest – that allow teachers to incorporate the HOS into the classroom more easily. Each resource was developed and assessed by experts and was not considered as a finished product until reviewed by all researchers. In the development of stories, the historical information was reviewed and adjusted according to the knowledge, understanding and skills objectives of the Turkish national curriculum standards. In particular, the reforms made in the Turkish national curriculum since 2007 and in the most recent curriculum developed at every educational level have focused on the use of the history of science more effectively in science education within a constructivist teaching framework. (Ministry of National Education [MoNE], 2011a, 2011b; Guney & Seker, 2012). Below we provide two objectives as an example from science curriculum of the Ministry of National Education (MoNE, 2011a, 2011b). 'Explain with examples the contributions of human societies with different historical and cultural backgrounds to the development of scientific ideas and biology with examples from the history of science' (10th grade biology) and 'In the historical process, the scientific discussions between Thomas Edison and Nikola Tesla should be examined and how to create a variable and direct current should be discussed' (12th grade physics).

The materials also included guidance notes for the teacher indicating the relevance of the stories with the standards in the curriculum and on the possible ways of using the material in the classroom. However, teachers were not obligated to use the materials as described in guidance notes. They were asked to incorporate the materials into their teaching as they believed to be appropriate. An example of the teaching material and suggested use with guidance is provided as a supplemental file. In order to determine the sample for the study, a workshop for teachers, who were interested in the project, was organised at the beginning of the project. Teachers were provided with information on the structure of the project materials, the content and focus of the history of science stories and their relevance to the curriculum. Teachers examined the sample materials and discussed the usability of the materials in their lessons, and then volunteer teachers who wanted to use the materials in their lessons were contacted. For a full academic year, a group of 29 teachers voluntarily participated in the project. Participant teachers offered feedback about the HOS materials after using them in their lessons. There was a constant interaction and feedback mechanism between researchers, who developed the material, and the teachers, who implemented the material in the class. Teachers provided feedback to the researchers about classroom interaction and student interest. According to the feedback received the experts revised the teaching materials and the development process continued. At the end of the project, nine of the participants, who participated actively from the beginning of the research process and had shared their experiences in detail, were purposefully selected (Patton, 2002) for interviews of this study. Table 1 presents the participants and their fields of study, degrees, and levels of teaching experience. All participants – including those with graduate degrees – reported that they did not take any courses related to the history and philosophy of science during their education. The participants' backgrounds allowed for a broad range of viewpoints on the implementation of the history of science curriculum and materials.

Data collection tools

The data for this study were collected through interviews and reflective journals. Friedrichsen et al. (2011) drew attention to the need for new instruments with a structure that includes two dimensions of science teaching orientation. Until the development of new methods, they advised that the questions in the 'Teacher Belief Interview' (TBI) (Luft & Roehrig, 2007) could be used to explore the dimensions of beliefs about learning and teaching, but researchers must also add questions to assess participants' views on science (Friedrichsen et al., 2011, p. 372). The framework of the science teaching orientation (STO) interview questions used in this study, adapted from the TBI (Q1–Q7)

Table 1. Overview of participants' background Information.

Participant	Field	Degree	Teaching experience
T1	Physics	Physics education (BA)	16 years
T2	Chemistry	Environmental science (MS)	6 years
T3	Chemistry	Chemistry education (MS)	14 years
T4	Biology	Biology education (BA)	6 years
T5	Biology	Biology education (BA)	10 years
T6	Biology	Biology education (MS)	11 years
T7	Physics	Physics education (BA)	13 years
T8	Chemistry	Chemistry education (PhD)	9 years
T9	Biology	Educational management (MA)	23 years

and research by Tsai (1998) (Q8–Q13), is presented in Appendix 1. The themes and interpretations of teachers' STO profiles were based mainly on this interview protocol. Additionally, materials such as worksheets and annual instructional plans were collected as supportive data sources. Participants chose the location for their interviews. After developing rapport with the participants, the researcher began asking probing questions. To ensure that the teachers spoke about their beliefs, the researcher asked questions about their teaching experiences, the current Turkish curriculum and their daily life in the classroom. Each interview lasted about 30 minutes and was audio recorded. In addition to these semi-structured interviews, participants were asked to keep reflective journals about their experiences using the history of science in their teaching. Over the course of two years, a total of 53 hours of interview data and 26 reflective journals were collected from the nine participants (Table 2).

Interview form for experiences of HOS implementation. Teachers participated in semi-structured interviews within a few days of using a HOS resource. The researcher designed the interview protocol, which covered three main areas: the reasons why teachers used the history of science, the stage of the course when the resource was used, and how they used it (see Appendix 2). The interviews gave the teachers numerous opportunities to reflect on their integration experiences. During the interviews, all teachers shared their experiences related to the planning process and how they incorporated the HOS resources into their teaching and gave detailed information about the difficulties they faced while using the materials. The interviews lasted approximately one hour. All interviews were recorded and transcribed.

Reflective journals. When it was not possible to interview the teachers soon after they used a HOS resource in the classroom, the teachers wrote reflective journals about their practices. All teachers kept reflective journals after the implementation of HOS resources in their classrooms. They wrote about their feelings, ideas, experiences and students' interactions with the HOS materials. Reflective journals were designed according to the Loughran (2002) framework which consisted of three levels (anticipatory, contemporaneous and retrospective) of reflection. In the first part, teachers wrote about their feelings and thoughts of the potential problems they might encounter during the implementation and solutions they foresee before the lesson. In the second part, they described their experience in the class. They assessed their initial expectations and discussed if they had to change their plan and adjust their teaching according to interactions during the lesson. In the last part, they wrote their reasoned evaluations of the implementation. Both successful aspects and/or the aspects that needed improvement were

Table 2. Sources of data collected in the course of the study.

Participant	The number of HOS materials	Reflective journal	Interview duration
T1	12	2	8 hours 34 minutes
T2	10	3	5 hours 45 minutes
T3	14	1	9 hours 8 minutes
T4	13	2	5 hours 34 minutes
T5	9	5	3 hours 53 minutes
T6	14	4	5 hours 15 minutes
T7	11	1	6 hours 15 minutes
T8	10	5	4 hours 24 minutes
T9	11	4	4 hours 15 minutes
TOTAL		**26**	**53 hours 5 minutes**

discussed. Helpful explanations were included in reflective journals to help teachers express their views under themes like 'I specifically thought of using the following section(s) in the materials, because … ' The reflective journals were examined to determine the purposes of the teachers for using and/or planning to use the history of science.

After the reflective journals were analyzed by two researchers, the teachers were interviewed about what they thought about their experiences using the history of science. These follow up interviews were conducted to understand exactly what the participants meant in their reflective journals. In the follow up interviews, issues included in the interview protocol but not mentioned in the journal of the teachers were discussed. Participants had the opportunity to discuss and comment on every question in the HOS Implementation Interview Protocol. Participating teachers provided a variable number of reflective journals depending on their availability on the day of HOS implementation for an interview with the researchers (Table 2).

Data analysis

The data was analyzed in two stages. In the first stage, teachers' science teaching orientation and their experiences using HOS were analyzed separately, and their individual profiles were generated. In the second stage, these two data sources were analyzed and evaluated together.

In this study, science teaching orientation is discussed within a conceptual framework consisting beliefs' about science teaching and learning and views about science (Friedrichsen et al., 2011). Although none of these dimensions are independent of each other, all of them constitute components of science teaching orientations (Friedrichsen et al., 2011; Magnusson et al., 1999). For this reason, teachers' science teaching orientation profiles were analyzed considering these two dimensions.

Data analysis started with coding in order to categorise participants according to their learning and teaching beliefs, using a five-category analytical framework first developed by Luft and Roehrig (2007); namely, traditional, instructive, transitional, responsive and reform-based. A total score for the interview items was calculated by assigning scores from one (1) to five (5) to the seven interview questions. Participants' responses that fell under the theme of traditional teaching beliefs were assigned a score of one (1), while responses that indicated reform-based teaching beliefs were assigned a score of five (5). Therefore, the possible teaching belief scores for participants ranged from 7 to 35. Participants with total scores between 7 and 14 were categorised as having a traditional teaching belief, those with total scores between 15 and 21 were categorised as having a transitional teaching belief and those with total scores between 22 and 35 were categorised as having a reformist teaching belief. For example, participant T2's responses to three of the seven semi-structured interview items fell under the traditional belief category (receiving one point for each item, which added up to a total of three), while her responses to the remaining four items fell under the instructive belief category (receiving two points for each item, which added up to eight). Accordingly, T2 received eleven points (three from three interview items and eight from the remaining four items) and was thus categorised in the traditional teaching beliefs profile. Coding of TBI interview data was performed by two researchers independently, resulting in inter-rater agreement of 79% for TBI data. Results for all participants are shown in Table 3.

Table 3. Teachers' responses to the beliefs about teaching and learning questions.

	Traditional	Instructive	Transitional	Responsive	Reform-based	Total
T1	—	***	****	—	—	18
T2	***	****	—	—	—	11
T3	—	*	****	**	—	22
T4	**	***	**	—	—	14
T5	*	**	****	—	—	17
T6	*******	—	—	—	—	7
T7	—	***	***	*	—	19
T8	—	—	***	****	—	25
T9	**	****	*	—	—	13

Each "*" symbol represents the coded response to a question on the TBIs interview.

After analyzing the teachers' beliefs about learning and teaching, the orientation profiles were finalised with the data obtained on the teachers' views about science (Question 8–13). The teachers' views about several aspects of the nature of science (NOS) were assessed by inductive code generation. Results are summarised and presented in Table 4. In the left-hand column of Table 4 are the aspects that have been frequently cited by various studies (Abd-el-Khalick & Lederman, 2000; Irez, 2006; McComas & Olson, 1998). These aspects were the empirical and tentative nature of scientific knowledge, the nature of the scientific method, imaginative and creative NOS, the nature of scientific theories and laws and the subjective nature of scientific knowledge. Participants received one point for each opinion compatible with the tenets of NOS in the literature. Participants scores ranged between two (10%) and twenty (100%). The teachers' scores and percentage of agreement with the statements are summarised and presented in Table 4. Participants were classified into three groups according to their total scores; namely, naïve (scores ranged from 2 to 8), eclectic (scores ranged from 9 to 15) and informed (scores ranged from 16 to 20). For example, T8 scored 18 points. It means that her/his views about the NOS were found to be 90% compatible with the tenets of the NOS and classified as informed. On the other hand, T9 scored 3 points, therefore, she was classified as naive. Coding of interview data for the NOS questions were also performed independently by the two researchers, the inter-rater agreement for NOS data was 84%.

After the analysis, two descriptive systems – one for beliefs about teaching and learning and one for beliefs about science – were combined and grouped together. As a result, teachers' were placed into three STO profiles according to their total score from TBI (Q1–Q7) and from beliefs about NOS (Q8–Q13) (traditional STO (Q8–Q22), transitional STO (Q23–Q34) and reformist STO (Q35–Q55) (see in Table 5). While teachers who are teacher-centred, focus on memorisation and have naive views – 'fails to present an adequate understanding' – on science are categorised under the traditional profile, participants who focus on student-centred teaching methods define learning as the process of forming one's own ideas and have informed views – 'has an adequate coherent understanding' – on the nature of science are categorised under the reformist category. On the other hand, teachers in the transitional group showed transitional characteristics between the two orientations. Transitional teachers mostly used problem-solving procedures and question–answer techniques in their teaching. They viewed science as a consistent and objective process and had eclectic ideas – 'has inconsistent and often conflicting views' – about NOS. Table 6 describes the STO profiles as well as representative quotes related to the participants' views that were identified from the data.

Table 4. Overall analysis of the participants' views about the NOS.

NOS Aspects	Participating Scienc – e Teachers									Overall Group performances
	T6	T2	T9	T4	T5	T1	T7	T8	T3	
Description of science										
Science as a way of knowing					•	•	•	•	•	5
Can not answer metaphysical question		•		•	•	•	•	•	•	7
The emprical NOS										
Doesn't rely solely on direct evidence				•			•	•	•	4
Supportive role of evidence								•	•	2
Scientific method										
No single scientific method					•			•	•	3
Is not a step-wise procedure						•			•	2
The tentative NOS										
Scientific knowledge is tentative	•	•	•	•	•	•	•	•	•	9
Relative to social context			•		•	•	•	•	•	6
Theories and laws										
Theories are well sustained						•	•	•	•	4
Theories may change	•	•	•	•	•	•	•	•	•	9
Due to new evidence								•	•	2
Law may change					•			•	•	3
No hierarchical relationship								•	•	2
Inference and theoretical entities										
Inferential nature of some theories							•	•	•	3
The subjective NOS										
Differences in data interpretation					•	•	•	•	•	5
Are affected by values and beliefs					•		•	•	•	4
Social and cultural influences										
Science as a product of culture							•	•	•	3
Society influences science				•		•	•	•	•	5
Creativity and imagination in science										
Involves imagination and creativity				•		•		•	•	4
At all stages									•	1
Overall individual performances	**2/20 10%**	**3/20 15%**	**3/20 15%**	**6/20 30%**	**9/20 45%**	**10/ 20 50%**	**12/ 20 60%**	**18/ 20 90%**	**20/20 100%**	**82/180**

The (•) sign means that the participant who corresponds to that box has expressed views compatible with the sentence in question.

Table 5. Participants' science teaching orientation profiles.

Participant	TBI score	NOS score	Total score	Classified as
T6	7	2	9	Traditional
T2	11	3	14	
T9	13	3	16	
T4	13	7	20	
T5	17	9	26	Transitional
T1	19	12	28	
T7	19	12	31	
T3	22	20	42	Reformist
T8	25	18	43	

After the analysis of STO profiles, the interpretation of the data from the reflective journals and interviews about HOS experiences began with inductive code generation. During this process, each unit of information expressed in interview transcripts and

Table 6. STO profile category descriptions.

	Quotations	
Orientation	Teaching and learning	View of science
Traditional: Focus on information, transmission, and teacher centred instruction. **Science** is rule or fact.	'… If I see something wrong I **fix** it. I **tell** the **correct** answer because it is so much easier for the teachers.' (T6)	'Science is a **fact** because it represents the truth in the world and scientist collect evidence by using **the** scientific method for discovering this truth.' (T6)
	'I **pass** to the next student and ask again. When someone tells the correct answer I start to new topic.' (T2)	'If it were correct, it would be a law. Theory is suspected … .' (T9)
Transitional: Show **transitional** characteristics **between two orientations**. Mostly use **problem solving procedures** and question–answer technique.**Science** is as a consistent and objective process.	'As a teacher, I must be good in laboratory practice and solving problem because I'm responsible for guiding them' (T1)	'Science is a **procedure** of problem solving to reach **correct** knowledge.' (T5)*
	'You execute, make mistakes, continue execution, make corrections and then finally you learn.' (T5) 'I try to get students to discover or guess something rather than describe something. Students learn by questioning, that is, they learn what they are curious about, we learn that way, we do not learn much when we convey something … .' (T7)	'I know that theory doesn't become a law and it's a scientific explanation, but law is much more reliable than theory because contrary to laws theories could be changed.' (T7)
Reformist: Focus on mediating student knowledge or interactions, collaboration, feedback, or knowledge development. **Student centred** instruction. **Science** is a dynamic structure in a social and cultural context, clearly informed by views about NOS.	'Teacher should help students realize their misconception.' (T8)	'Science as a dynamic structure in a social and cultural context.' (T3)
	'Writing is important learning strategy to reflect what is in someone's mind because students realize what they know or not.' (T8) 'For me, it is more important to students' developing process in lesson than the exam result.' (T3)	'Theory and law are different types of information about nature – one of explanation (theory) and one of description (law) and both can change. They are supported by scientific data.' (T8)

Table 7. Purposes for using the history of science according to teachers' STO profiles.

		Traditional				*Transitional*			*Reformist*		
Domain	Integrate the HOS to/for	T6	T2	T9	T4	T5	T1	T7	T3	T8	Total
Affective	Humanization			o					o	o	3
	Encourage to be a scientist				o				•	•	3
	Appreciate science and scientists		o	o		o			o		4
Pedagogical	Take a break/entertainment	o	o	o			o		o		5
	Enhance teaching	•				o	o	o	o		5
	Attract students' attention to the topic		o		o		o		o	o	5
Conceptual	Teach scientific concepts					•	•	•		o	4
	Relate the subject with other disciplines					o	o				2
	Reinforce learning		•	•	•	o	o		o		6
	Relate science with daily life			o			o			o	3
Epistemological	Teach the science/society relationship								o	o	2
	Teaching how the scientific community works		o						o	o	3
	Teach methods of science								o		1
Number of purposes		2	5	5	3	5	7	2	10	7	46

• Main purpose.
o Used at least one time.

reflective journals related to the teacher's purposes for using a HOS material was coded and grouped. Codes and categories were updated and applied to all data throughout this process using the constant-comparative method. Finally, broad domains of purposes were created by grouping related themes. For instance, all of the themes regarding teachers' purposes for using the materials to teach aspects of the epistemology of science were grouped under the epistemological domain. On the other hand, statements that indicated teachers used the materials to develop a certain attitude in students led to themes like 'encourage to be a scientist, appreciate science and scientists, and humanize science', which were grouped under the affective domain (see in Table 7). This process also involved a comparative frequency analysis of the teachers' purposes for using HOS materials in the classroom to reveal the most preferred purposes for incorporating the HOS into science teaching. Inter-coder agreement between the researchers was 87%. Participants with traditional STO had low while those with reformist STO had high scores in both TBI and NOS. However, it is interesting to note that all participants with transitional STO had medium scores on both TBI and NOS dimensions as opposed to having a high score in one and a low score in the other dimension.

Results

Science teachers' orientation (STO) profiles

The data obtained from STO interviews with the nine participants were classified into three main science orientation groups. To protect their anonymity, the teachers are referred to by numbers 1–9 in the interview results. The distribution of the teachers' responses to the interview items is presented in Table 5. As seen in Table 3, the TBI analytical framework demonstrated that four science teachers (T2, T4, T6 and T9) operated from traditional beliefs about the teaching and learning process. These teachers viewed their purpose as transferring the correct explanation contained in science books to students. To them, lecturing is the easiest, fastest and most effective technique to cover all of the subjects in the curriculum. Analysis of the responses from this group of participants shows that these four traditionalists hold a naive view of NOS (see Table 4). For these teachers, science is a collection of unchangeable and undeniably correct pieces of knowledge. For example, T6 stated that if students want to be a scientist, they should know all of the 'information' and 'mathematical formulas' in scientific books. They claimed that this single, unique truth can only be reached through fixed scientific knowledge. Furthermore, such teachers demonstrated many misconceptions about NOS, like the relationship between scientific theory, scientific law and their nature.

On the other hand, the participants with transitional STO profiles (T1, T5 and T7) had slightly different views about science, as well as about teaching and learning. They defined the student in a relatively active position, unlike their more traditional colleagues. In addition, these teachers often used the phrase 'meaningful learning', instead emphasising repetition in the learning process. Consequently, the most distinctive difference for these teachers was their focus on 'problem-solving' as a teaching method, aiming to replicate the procedural structure of science. The problem-solving ability is only one component of scientific practice; therefore, students need to improve their ability to use mathematical formulas and procedures by repeated practice and application. Participants operating under this orientation largely held eclectic views of NOS. For example, T5, a biology teacher, emphasised that students should know and understand the scientific process to be scientists. On the other hand, she believed that science can be done *without creativity* because scientist should only follow the universal scientific method.

> … I can say that science is a cluster of experiment and testability is more important things in science. If there are two different scientists where one has high imagination but the other has not, it would not make any difference to the final model. Maybe scientist who has creativity was spending less time that is all. Creativity maybe makes scientists' work easier but it is not fundamental. The scientific method is fundamental. (T5, Biology teacher)

One considerable observation was that the teachers belonging to both these orientation profiles (seven of the nine total) expressed that they themselves were the correct source of scientific information. While the traditional STO teachers conveyed the correct information didactically, transitional STO teachers guided students to the correct information by performing various practices. For example, T5 described the teaching process as a discovery, and defined herself as a representative of science who guided students to accurate and precise information. When interpreting these teachers' views about science, it is noteworthy that they define science as a procedure to reach *correct* information.

> There should be no such thing as not trusting scientific knowledge. Because science is accumulation of experiments. You know, information that, when designed with the right methods, gives the **correct** results. (T5)

> … **Truth** exists in nature. We do not notice it, but it does exist. Here, someone notices, pours it into physics, pours it into chemistry, and shapes it with concepts. (T7)

Finally, only two teachers were categorised in the reformist STO profile (T3 and T8). These teachers were separated from the others by their views on teachers and learning. They were the only participants who mentioned that learning is a construction of knowledge by students based on environmental stimuli, and the teacher should be a guide to help students realise their own conceptions.

> When the student shapes it with his/her own knowledge, when he puts it into practice, when s/he uses this knowledge in another subject, they have learned. (T3)

> The word I used there has a special meaning for me, but it may not be for that student. So why should I get the student into one kind of explanation, one kind of truth perception? (T8)

In addition, these teachers also operated from a distinctly different understanding of the nature of science than their colleagues with other orientation profiles. Among the nine teachers, only T3 and T8 defined science as a dynamic structure within a distinct cultural and social context. The social structure of science stands out in both teachers' definition of science.

> … Science means **working** together and it is like a social creature, I mean; it is effect and affected and growing in social structure … . (T3)

> **Creativity** in science is very important. Isn't science already the models that the scientist **produced** using his creativity? More creative scientists **produce** better explanations and science changes or develops … . (T8)

The distinction between the transitional and the reformist perspectives on the creative nature of science is clearly seen when comparing T5 with T8 (see above). For T5, creativity is only an element that saves the scientist time but does not change the result, while for T8, it is the essence of scientific knowledge production.

Science teachers' integration of the history of science in science class

As explained above, semi-structured interviews were conducted with the teachers to assess their purposes for using the history of science in their teaching. When these interviews conducted, the researchers examined their transcripts for potential relationships between the teachers' STO profile and their purposes for incorporating HOS into the classroom. This section first presents participants' purposes for incorporating HOS before examining potential relationships between their STO profile and integrations. Participants' purposes for using HOS in their lessons are summarised and presented in Table 7, which enables comparisons across teachers' STO profiles and their aims for using HOS in the classroom. During analysis, we identified four domains of purposes for incorporating HOS into science teaching. These domains, presented in the left-hand column of the table, are: (1) the affective domain, which includes purposes for developing student attitudes; (2) the conceptual domain, which includes purposes for promoting the conceptual learning of content; (3) the epistemological domain, which includes purposes for promoting the appreciation of the aspects of science; and (4) the pedagogical domain, which includes purposes for developing the quality of teaching and learning.

The participants are grouped in Table 7 according to their STO: traditional, transitional, and reformist. In each orientation category, participants are arranged in order of their orientation scores (also presented in Table 5). For example, participants in the traditional STO profile are ordered as T6, T2, T9 and T4 according to their total scores, which were 9, 14, 16 and 20, respectively. In Table 7, the '●' sign indicates the participant's main purpose – for using HOS in the classroom, and the 'O' sign indicates that the participant expressed a view corresponding to the respective category at least once in interviews. A cell with no symbol indicates that the participant did not report incorporating the HOS into their lessons for that purpose. The last column on the right side gives the number and percentage of the participants who indicated incorporating the HOS for that purpose. These percentages show which domains and aims are preferred within the group. As seen in Table 7, a total of 13 different purposes (under four domains) were identified. The analysis revealed that the teachers mostly preferred to use HOS to 'reinforce learning', the aim of 'teaching science methods', which is under the epistemological domain, were the least preferred.

Only three participants (T2, T3 and T8) used HOS for epistemological purposes – however, it was one of the main purposes of using HOS for T3 and T8. Table 7 reveals that these two teachers demonstrated a reformist orientation, with informed views of NOS that portrayed science as a matter shaped by social context. For these teachers, infusing their teaching process with the epistemology of science was as important as content knowledge for students' education. T3 presented a similar approach, stating that integrating the epistemology of science into lessons helps students to think in more multidimensional ways.

> Without HOS, students learn many things, but they learn only the concept and memorizing it. When I integrate the HOS in my teaching like what kind of social situation did scientists face? They are aware of or understand the social structure of science and what is science. If you separate history about social structure from the lesson, this is not a science lesson this is something else but not science. (T8, reformist STO)

> … Davy's wrong conclusion at the end of the scientific process also should be mentioned in the course. I think it is useful to explain the process regardless of the accuracy of the result. Not only true knowledge but also the scientific process is important for understanding science and I honestly say that history of science is very helpful to me. (T3, reformist STO)

T2 used historical material to teach about the scientific community. However, it was noteworthy that her lessons on the history of science included many misconceptions about the nature of science. She described science as 'correct information under an authority', explaining that students should be provided with examples of how researchers' results are confirmed by the scientific community. In her reflective journals about teaching material on Avogadro, she mentioned plans to explain the scientific society to students. During follow-up interviews, she explained these practices, saying:

> It's not every question that's happening, let's just go suddenly. Its accuracy must be confirmed. For example, the theoretical explanations are approved by the scientific council and then become a law. I added this [the scientific society] for to show that research passes some committee and then is accepted as correct. (T2, traditional STO profile)

This situation shows the need to understand that incorrect deployment of HOS has the danger of creating misconceptions for students. Another significant observation involved teachers' primary aims. The HOS is one of the most effective resources for enhancing students' conceptual learning (Galili & Hazan, 2001; Seroglou et al., 1998). The literature indicates that teachers tend to focus on conceptual understanding rather than contextual understanding in their HOS lessons (Wang & Cox-Petersen, 2002). Our study revealed that these nine teachers commonly integrated HOS to facilitate conceptual learning, such as 'to reinforce learning' (6 participants), 'to teach scientific concepts' (4 participants), or 'to attract students' attention to the topic' (5 participants).

In particular, the physics teachers (T1 and T7) showed little evidence of intentions in the affective or epistemological domains, instead focusing on the conceptual field. Due to the culture and subject nature of physics, the teaching process is typically more quantitative in style than narrative-based. Throughout the course of this study, T7 reviewed and integrated more than 20 historical physics cases into his class. Remarkably, he only preferred to use HOS for teaching scientific concepts. T7 claimed that physics revealed clear and certain information.

> There are so many stories here … it doesn't make much sense to explain physics historically. Because we need to calculate something and solve problems [using math], physics is not any lesson but a science lesson … I couldn't spend all of the course just for explaining some cultural or historical things, I need to do science also! I must calculate and talk about certain knowledge … [He sounds serious]. (T7, transitional STO profile)

T1 presented a similar approach. As seen in Table 7, T1 preferred not to use HOS for epistemological or affective purposes. In one of the interviews, she explained why she hadn't used historical stories about changing scientific knowledge or thought experiments.

> I'm not sure. I mean … it seems to be unreliable ground. It may give rise to negative attitudes toward science … I can't really integrate this part because if I share this story, the image of physics loses its seriousness, its [physics] reliability becomes zero. They may think it's not certain and only imagined. (T1, transitional STO profile)

During the interviews, T1 and T7 stated many times that students want to develop clear knowledge; hence they strongly rejected stories about the tentative nature of science. This finding is supported by the literature, which indicates that physics teachers' tend to view their subject matter as a collection of stable, timeless facts (Höttecke & Silva, 2011).

Analysis of the relationship between STO profile and purposes for integrating the history of science

Table 7 reveals that the teachers with a reformist STO presented a greater variety of purposes for integrating HOS than those with a more traditional STO. It was noted that among the participating teachers, the reformist teachers used the HOS for much more diverse purposes than the traditional teachers. Additionally, there were clear differences between the orientation groups' main purposes for using HOS. As seen in Table 7, the transitional STO teachers' main purpose was to teach scientific concepts, while the traditional teachers used HOS as a supporting tool to reinforce learning. The traditional teachers tended to use the history of science as an additional activity after their typical science teaching practices. According to these traditional teachers, HOS is just additional knowledge with some helpful anecdotes for reinforcing formulas and concepts. For example, T6 stated that the traditional approach was the most effective method for teaching, emphasising reading and note taking as key activities in her classroom. According to her orientation, she incorporates HOS materials only as supplemental texts for students or herself to read.

> … Reading this part about Leeuwenhoek's starting point, it helped me to tell a lot of things. I would speak 10 minutes either way; without HOS, I will give my usual lecture. It gave me

> more anecdotes to talk about the subject … I used it as an icing on the cake after the lesson. (T6, traditional STO profile)

Analysis showed that this situation was not unique to T6; in fact, all of the traditional teachers only used the HOS materials after the lesson to help students memorise concepts or formulas. T2 provided another example, saying:

> I used the historical text after I finished my usual class. I think this material helps the child to memorize the lesson. It is a useful tool to repeat the lesson. (T2, traditional STO Profile)

This style of employing HOS is called an 'add-on strategy', which represents a traditional (rather than historical) teaching approach (Matthews, 1994). On the other hand, the transitional teachers integrated the HOS during their lessons. Contrary to the traditional teachers, transitional teachers used HOS as a tool to make learning meaningful and dynamic, rather than simply relying on memorisation.

> If the teacher gives the knowledge directly, it is only memorizing. But if you explain how concept was born and why the scientists thought like this, it helps to put the ideas in place. It is so necessary for meaningful learning. (T5, transitional STO profile)

As mentioned in the previous section, the teachers with transitional STO gave weight to teaching scientific concepts. Findings show that they use HOS texts to understand students' misconceptions. The similarities between students' previous knowledge and the prevailing notions of the historical period are useful tools to encourage students to enter the investigation process.

> For example, I first asked the students about the force. They already had some prior knowledge in mind, and from there they saw the definition of Aristotle, they realized that is the same their idea. After that I tried to challenge them with historical questions and by this way they started up the learning. (T7, transitional STO profile, on a lesson about the material of force and motion)

This observation indicates a distinctive difference between traditional and transitional teachers' usage of HOS. The teachers operating from a traditional orientation used the history of science as an extra activity after their typical science teaching practices. On the other hand, the transitional STO teachers integrated the HOS into their lessons after considering students' dynamic learning. As discussed earlier, the physics teachers didn't integrate HOS into their lessons for affective aims. However, T5, who also operated according to a transitional orientation, rarely integrated HOS to ensure the appreciation of scientists' work. Additionally, both physics teachers expressed perceptions of scientists as exceptional, or even divine, figures. For example, T1 preferred not to use HOS for humanising purposes, claiming that not everyone can be a scientist because science requires a different mindset; for this reason, she refused to use the material if it portrayed the scientist as an ordinary person.

> I'm saying they're the chosen people. They came to complete a mission. They have been sent by God for this mission [doing science]. (T1,Transitional STO Profile, on Newton's law of motion material)

Similar to T1, T7 explained that he didn't integrate the stories about scientist' lives into his lessons because a scientist would be seen as ordinary people. He also expressed corresponding views about scientists' traits, explaining that it is not possible for every student to become a scientist:

> Scientists look at nature so differently; we can't see what he sees—their brain works differently. (T7, Transitional STO Profile)

As discussed earlier, only two participants expressed epistemological domain aims as their primary goal for integrating HOS into classroom instruction. When examining the responses of these two participants (T3 and T8), they demonstrate informed knowledge about the NOS. These results indicate that teachers' views about science and scientists are also important for effectively integrating HOS into the curriculum. For example, T3 is also the participant who integrated HOS for the most diverse purposes. She stated that sometimes the lesson is not as important to her, but rather she focuses on integrating HOS to help enhance students' awareness of science. Also, 'enhancing teaching' as a term had different meanings for traditional and reformist teachers. For the traditional teachers enhancing teaching meant better knowledge transmission, while for the reformist teachers, it meant better facilitation of student conceptual development. Another crucial observation was seen in the affective domain. Analysis showed that HOS was primarily used for affective aims only by two teachers who have reformist orientations. Although three teachers with traditional orientations also used the HOS for affective aims, their primary targets were not affective aims. Reformist teachers emphasised that their primary goal as educators was to encourage students by giving the message of 'you can do it'. For example, T8 used Faraday's story to show that it is not necessary to be from a privileged background to be a scientist. T3 was the only participant who pointed out that providing examples of woman scientists is important for female students.

> Young female students subconsciously think that only men can become a scientist. I try to integrate stories to show that you can do it because these women did it. (T3, in a lesson on pollution and chemical waste material, about Joan Berkowitz)

The other teachers used the same stories for different aims. For example, T2 (traditional orientation) used the same historical story during a break in the lesson, while T1 used the Faraday story to draw attention to the subject at the beginning of the lesson.s

> I'm only interested in the medal. I like to give this kind of stuff to show that science is a very important thing. (T1, transitional orientation).

As described previously, physics teachers tend not to use HOS to humanise science because they viewed scientists as particularly gifted individuals.

Discussion and conclusion

This study presents two crucial observations: a list of purposes that teachers expressed for integrating the HOS into their teaching and illustrations of the relationships between these purposes and their science teaching orientations. While some previous studies have reported rationales for or benefits of using HOS in teaching, no study has directly focused on what happens in the real classroom dynamics when integrating HOS. The outcomes of this study provide indications of whether teacher orientations are compatible with the ideal benefits described in the literature for HOS teaching.

Many studies have shown that HOS can be of benefit to teachers as a meaningful device for both teaching content and developing an understanding of the NOS (Abd-el-Khalick & Lederman, 2000; Adúriz-Bravo & Izquierdo-Aymerich, 2009; Galili & Hazan, 2001; Lin & Chen, 2002; Seker & Welsh, 2006; Seroglou et al., 1998). For example, Nouri et al. (2019) listed ten instructor rationales for teaching HOS, some of which match our participants' purposes listed under the affective and conceptual domains. Their findings showed that instructors mostly emphasised the role of HOS in helping students develop a positive attitude towards science and scientists. Their participants argued that understanding scientists' mistakes can foster the motivation and creativity necessary for scientific activity (Nouri et al., 2019). Participating science teachers emphasised the use of HOS for affective purposes, such as humanising the scientific process and encouraging students to pursue careers in science. However, our results also revealed that these teachers failed to effectively integrate these educational tools in their teaching practice. The teachers preferred to integrate HOS for pedagogical (15) and conceptual purposes (15) to facilitate conceptual learning. However, the teachers did not target epistemological purposes (6), such as illustrating the tentative nature of science or the role of creativity in scientific inquiry. A similar situation is seen in Wei and Chen's (2021) study on award-winning lesson plans in Macao. They found that these science lesson plans privileged conceptual emphases, to the detriment of epistemological emphases. Nouri et al. (2019) stated that when instructors compare rationales and science teaching strategies, most demonstrate an orientation focused on knowledge and attitude, while instructors who emphasise the development of skills such as scientific process and argumentation are comparatively rare. This result is expected, as the literature indicates that science teachers tend to emphasise conceptual understandings (Gallagher, 1991; Wang & Cox-Petersen, 2002).

Seven out of nine participants, regardless of their teaching orientation, considered themselves as a source of knowledge and emphasised the importance of content knowledge. When science teachers perceive the teaching process as a transfer of correct knowledge to their students, it is difficult to acknowledge the uncertainty of science. Moreover, many teachers, particularly those in the transitional STO profile, reported considerable concerns that portraying science as a part of culture, relying on creativity, would lead to insecurity in science's importance and authority. For example, T7 stated that he did not find the story about thought experiments, which contains messages about the role of imagination and creativity in science, useful for classroom instruction, because students might become sceptical. T7 explained, 'they may just say they are just imagining', while T1 stated that 'if I explain this, physics will collapse, our reliability will be zero'. The physics teachers in particular believed that epistemological or affective purposes are unrelated to the core purpose of science lessons, and that students need to learn precise and correct knowledge. Höttecke and Silva (2011) explained that perceptions of science as a collection of facts is one of the main obstacles to implementing HOS. Likewise, traditional teachers are reluctant to integrate HOS because it conflicts with their beliefs in a single stepwise scientific method and the incompatibility of creativity with this scientific process.

The different integration styles of the reformist teachers stood out in the results of this study. These teachers incorporated the HOS materials into their classes in many different ways, and were the only orientation profile who integrated it for epistemological purposes. The traditional teachers saw the HOS content as just another source of information, whereas the reformist teachers highlighted the role of the materials in developing contextual understandings as a part of their teaching practices. It is reasonable to assume that these teachers' views of science play a critical role in shaping their styles of HOS integration, because their definition of science and views of reality conform to the uncertain nature of science. Similarly, only a few instructors in the study of Nouri and his/her colleagues (2019) study, who reported a strong educational background focused on NOS, shared the belief that the HOS served important epistemological purposes in the classroom. This result shows that if teachers become more informed about NOS, they can integrate the history of science more effectively. It should be noted that teachers, as well as students, often demonstrate naive views about the nature of science (Abd-el-Khalick & BouJaoude, 1997; Abd-el-Khalick & Lederman, 2000; Irez & Bakanay, 2011; Höttecke & Rieß, 2007; Lederman & Lederman, 2014). Considering T2's case, if teachers have misconceptions about NOS, they could give harmful messages about science when using HOS in the classroom, as Kolstø (2008) warned.

Although the materials used in this study were developed to include all aspects of NOS, even the reformist teachers emphasised only the socio-cultural dimensions of NOS in their practice. A review of the literature suggests that historical stories may be more appropriate to reflect the cultural nature of science (Justi & Mendonça, 2016; Kokkotas et al., 2009; Williams & Rudge, 2016). Future quantitative studies should try to establish if the observations from this long-term, small-scale qualitative study is generalisable to a wider population. Others should focus on the reasons why other aspects of NOS such, as the tentative nature of science or paradigm shifts, are less preferred even by informed teachers. This longitudinal study provides an in depth understanding of participating nine teachers teaching orientations and classroom practices related of HOS. However, the results obtained from these participants cannot be generalised, and the readers should decide whether conclusions are transferrable to their own context. It is important to note that the Turkish curriculum has strict objectives that teachers must consider when designing and implementing their lesson plans. Even though the materials developed for this study were prepared according to the Turkish national curriculum objectives and the relationship of each story with the standards in the curriculum was stated in the materials, teachers seemed to experience difficulty integrating these historical objectives into their practices. If teachers do not have sufficient awareness of the history of science's importance in science education, it can be interpreted that the inclusion of the history of science in the curriculum or textbooks is not sufficient. Further analysis of these difficulties will contribute to the development of effective teacher training programmes.

We would like to note that the teachers who participated in this research used historical materials without receiving any additional training. Considering the significant role of HOS in understanding the nature of science, no matter how effective or student-centred the HOS learning materials, teachers' ability to effectively and comprehensively integrate such concepts depends on their science teaching orientation. We believe that teacher perspectives need improvement, which can be accomplished through adequate training in both the nature of science and teaching strategies. Improving teacher education programmes by considering and incorporating HOS both theoretically and pedagogically can facilitate more effective usage of HOS in science education.

Ethical approval

To protect their anonymity, the participants' information like name, institutions are confidential in this study. All phases of the research process are within the approval of participants.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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