International Journal of Progressive Education, Volume 18 Number 2, 2022

Investigating the Scientific Research Inception Process From the Perspectives of Physicists*

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Abstract

The aim of the present study was to explore how physicists start their research studies, how they identify their research questions and what factors influence their involvement in studying a specific research problem. The grounded theory methodology was adopted in the study by considering the qualitative nature of the research questions. The study was completed in two stages. At the initial stage of the study, face-to-face interviews were conducted with physicists to elicit the diversity of their views about the research inception process. At the second stage, an empirically-based multiple-choice survey was prepared on the basis of the themes generated from the responses of the interviewees. 140 physicists working in several Turkish universities completed the survey to reveal how common the diverse views, which were extracted from the interviews, among other physicists. The study results indicated that although physicists started their research studies mostly with a problem, they did not necessarily look actively for a problem when starting a new research study because new problems had already been identified during their previous research. According to the participant physicists, the research inception process was affected by a number of factors related with the available resources and the individual scientist conducting a given research study. These obtained results were discussed in terms of nature of science and nature of scientific inquiry, which are critical issues in science education.

Keywords: Scientists, Scientific Research Inception, Nature of Science

DOI: 10.29329/ijpe.2022.431.19

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* This article is a part of the first author's doctoral dissertation entitled “Development and Application of an Instrument Based on Scientists' Understandings of Scientific Inquiry.” The doctoral thesis was carried out under the supervision of other authors.

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INTRODUCTION

In 1960s, U.S. authorities decided to make radical changes in education after Russia made its mark in history as the first nation to reach space in the cold war era. Americans realized that reforming science education was essential to survive in the competition with Russians. American policy makers set a target to achieve scientific literacy among all U.S. citizens. Training individuals in scientific literacy, in turn, became a common goal for science education almost all around the world. Turkey was also among the countries that pursued this common goal. In Turkey, training individuals with scientific literacy has been considered to be important since 2005. Although scientific literacy has become a global concept, researchers have yet to agree on a single definition of it. However, there are certain assumptions about the knowledge expected from individuals with scientific literacy. Individuals with scientific literacy must reportedly possess a contemporary understanding of epistemic and process knowledge concerning the generation of information (OECD, 2016). While the epistemic knowledge pertains to nature of science (NOS), the process knowledge is regarded as nature of scientific inquiry (NOSI) (Lederman, Antink, & Bartos, 2014; Schwartz, Lederman, & Crawford, 2004). Therefore, a scientifically literate individual is expected to possess a contemporary understanding of both NOS and NOSI.

In science education literature, the concepts of NOS and NOSI are intertwined and generically addressed as NOS. While NOS is generally related to the status and structure of the scientific knowledge, NOSI is usually connected with the production and justification processes of the scientific knowledge. Despite on-going discussions on what students need to be taught with respect to NOS, a group of researchers were reported to have reached a consensus view (Abd-El-Khalick, 2012; Lederman, 2006; McComas & Olson, 2002; Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003). On the other hand, other researchers heavily criticized the consensus view and offered new suggestions thereto by referring its certain shortcomings and weaknesses (Allchin, 2017; Erduran & Dagher, 2014; Hodson & Wong, 2014; Irzik & Nola, 2011). A review of the relevant literature reveals that the opinions of scientists were not sufficiently included in the efforts to reach such consensus view. In a limited number of research studies involving scientists as participants, the conceptions of scientists about NOS were classified either as conventional/inadequate (e.g. Aydeniz & Bilican, 2014) or almost completely unaligned with the current research results (e.g. Wong & Hodson, 2009). In other words, NOS conceptions of scientists in the literature were generally described as inadequate in comparison with the standards set primarily by science educators. That was partly because the opinions of scientists had usually been ignored in constructing the standards about NOS and NOSI concepts. Consequently, there are perceived differences between the opinions of science educators and scientists when it comes to NOS concepts. A plausible reconciliation of such differences requires a comprehensive depiction of the opinions of scientists. Considering their individual fields of expertise and the time they devote to their own research studies, it is important that scientists should be given a voice in characterizing scientific research process. The results obtained from studies investigating the opinions of scientists would enrich the literature concerning NOS and NOSI.

Due to the extensive nature of the notions involved in NOS and NOSI, the conceptual scope of the present study was solely restricted to the scientific research inception process. In the literature, issues related to the research inception process were mostly discussed under NOSI. Researchers advocating the consensus view objected to the conventional understanding of the scientific method, which prescribed that the first step of all scientific investigations included a hypothesis. They instead asserted that all scientific investigations begin with a question (Lederman et al., 2014; Schwartz, Lederman, & Lederman, 2008). On the other hand, Irzik and Nola (2011; 2014) criticized consensus view and offered family resemblance approach. In this approach, all scientific areas are represented by the following four family characteristics: aims and values of science, scientific methods, scientific practices, and scientific knowledge. They argued that all fields of science incorporated generic cognitive practices such as formulating a problem or a question and generating a solution. Although scientific questions or problems were regarded generally as the starting point of scientific inquiry in science education literature, there were no detailed explanations about the research inception process. Conducting a research study with scientists actively working in the field would uncover their diverse views about the research inception process. For that purpose, the views of physicists working in various subdisciplines of physics with different academic titles were investigated in this study. Besides, different research approaches of the participant physicists, namely experimental, observational and theoretical, were also identified as an important variable of the study. Therefore, the study aimed to explore the scientific research inception process as declared by physicists working in diverse subdisciplines of physics, adopting various research approaches and having different academic titles. The study sought answers to the following research questions:

1. How do physicists start scientific research?
2. How do physicists identify their research questions?
3. What are the factors affecting physicists in the research inception process?
4. How do the different research approaches of physicists influence their research inception process?
5. How do the specific research fields of physicists influence their research inception process?
6. How do the academic titles of physicists influence their research inception process?

Study Design

The research questions in the present study was addressed with the assumption that individuals construct their own realities based on their personal experiences and our understanding of these peculiar realities takes place only through interpreting their expressions. That is the main reason that we adopted interpretivism as our theoretical framework. As the research methodology, the grounded theory, which was reported by Suddaby (2006) as the most suitable design to understand a process that respondents experience personally and construct a meaning for, guided the research study. In addition, theoretical sampling technique used in the grounded theory design was appropriate for unveiling the diverse perspectives held by the participant physicists in the study. In theoretical sampling, the data collection process is guided by theoretical developments emerging from the analysis of past data. This helps the researcher present data, which pertain to the concepts under research, from a wider perspective. That is mainly because the grounded theory is the product of inductive reasoning prioritizing data in constructing the theories. The initial stage of the two-stage study was conducted with face-to-face interviews with the physicists. The data obtained from the interviews were analyzed to put forth theoretical arguments concerning the scientific research inception process conceptualized by the physicists. In the second stage of the study, interview analyses were followed by the development of empirically-based multiple-choice questions as a technique similar to the one employed by Aikenhead & Ryan (1992) to test the accuracy and adequacy of such theoretical arguments. The research process was completed by applying the multiple choice questions, which was constructed from the theoretical arguments, to a larger group of physicists. This yielded useful information about the accuracy and adequacy of theoretical arguments generated from the views of the interviewed physicists.

Participants

The two-stage structure of the research study required two separate groups of participants. The initial stage of the research study included interviews with scientists working in the various subfields of physics. The scientists to be interviewed during this stage were selected through a convenience sampling strategy. All interviews performed by the first author, and she has already known the physicists with whom the interviews were conducted. Based on this acquaintance, it was aimed to reveal the in-depth views of the participant physicists. In line with the nature of grounded theory design, several interviews were held with selected physicists until data saturation was achieved. This process started with requests submitted to selected physicists for conducting preliminary interviews aiming to introduce them to the research study. Physicists who agreed to take part in the study during these preliminary interviews were included in the actual interviews. The interviews were concluded once a decision had been made concerning the achievement of data saturation as entailed by theoretical sampling principle in the grounded theory. Data saturation was reached in the first stage of the study after conducting interviews with a total of 19 physicists, 10 of whom were postdoctoral scientists and 9 of whom were doctoral students. In order to fulfil the maximum-diversity sampling strategy, efforts were spent as much as possible to interview with respondents working in various subfields of physics and employing different research approaches. Therefore, interviews were made with physicists conducting observational, theoretical and experimental research studies.

For the second stage of the research study, a multiple-choice test generated from the interview responses of the participants in the first stage of the study was submitted to scientists and candidate scientists by e-mail. The questions were sent to 1616 scholars in the field of physics at various universities in Turkey and attracted responses from 140 physicists. Some characteristics of the participants are given in the Table 1.

Table 1 Some characteristics of the participants

First study group*			Research Approaches	Second study group**		
Postdoctoral Physicists	Doctoral Students	Research Fields		Research Fields	Postdoctoral Physicists	Doctoral Students
DD1	LD1, LD2	Solid-State Physics	Experimental	Solid-State Physics	20	15
				Atomic & Molecular Physics	12	3
				High Energy & Plasma Physics	3	3
				Nuclear Physics	5	-
				Astrophysics & Astronomy	1	1
				Other	1	2
DG1, DG2, DG3, DG4, DG5, DG6	LG1, LG2, LG3, LG4	Astrophysics & Astronomy	Observational	Astrophysics & Astronomy	7	5
				Other	2	2
DT1	LT1, LT2, LT3	Mathematical Physics	Theoretical	Solid-State Physics	9	4
				Atomic & Molecular Physics	7	2
				High Energy & Plasma Physics	8	1
DT2		Atomic & Molecular Physics		Mathematical Physics	7	1
				Nuclear Physics	2	5
DT3		High Energy & Plasma Physics		Astrophysics & Astronomy	4	1
				General Physics	3	1
				Other	2	1

* Code names of participants
** Number of participants

Data Collection Process

The data required for the first stage of the research study were collected through interviews with respondents. The initial interview form was prepared on the basis of the relevant literature. Pilot interviews were held with two scholars, one of whom was a scientist and one of whom was a scientist candidate conducting research in the field of physics. However, the nature of grounded theory design allows for a level of flexibility in that the interview questions can be modified at each interview depending on the outputs of the previous interview. Each interview was guided by the questions in the interview form and took between 45 and 90 minutes to complete. Almost all the interviews were recorded on a voice recorder. However, since two respondents did not agree to voice recording, their interviews were recorded in written notes.

The second stage of the research study was conducted with multiple-choice questions prepared on the basis of the outputs of interviews. In the preparation of multiple-choice questions, the procedure suggested by Aikenhead and Ryan (1992) was followed as an example. The data collected from the interviews were analyzed following the process proposed by Charmaz (2014) for the grounded theory design. The choices in the multiple-choice questions were formulated from the axial codes identified as a result of the coding process. As the choices were determined through the interviews conducted with the respondents, each question was structured with a different number of choices. Each question was also supplemented with the option "None of these choices represent my opinion" in addition to the choices. Any respondent marking this option was requested to write in their opinions in an open-ended field. The title "Understandings on Scientific Research" of the multiple-choice survey is abbreviated as BAHA (based on Turkish initials) and will be referred to as such for the rest of the study.

Data Analysis Process

The data collected from the interviews held during the initial stage of the research study were analyzed through the constant comparative method as a specific component of the grounded theory design. In addition, this stage followed the initial coding, axial coding, and theoretical coding as proposed for the grounded theory design (Charmaz, 2014; Glaser & Strauss, 1967). In the initial coding stage, all interview transcripts were encoded line by line. In-vivo codes were also used as much as possible during this stage. The specific relationships among the codes created in the initial coding stage were built in the axial coding stage. Finally, in the last stage of the coding process, theoretical codes were created based on the relationships between axial codes. Maxqda 12, qualitative data analysis software, was employed in the coding process.

In the second stage of the research study, the multiple-choice questions were formulated in line with the axial codes identified as a result of the analysis of qualitative data. While one code attracted multiple choices in some cases, two different codes were combined to represent a single choice in some other cases. If one code was considered to have been represented in other choices, it was not supplemented with a specific choice. The process of formulating the choices was guided by the differences between the expressions as the main concern. As an example, the analysis of the responses received to the question concerning the factors affecting the research inception process revealed the theoretical codes of persons, resources, study environment, and research. The code named 'persons' was represented by three different choices while the codes named 'resources' and 'research' were translated into 1 choice each. On the other hand, the code named 'environment' was not shaped into a separate choice, as it is included in both one choice concerning scientists (affected by persons in the study environment) and one choice concerning resources (physical circumstances in the study environment).

FINDINGS

The findings obtained as a result of the present two-stage study will be elaborated under three headings. Each heading will, in turn, feature the findings of the interviews followed by the findings identified with BAHA. All axial and theoretical codes designated in the first stage of the study were given in Table 2.

Opinions of scientists on the research inception process

Five axial codes were designated through the analysis of the opinions of scientists as to how they start their research studies. These codes were named as literature, scientific question, hypothesis, subject, and problem. All of the axial codes were thus formulated featuring the opinion of at least one observational physicist. On the other hand, theoretical physicists offered their opinions on scientific questions, subject, and problem codes, while experimental physicists indicated their research inception to be limited only to the literature and a hypothesis.

In response to the question on the starting point for research, some of the physicists pointed out to **literature review** as one of such starting points. As an observational physicist and continuing her/his doctoral education, LG3 stated that all scientific research started with literature review regardless of the specific field with the following statement: *"In my opinion, the initial stage of literature review and background study applies to all sciences, whether social or physical."*

Table 2. All axial and theoretical codes

Opinions of scientists on the research inception process	Opinions of scientists on how they determine research questions		Opinions of scientists about the factors affecting them in the research inception process	
Axial codes	*Axial codes*	*Theoretical codes*	*Axial codes*	*Theoretical codes*
Literature review	Scientists themselves	Persons	The background of the scientists	Persons
Scientific questions	Advisor		The internal motivation of the scientists	
	Other scientists		Other scientists	
Hypothesis	Following up to literature	Literature	Technical resources	Resources
	Identifying the shortcomings in the literature		Access to publications	
Subject	Subjects not yet Studied in the Literature		Study environment	
	Theories and Laws	Theories and Laws		
Problem	Failing to Generalize Theories and Laws		Research	
	Failing to Support Theories and Laws			

Scientific questions represent another starting point indicated by the interviewed scientists. LG1, was an observational doctoral student with experience in a project abroad and in multiple projects of a national scale. LG1 stated that they started research with questions by saying, *"You need to have a question in your mind; is this really the case? You need to collect data for this question."*. DT2, a theoretical physicist and 15 years of experience in the field, offered the following opinion to indicate that she/he started her/his own research with questions and everyone, involved in positive sciences do the same: *"I can say a question first and foremost. ...In fact, I don't know if this is a hypothesis in essence, but I can say more definitely that we start with questions."*

Using a **hypothesis** is another way to start research pointed out by some participant physicists. DD1, an experimental physicist, stated that her/his starting point for scientific research was a hypothesis: *"We conduct our experiment according to that hypothesis"*. LG3, a doctoral student, involved in observational studies in astronomy, also indicated her/his starting point to be a hypothesis by saying, *"there must be a hypothesis, the first piece should always be that"*.

Another starting point for scientific research as addressed in the opinions of scientists is the designation of a **subject**. DG5, an observational physicist in astronomy with a post-doctorate degree abroad, expressed her/his opinions on the question as follows: *"You first choose your subject. While choosing a subject, you start a literature ... review. While doing that, I seek something that has not been studied or something that appears interesting to me."*

Another axial code we identify in the discourses of the interviewed scientists is research inception with a **problem** or by specifying a problem. This axial code was formulated with such initial codes as identifying the problem, presenting a problem, or finding and specifying a problem. DT3, an experienced theoretical physicist and with a self-proclaimed interest in philosophy of science, explained that any scientific research primarily requires a problem: *"Any scientific research primarily* *requires a problem. If you are in it yourself, you find the problem or specify the problem yourself. There are stages to it. Firstly, the problem needs to be specified."* DT1, theoretical physicist in mathematical physics, elaborated on what the problem should be and indicated her/his starting point to be a problem by saying, *"the starting point should be an original problem that will contribute to science".*

For the purposes of the second stage of the study, a multiple-choice question was prepared based on the axial codes identified from the opinions of interviewed physicists. The multiple-choice question and the corresponding responses of the physicists were given in Table 3. Three exceptions emerged when the fields of research were considered. Half and more than half of the physicists, involved in general physics and in fields represented by "other", respectively, marked the option indicating the starting point for scientific research to be scientific questions. The second exception arises from one-fourth of the nuclear physicists marking problem as their starting point and another one-fourth marking hypothesis for the same question. The great majority of researchers marking hypothesis as their starting point for scientific research are involved in nuclear physics. The third exception pertains to the high-energy physicists and plasma physicists. 36 % of these physicists marked the option for starting research with a problem, while the remaining physicists marked scientific question, literature review, and designation of a subject with a share of 17 % each.

Table 3 The multiple-choice question and the breakdown of responses as percentages about starting scientific research

		Research approaches*			Research fields†								Academic titles				
Scientific research starts with	Total (140)	Experimental (68)	Theoretical (58)	Observational (17)	Astrophysics & Astronomy (19)	Atomic & Molecular Physics (24)	General Physics (6)	Solid-State Physics (48)	Mathematical Physics (10)	Nuclear Physics (12)	High Energy & Plasma Physics (14)	Others (7)	Professor (32)	Associate Professor (33)	Assistant Professor (23)	Doctor (12)	Research Assistant (40)
a scientific question.	27	23	33	29	42	42	50	15	20	17	21	57	28	27	31	8	32
the designation and specification of a problem.	47	46	45	53	48	46	33	56	60	25	36	29	56	40	52	58	38
a hypothesis.	3	3	3	6	5	-	-	-	-	25	-	-	-	-	-	17	5
literature review.	9	10	5	12	5	8	-	6	10	8	21	14	6	9	13	-	10
the designation of a subject.	12	18	9	-	-	4	17	19	10	17	21	-	10	21	4	17	10
None of the choices reflect my opinion.	2	-	5	-	-	-	-	4	-	8	-	-	-	3	-	-	5

The numbers in parentheses indicate the number of participants included in that group.
Some participants wrote two different statements for their research approach (E.g., both experimental and theoretical). In this case, they were considered both experimental and theoretical. Therefore, the total number of participants (143) appears to be more than the number of participants in the research.
† *Medical physics, phonetics, optics and climate physics were grouped as others.*

Considering the exceptions in terms of academic titles, physicists with the doctorate title were observed to have marked the choice for starting research with a hypothesis and a subject to a greater extent than starting with scientific questions. An assessment of the responses in terms of academic titles, the choice for hypothesis was not marked by any scientist with the title of professor, associate professor, or doctor, but by a small number of physicists holding the doctorate title or in the process of completing their doctorate degree.

Finally, 3 physicists specified that none of the choices reflected their opinions. An associate professor, theoretical physicist in solid-state physics, wrote *"all of the above"* in the open-ended remarks field and indicated that scientific research could start with a scientific question, a problem, a hypothesis, literature review, and designation of a subject. The two remaining physicists indicating that the choices did not reflect their opinions were research assistants and one of them was, involved in theoretical studies in nuclear physics and the other in solid-state physics. Out of these physicists, the one, solid-state physicist, explained her/his response by stating, *"I think this question does not have a single answer".* The other physicist, involved in nuclear physics, indicated that research could start with questions, whether or not of a scientific nature, as follows: *"Scientific research starts with questions, which may easily be of an ordinary nature.*

Opinions of scientists on how they determine research questions

Another research question of the study was to uncover the opinions of physicists about the process of determining their research questions or problems as they started a new research study. The question as to the starting point for scientific research was supplemented with a discussion on how they make the choice as such in order to identify the opinions of the physicists on the matter.

The first axial code, **the scientist themselves**, was the result of the opinions of the scientists to the effect that new research questions emerged during and as a result of their own research studies and any scientist working in a specific field would already know the current problems affecting the field concerned. LG1, a doctoral student indicating scientific questions as her/his starting point for scientific research, said *"questions generate more questions",* while LT2, a doctoral student in high-energy astrophysics, stated *"while dealing with a problem, that research study may branch out before I reach my desired destination"* and these opinions gave way to the understanding that new research questions emerged already during the research studies conducted by scientists themselves. DT3, a theoretical scientist, explained that they found the problem themselves with the following sentences: "*I don't know how I specify the problem; the problem finds me. It hits me in the face while I read something. I found the solution method for my doctoral dissertation in the open market. My research subject was always on my mind those days."*

Another axial code formulated under the theoretical code of persons is the **advisor** code. This code consists of opinions indicating that research questions are determined on the basis of a suggestion or approval from the respective advisor and the advisor has an impact on the entire research career of a scientist. As can be expected, this code was predominantly composed of opinions from doctoral students. In addition, two scientists that had completed their doctorate degree also mentioned the effect of the advisor on research inception. One of these scientists, DG1, used the following statements to indicate how research subjects were formulated with the effect of the advisor in a master-apprentice relationship: *"First of all, there is, perhaps, a master-apprentice relationship in science – it is not pronounced or defined much, but I can say that in clarification. All in all, when we enter this field and start working, we are guided and affected by certain teachers…. They are primarily the ones determining the research subject. At least, I can say that this was the case for me."*

The final axial code in the theoretical code of persons is the code for **other scientists**. This code was created through analysing the diverse opinions of the participant physicists who expressed that researchers should consult with leading expert scientists in a specific field and contact with other scientists to receive their assistance or to benefit from their experiences. DG4, a scientist with years of experience in her/his field, stated that other scientists were influential on the determination of research questions by stating, *"… first of all, being in contact with other scientists in one's field. Being able to follow up any events organised in that field to the extent possible. For example, if one follows up scientific meetings, seminars, and workshops, they have better guidance for their studies".*

In the study, there were some physicists who made specific references to the **literature** in their responses to the question of how they determine their research questions. The physicists specifically pointed out to following up the literature and identifying the shortcomings or subjects not yet studied in the literature. These responses gave way to the theoretical code of literature. With respect to following up the literature, the physicists referred to knowing what has been done, reading the literature to do something new, and keeping abreast of the constantly developing literature. LG3, a doctoral student, deliberated on knowing the literature well as follows: *“science ... moves fast and we always have to keep abreast of the literature and you have to know what those before you have done so that you can add something to that…”* Identifying the shortcomings in the literature represents another axial code under the theoretical code of literature. This axial code was the product of opinions indicating that research questions would be formulated on the basis of any issues missing in publications or not covered by other research studies. DT3 stated, *“We review previous studies on the subject, read the previous studies. We identify the shortcomings of previous studies”* as an example representative of the axial code of identifying the shortcomings in the literature.

The final axial code pertaining to the theoretical code of literature is the code for identifying subjects not yet studied in the literature. The opinions considered under this code point out to the need to find subjects not studied before in the literature and something that has not been done before. Scientist DG3 used the following statements with respect to the need to find what has not been done before through literature review, even though she/he also pointed out to the difficulty of a subject not covered in the literature in her/his respective field of research: *“So, reviewing the literature and sorting out what has not been done with respect to your own field. As I have said just now, current studies concerning ... have currently fallen into a vicious circle and so, it is a bit problematic to find something that has not been done before.”*

The theoretical code of **theories and laws** is the final code arising from the opinions of the scientists on how they determine their research subjects. The opinions grouped under this code consists of the axial codes of failing to generalize theories and laws and failing to support theories in the determination of research questions. All opinions addressed under the axial code for theories and laws were expressed by physicists, involved in theoretical studies with one scientist and two doctoral students. One of the doctoral students, LT1, pointed out to the correlation between questions and theory by saying, *“this question and curiosity are actually shaped according to an existing theory. In my case, it is theory of general relativity”.*

A multiple-choice question was prepared based on the axial codes identified from the opinions concerning the starting point for research as exemplified above. The multiple-choice question was thus formulated and the breakdown of responses was given in Table 4. As can be seen in the table, 36% of the scientists who responded to the BAHA marked the option indicating that their research studies give way to the formulation of their next research question.

Table 4. The multiple-choice question and the breakdown of responses as percentages about how research question are emerged

		Research approaches*			Research fields†								Academic titles				
New research questions emerge	Total (140)	Experimental (68)	Theoretical (58)	Observational (17)	Astrophysics & Astronomy (19)	Atomic & Molecular Physics (24)	General Physics (6)	Solid-State Physics (48)	Mathematical Physics (10)	Nuclear Physics (12)	High Energy & Plasma Physics (14)	Others (7)	Professor (32)	Associate Professor (33)	Assistant Professor (23)	Doctor (12)	Research Assistant (40)
during and as a result of scientists own research studies	36	35	36	41	32	46	50	23	50	58	50	14	31	39	35	50	35
with the effect of the post-graduate advisor.	23	21	7	6	5	25	-	19	-	-	8	14	22	10	4	-	18

with the effect of the results of research undertaken by leading scientists in the respective field.	24	21	26	24	16	8	50	33	20	17	14	44	28	18	26	25	22
line with theories and laws governing the respective field.	19	16	22	24	32	17	-	17	30	25	14	14	16	18	31	17	18
None of the choices reflect my opinion.	8	7	9	6	16	4	-	8	-	-	14	14	3	15	4	8	7

The numbers in parentheses indicate the number of participants included in that group.
[*]Some participants wrote two different statements for their research approach (E.g., both experimental and theoretical). In this case, they were considered both experimental and theoretical. Therefore, the total number of participants (143) appears to be more than the number of participants in the research.
[†] Medical physics, phonetics, optics and climate physics were grouped as others.

The most striking finding when considering the table with research approaches is that only rather a small portion of observational and theoretical physicists marked the choice concerning the effect of the advisor on the determination of research questions, while the same choice was marked by one-fifth of experimental physicists.

A review of the table specifying the breakdown of fields of research among the physicists, an equal number of astrophysicists were observed to have marked each of the choices indicating that their current research would lead to the formulation of their next research questions and their research questions would be shaped in line with theories and laws governing the respective field. On the other hand, general physicists equally marked the choice indicating that research questions were formulated during current research studies and the choice relating to the effect of the results of research undertaken by leading scientists in the respective field. Physicists declaring their field of research as solid-state physics and medical physics, phonetics, and optics, etc. were grouped as other scientists and indicated, as a different opinion than those of the other responding physicists, that their new research questions were formulated mainly with the impact of the results of research studies undertaken by leading scientists in the respective field.

8 % of the physicists, i.e. 11 physicists, marked the choice indicating that none of the choices represented their opinions. Three physicists, involved in high-energy and plasma physics, astronomy, astrophysics, and space sciences and solid-state physics as associate professors stated in their remarks that all of the choices applied to the determination of research questions. A high-energy and plasma physicist also pointed out to the effect of a scientist's imagination: *"All of the above apply to the determination of research questions for scientists. In addition, they also use their intuition and imagination to offer a different perspective and propose solutions to existing studies."* Two of the experimental physicists, who were titled as research assistants in the field of solid-state physics, were observed in their remarks to have been torn between two choices. As an example, a high-energy and plasma physicist as an associate professor, wrote *"between 1 and 4"* to express her/his opinion that the research studies undertaken by scientists gave way to new questions and at the same time, research questions were also formulated in accordance with theories and laws. One experimental solid-state physicist as a member of faculty with PhD, declared her/his hesitation between two choices by stating, *"Subjects and relevant questions appear as a result of both the research undertaken by scientists and the research undertaken by other scientists"*. As explained above, no physicist with the doctorate title marked the choice pertaining to the effect of the advisor in the determination of research questions. Indicating that none of the choices reflected their opinion, a solid-state physicist as a doctor offered the following comment on the effect of the advisor: *"The effect of the advisor is relevant in the beginning, then, as the scientist develops further in science, they ask their own questions and generate specific scientific objectives for themselves."* Among other physicists indicating that none of the choices featured in the BAHA reflected their opinions, one atomic and molecular physicist offered a remark

similar to the choice indicating that the research studies undertaken by a given scientist would generate new questions. The convergence of the remark of our physicist with the professor title with the choice was apparent in their following statement: *"Questions appear in the process of solving the original question designated for research."* Finally, a solid-state physicist as a member of the faculty with PhD, explained how research studies were sometimes shaped entirely out of curiosity as follows: *"Sometimes, there are already certain questions tied to a problem. In other words, the research questions are ready. Other times, there is no question embodied in the problem, but mere curiosity over a subject. Research studies conducted to satisfy such curiosity produce the questions spontaneously."*

Consequently, physicists are observed to reach a consensus on certain opinions concerning how questions are formulated for the purposes of scientific research. The choices designated for the BAHA are in considerable consistency with the opinions of physicists.

Opinions of scientists on the factors affecting them in the research inception process

Participant physicists were not only asked how they started the scientific research process and how they determined the research questions but also how they identified the specific factors influencing them in this process. The opinions of the interviewees were represented with the following theoretical codes: persons, resources, study environment, and research.

The responses of the interviewed scientists who pointed out to themselves and other scientists as factors of influence on the research process were compiled under the theoretical code of **persons**. The theoretical code of persons consists of the axial codes of the background of the scientist, the internal motivation of the scientist, and other scientists. The scientists we interviewed for the initial stage of the research study indicated that the research process was affected by the background potential, knowledge, educational background, and experience of the scientist. Such expressions gave way to the understanding that the background of a given scientist is influential on the scientific research inception process and thus, to the designation of the relevant axial code. LG2 explained that research studies were shaped in line with the educational background of the scientist by stating, *"The education you receive more or less shapes what you will do. A scientist acts on the basis of such knowledge",* while DG4 used the following statements with respect to experience: *"Now, I am educated. I am a scientist. I have already been involved in scientific research and teamwork right from the start owing to master's and doctorate studies. There, I learn the process and gain experience."*

According to the opinions of the physicists, another factor of influence on the scientific research inception process is the motivation of a given scientist. This category covers discourses mentioning such concepts as internal motivation, impulses, and eagerness. DG3, a doctoral student, indicated that her/his own laziness and procrastination were influential on the research process: *"as I have said, the environment has an impact to an extent, but it is mostly about me, because I procrastinate a bit and am a lazy person."*

Another axial code under the theoretical code of persons, formulated with respect to the factors affecting the scientific research inception process, is the code for other scientists. The opinions compiled in this category relate to scientists in the study environment and scientists in the scientific community. The physicists expressed that the hard work of scientists in the study environment, or lack thereof, was influential on scientists.

Another theoretical code emerging from the opinions of the physicists with respect to the factors of influence on the scientific research inception process relates to the code of **resources**. The said code consists of the axial codes of technical resources and access to publications. Nearly all of the opinions in the categories of technical resources are sourced from observational physicists.

The opinions received with respect to administrative burden, office hours, and the working culture of the country gave way to the formulation of a code for the **study environment**. LG2, a doctorate student employed as a research assistant, stated that unscheduled work burden affected her/his studies: *"if it is scheduled, it's fine, as I like to work on a schedule. So, any tasks given to me outside of my schedule directly affect me …What matters is when and where a task is to be done rather than its size; for me, it should be on a scheduled format."* Another doctoral student, LG1, pointed out to the effect of office hours by stating, *"For example, research assistants are regarded as public servants and expected to stay in office from 8 to 17.00. But they may be working at nights. Maybe working until the morning. You then ask them to be at the office at 8 in the morning. You also burden them with daily tasks".* The other opinions considered under the code of study environment mentioned the effect of the working conditions of the country. *DG4,* an experienced scientist, emphasized the study environment as an influential factor by saying, *"In my opinion, it has something to do with the culture; unfortunately, this is our greatest disadvantage, this is our culture. Trying to make money the easiest way, without working to the extent possible. This is the mindset we have".*

The final code concerning the factors affecting the scientific research inception process in line with the opinions of the physicists is the code of **research**. The physicists with opinions under this axial code mentioned such factors as the reasonable time required for the conduct of a study, the ability of the researcher to conduct the study, and the publishability of the research.

As a result of the interviews held with physicists, two questions were prepared for the BAHA on the basis of the axial codes identified during the interviews with respect to the factors affecting the scientific research inception process. The first of these questions asked scientists *"In your opinion, are there any factors affecting scientists in the research inception process?".* 9 out of the scientists responding to the BAHA (~6 %) indicated that scientists could not be affected by any factor in the scientific research inception process. The 131 remaining scientists marked the choice indicating that scientists could be affected by certain factors in the scientific research inception process. The second question prepared for the BAHA and the breakdown of responding scientists by their responses are specified in Table 5. A review of the table shows that scientists in physics focused on three choices in their responses concerning the factors of influence on the scientific research inception process. These choices cover expressions relating to the background of the scientist, internal motivation of the scientist, and resources.

Table 5. The multiple-choice question and the breakdown of responses as percentages about factors in the process of starting scientific research

		Research approaches[*]			Research fields[†]								Academic titles				
In the process of starting scientific research, scientists are affected by	Total (140)	Experimental (68)	Theoretical (58)	Observational (17)	Astrophysics & Astronomy (19)	Atomic & Molecular Physics (24)	General Physics (6)	Solid-State Physics (48)	Mathematical Physics (10)	Nuclear Physics (12)	High Energy & Plasma Physics (14)	Others (7)	Professor (32)	Associate Professor (33)	Assistant Professor (23)	Doctor (12)	Research Assistant (40)
their own background.	30	25	38	27	33	39	60	28	0	20	33	33	18	39	32	8	38
their internal motivation.	29	26	31	27	33	22	40	31	56	30	8	17	32	14	41	50	23
their colleagues.	1	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	3
the availability of resources.	32	42	17	40	22	39	0	37	11	30	42	33	43	36	27	25	26
feasibility and publishability of research studies.	5	3	8	6	0	0	0	0	33	10	17	17	7	4	0	8	7
None of the choices reflect my opinion.	3	3	6	0	11	0	0	2	0	10	0	0	0	7	0	8	3

The numbers in parentheses indicate the number of participants included in that group.
[*]*Some participants wrote two different statements for their research approach (E.g., both experimental and theoretical). In this case, they were considered both experimental and theoretical. Therefore, the total number of participants (143) appears to be more than the number of participants in the research.*
[†] *Medical physics, phonetics, optics and climate physics were grouped as others.*

Considering the variety of research approaches, 40 % of the scientists involved in experimental and observational studies indicated resources as an influential factor, while this ratio was naturally lower among scientists involved in theoretical studies. Almost one-fourth of the scientists involved in theoretical studies marked factors pertaining to the scientist themselves. Scientists involved in experimental and observational studies marked the choices pertaining to the scientist themselves in approximately equal shares.

A review of the factors considered by the scientists to be influential on the scientific research inception process by academic titles indicated that scientists with the professor title mostly pointed out to resources as a factor of influence. On the other hand, scientists with the titles of associate professor, research assistant, and expert mostly marked the background of a given scientists as a factor. The striking finding from the perspective of academic titles was that slightly less than half of the members of the faculty with PhD and half of the doctors indicated internal motivation to be an influential factor.

DISCUSSION AND CONCLUSION

As a brief summary of the results of the present study, the participant physicists reported that they started their research studies mostly by specifying a problem or a scientific question. With respect to the determination of such problem or scientific question, the respondents most frequently expressed that their preceding research studies generated the specific questions of their subsequent research studies. In a specific subdiscipline of physics, the research studies conducted by some influential scholars also played an important role in developing their research questions. The participant physicists expressed that the scientific research inception process was affected by some factors such as the availability of sufficient resources, and the background and internal motivation of the scientists. At this point, it should be emphasized that the present study did not aim to offer any generalization or statistical relationship about scientists' opinions of the scientific research inception process. It aimed to unveil the diverse opinions of physicists conducting research studies in various subfields of physics. The results of the study verified that there existed no single course or method of action pursued by all physicists to conduct their scientific research studies. In addition, a specific pattern was almost impossible to detect in the answers given by participant physicists to multiple-choice questions based on their specific research approaches, fields of research and academic titles.

However, certain differences observed during the study warrant more emphasis. In response to the question as to how scientists started their research, only 4 out of 140 responding physicists (3%) acknowledged a hypothesis as a starting point in their research studies. 3 of these scientists involved in nuclear physics (one-fourth of the scientists involved in nuclear physics) and 1 in astronomy and astrophysics. These 4 scientists are either doctors or PhD candidates. One of these scientists stated that they were involved in experimental studies, another one in theoretical studies, another one in observational studies, and the last one in both experimental and theoretical studies. At this point, it is impossible to comment on their research approaches. Our lack of knowledge on the respective research subjects precludes us from offering any comment on this matter, as well.

Another striking difference observed in the study was that the higher number of the physicists in the field of solid-state physics marked the option of determining research questions from the results of research studies undertaken by leading scientists in the respective field than those of physicists in other fields. Although providing a readily available explanation to this difference is an uneasy task, it may stem from the specific nature of solid-state physics. Solid-state physics is quite an extensive field encompassing such concepts as the structure of solids, material physics, superconductivity, and semi-conductivity. There are fast-paced developments today in the field along with the rapid advancements in technology. Leading physicists in the field may adapt to such rapid changes and guide the field accordingly. Therefore, the research studies conducted by leading physicists in solid-state physics help other physicists in the field decide the scientific questions to investigate in their respective research projects.

One another result to be underlined in this study was related to the influence of the graduate academic advisors on determining the research questions to be pursued in research studies. While none of the physicists with a postdoctoral title preferred to choose the option that new research questions emerged with the main influence of the major professors, only 4 % of the assistant professors chose this option. In comparison to other scholars, this option was selected by the professors with a highest rate of 22 percent. It is usually the case that the majority of the postdoctoral physicists and the assistant professors in Turkish universities are generally the academicians who recently completed their doctoral degrees. The physicists with the professor titles generally take the major responsibility in providing the academic advising to these doctoral students. In terms of initiating new research questions, there seems to be a noticeable difference between the notions of the physicists with relatively recent PhD degrees and the professors as their graduate advisors. Another interesting point of the study was that only one physicists selected the option that their colleagues were influential in the research inception process. This meant that physicists having various academic titles and adopting different research approaches recognized that their colleagues were the least influential factor in initiating the new research questions. In consideration of this result indicating the limited influence of their academic advisors and colleagues on the research inception process, it would be worthwhile to investigate the mutual interactions and communications of the scientists further by future research studies in order to gain a better understanding of the human factor in the scientific research.

In response to the question concerning the factors of influence on scientific research inception process, most of the responding observational and experimental physicists marked the choice resources. This result is somewhat expected as observational and experimental physicists need more equipment than theoretical physicists to conduct their research studies. On the other hand, the theoretical physicists emphasized more the factors relevant to themselves as the individual scientists working in the field. When it comes to the influence of the specific subfields of the participant physicists to their research inception process, none of the physicists in mathematical physics tended to choose the option of the background of a given scientist. In comparison to 5 % of all responding physicists, 33 % of the mathematical physicists marked the choice the feasibility and publishability of research studies as a factor influencing the research inception process. This difference between the mathematical physicists and the other physicists in the study might be resulted from the specific nature of their respective field of research. Mathematics is generally accepted as a formal science, which embraces rationalism as opposed to empiricism adopted primarily by natural sciences. In other words, formal sciences like mathematics as in our case have a special structure based on certain axioms and assumptions. In contrast to scientists, including physicists in this study, in natural sciences who dominantly maintain an inductive approach in their research projects and thinking perspectives, mathematicians generally hold a deductive approach. Considering the aforementioned differences between mathematics and physics, it would not be too odd to observe that scientists working in the field of mathematical physics possess some diverging views from the physicists in other subdisciplines of physics. The relatively higher rate of mathematical physicists in the study who supported the feasibility and publishability of studies in the research inception process might be attributed chiefly to these peculiar disciplinary differences. As a result, the present research study indicates that each sub-discipline of physics is of a specific nature of its own and therefore, there is no single course or standard model of action with respect to the scientific research inception process.

In the context of the scientific research inception process, Lederman et al., (2014) reported that all scientific research started with a question and did not necessarily require the designation of a hypothesis as dictated by the conventional understanding of the scientific method. Certain studies conducted in Turkey also maintained that scientific research started with questions (Bostan-Sarıoğlan, 2018; Yenice & Özden, 2016). Furthermore, according to the textbooks distributed by the Turkish Ministry of National Education, it is reported that scientific research starts with a question in the 6^{th} grade science textbook (Yıldırım, Aydın, & Sarıkavak, 2019, p.10), and a hypothesis based on observations in the 7^{th} grade science textbook (Akdemir & Çetin-Atasoy, 2019, p.14). On the other hand, the 9^{th} grade physics textbook at science high schools mentions that scientific research starts with a problem and a hypothesis may be developed depending on the individual problem (Aydın et al., 2019, p.25). This indicates that even the textbooks distributed by the Turkish Ministry of National

Education fail to reach a level of consistency in terms of providing a precise description of the very early stages of the scientific research process. There is a certain inconsistency among the relevant literature in science education, the science and physics textbooks used in Turkey, and the specific results of our research study when it comes to the scientific research inception process. In other words, there is a striking divergence between the opinions of scientists mandated with the task of generating new knowledge and the information provided by science education literature and science textbooks explaining the tasks of scientists. Lederman et al. (2014) argue that conducting scientific research studies remain inadequate to developing a proper understanding of NOSI. However, it is our belief that the genuine experiences of the scientists working actively in a field of science provide a first-hand portrayal of the scientific research process. It is arguable to claim that the responses given by scientists in response to the question *"How do you start your scientific research?"* on the basis of their own experiences remain an inadequate depiction of the nature of scientific inquiry? While some scientists may start a new research study with a problem that occurs to them in their routine visit to an open bazaar, some other scientists may start to search for a subject in the literature, as exemplified by some of the responding physicists in our research study. In our opinion, the problem with the argument put forth by Lederman *et al*. relates to the generalization that all scientific research starts with a question. Some scholars already found the statements reported by Lederman *et al*. with respect to the NOSI too generic (Hodson & Wong, 2014; Irzik & Nola, 2011; Matthews, 2012). This implies that it would be very difficult to achieve, if not impossible, to devise a domain-general description of the scientific research process as different fields of science tend to exhibit different characteristics. The family resemblance approach developed originally by the prominent philosopher Ludwig Wittgenstein was refined by Irzik and Nola (2011; 2014) to overcome the criticisms directed to the domain-general accounts of science. According to the authors, the four family characteristics of aims and values of science, scientific methods, scientific practices, and scientific knowledge apply to all fields of science. Irzik and Nola argued that all fields of science incorporated generic cognitive practices such as formulating a problem or a question and generating solutions. The results of the research study from this perspective give way to the understanding that even if scientists start their research studies in different ways, they formulate a problem or question and seek solutions to such problem or question under the influence of the researcher or other scientists and within the means of the available resources.

Wong and Hodson (2009) concluded that the literature on science education did not completely agree with the opinions of scientists about NOS concepts. The authors stated that the results they had obtained from their research studies strongly emphasized that there was no single NOS that would fit all disciplines. Even if the search continues for a common framework for NOS, the need for incorporating a variety components of NOS into each peculiar scientific discipline have recently been pronounced more frequently by several scholars (e.g. Schizas, Psillos, & Stamou, 2016; Tala & Vesterinen, 2015; Wong & Hodson, 2009). Specifically, some researchers discussed the importance of focusing on various topics from different disciplines in philosophy of science with respect to the scientific research process as an inherent element of NOS (Bhushan & Rosenfeld, 2000; Kampourakis, 2013; Mayr, 2008). The main structure of the philosophy of science has historically been shaped mostly in line with the field of physics rather than biology and chemistry. Despite supported by a very limited number of studies exhibiting a statistically strong evidence, there is an argument that physicists are said to offer different opinions on certain aspects of NOS than those of scientists involved in chemistry, biology and other natural sciences (Schwartz, 2004; Schwartz & Lederman, 2008; Tira, 2009). At this point, a more comprehensive understanding should be secured to elaborate the opinions of scientists adopting different approaches in a single field of science as proposed by Schwartz (2004) and Schwartz and Lederman (2008). Eliciting the opinions of scientists operating in different fields of science and with diverse research approaches would be highly informative to reveal the true nature of the scientific research process. An attempt was made in the present research study to identify the opinions of physicists working in different subfields of physics and with different research approaches about the scientific research inception process. In the study, there observed a striking difference among the notions of the physicists with different research approaches. This difference was represented by the fact that observational and experimental physicists considered resources to be a more influential factor on the research inception process than theoretical physicists. In our opinion, the finding concerning the differences among the opinions of the physicists with different research approaches warrants further investigation. This finding relates to the question as to whether the nature of scientific research process varies with individual sub-disciplines such as solid-state physics or mathematical physics.

Educational research studies on how to improve the teaching of science emphasize the importance of engaging students with authentic learning environments such as science fairs bringing students together with scientists. Science fairs offer learners the real-life scientific research experiences, the apprenticeship opportunities with scientists and the authentic science learning atmospheres. Education policies in Turkey already encourage scholars to organize interactive events bringing teachers and students together with scientists. The best example to such events is represented by the science camps supported by the Department of Science and Society under the Scientific and Technological Research Council of Turkey (TUBITAK). These environments bringing teachers and students together with scientists would allow both parties to discuss matters relevant to NOS concepts. However, what would happen if there are contradictions between the knowledge imparted by schools or science teachers and the opinions of scientists? An assessment of the matter from this perspective, there is an apparent need for a consensus. Therefore, it should be ensured that science teachers should hear the voices of scientists and vice versa.

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