THE COMPETENCIES OF SCIENCE TEACHER:
A DELPHI STUDY

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Abstract:

In this study, the authors aim to identify the competencies of science teachers based on the opinions of experts in the field. The Delphi technique was used to attain consensus among experts on science education through 3 rounds with 13 experts from 13 different universities. In the first round of the Delphi technique, open-ended questions sent to the expert group, which were created after a detailed literature review about teacher competencies. Descriptive analysis was applied for the qualitative data obtained at the end of first round. As a result of the analysis, a 5-point Likert-type questionnaire consisting of 172 items in 10 categories was prepared. The questionnaire was sent to the experts in the second round. The experts indicated their participation levels for each item. The data obtained at second round were analyzed by quantitative methods. In the third round, the results of the analysis from the second round were se nt to the experts and they were asked to re-evaluate their responses in the previous round by considering other experts' opinions. By the conclusion of the third round, 161 items referring to competencies of science teachers were identified and categorized into competencies for the science curriculum, competencies to improve students' cognitive characteristics, competencies to improve students' affective characteristics, competencies to improve students' psychomotor abilities, competencies for the objectives of the science curriculum, competencies for the content of the science curriculum, competencies for the learning-teaching process in science, competencies for evaluation in science, competencies for instructional technologies, and competencies for effective communication.

Keywords: science teachers, teacher competency, Delphi technique

1. Introduction

As the skills expected from people in the future cannot be clearly determined, the role of the educational system and its elements cannot be clearly defined. The 2016 World Economic Forum report titled "The Future of Jobs", it is stated that 65% of children starting grade school will have occupations that currently do not yet exist. In this regard, education for an unpredictable future must be an effective guide providing solutions to challenges people will eventually face. Schools must be able to prepare students for technologies yet to be invented, jobs yet to be discovered, and problems yet to be faced (OECD, 2018). The changing circumstances of the world has changed expectations from schools and teachers. While teachers used to be the primary source and provider of knowledge, they are now expected to consider personal differences, needs and interests, communicate effectively with students regardless of handicaps, have cultural and gender awareness, encourage kindness and social harmony, use new technologies, and keep up with rapidly developing knowledge and approaches. Today, where knowledge is updated rapidly in every field, teachers must be able to prepare their students for society with a will to learn, an awareness of learning how to learn and lifelong learning, think critically, creatively and through problem solving, effectively use technology, adopt democratic values, have great civic awareness, respect individual differences, and generally acquire 21st century skills (OECD, 2005, p. 2). During the "International Teaching Occupation Summit" in 2011, in which education ministers, union leaders and teacher representatives from leading countries participated, the development of teachers and teaching was discussed. It was stated that teachers must ensure the adoption of not only skills which are easy to teach and measure, but also higher order skills such as problem solving, critical thinking, and effective communication (Schleicher, 2011).

Beyond the aforementioned multi-faceted qualities, teachers are expected to be trained and equipped with certain ethical, moral, cultural and intellectual values because in the short term, the raising of future generations of society is on the table while in the long term, the building of a humane country and world is at stake (YÖK, 2018,; Ilgaz & Bilgili, 2006). As such, training teachers to be highly equipped regarding occupational ethics is considered very important and has been proposed as an implementation of educational policy (Karataş, Caner, Kahyaoğlu & Kahya, 2019).

When discussing the characteristics and values to be imbued upon students by teachers, the competencies required of the teaching occupation came into question. Today, the main and secondary vocational and individual competencies required of teachers who will raise individuals with 21st century skills have become a significant field of study. The raising of individuals with preferred characteristics is only possible through teachers who have adopted these characteristics themselves. We must remember that the quality of any educational system is directly proportional to the qualities of the teachers within that system (Barber & Mourshed, 2007; Schleicher, 2011; Schleicher, 2016). Accordingly, research findings regarding the elements that influence student achievement have shown that teacher qualities are more influential than any other

variable (Darling-Hammond, 2006, p. 300; Rivkin, Hanusek & Kain, 2005). One method of determining teacher qualities is to determine teacher competencies (Seferoğlu, 2004).

2. Conceptual Framework

2.1. Teacher Competencies

Teacher competencies are one of the most important factors that influence student achievement (Gustafsson, 2003). Countries with successful school systems are aware of the direct influence of teacher competencies on student achievement. Countries successful in various aspects of examinations such as TIMSS (Trends in International Mathematics and Science Study) and PISA (Programme for International Student Assessment) place great importance in the teacher training process and professional development of teachers (Darling-Hammond, Chung-Wei & Andree, 2010). As such, guidelines for standards, qualities, and competency frameworks are being established for both pre-service and in-service professional development of teachers.

The literature of the professional development of teachers reveals various terms in various countries when studied for the establishment and definition of competency frameworks. Some such terms are learning outcomes, competence, standards, validation, and qualification. These terms refer to very different dimensions (Allais, 2010; Malm & Löfgren, 2006; Méhaut & Winch, 2012; OECD, 2013). Allais (2010) states this situation stems from ambiguity between languages. Synonymous terms are referred to with different concepts in different languages. For example, studies exist in which qualification is used closely to competence. The definition of learning outcomes may actually define competence. All these concepts are used to shape and develop the professional development of teachers.

Competence frameworks and professional standards indicate expectations from teachers and how they can develop themselves in various stages of their professional careers in accordance with the needs of the educational system. Additionally, they guide teachers on what they need to know and do (Toledo, Révai & Guerriero, 2017). If the professional standards of teachers are determined, a measure for decision on teacher performance by an evaluator is thereby defined. The determination of professional standards is thought to create an internal control mechanism for teacher training, professional initiation and throughout their whole professional lives (Conway, Murphy, Rath & Hall, 2009).

OECD (2016) defines competence as the application and use of skills and knowledge in real life situations rather than as having expertise or technical knowledge in a field. For example, the skill of communicating effectively is a competence. Determination of this competence depends on the language knowledge, ICT use skills, and attitudes towards those being communicated with of an individual. Competence is a broad concept that encompasses both knowledge and skills (OECD, 2005). Crick (2008) emphasizes emphasizes that for one to be considered competent in a specific field, they must be able to put into practice the knowledge and skills they possess within their own values and attitudes. When the concept of competence is approached from an educational

perspective, Nessipbayeva (2012) states that the competences required from teachers are more than knowledge and skills, stating that the concept of competence must be evaluated as a natural element of an effective teaching process. The Turkish Ministry of Education (MEB, 2006) elaborates on the concept of competence as possessing the professional knowledge, skills, and attitudes required for conducting duties unique to a professional field. Considering the various definitions available, it may be stated that a broad statement of the fundamental competencies required of teachers would be the knowledge, skills, attitudes, and values required to effectively conduct the education/teaching process.

2.2. Teacher Competencies in Turkey

The concept of competence initially introduced in international vocational and technical education literature in the 1970's was later discussed at a higher education level (Le Deist & Winterton, 2005; Jeris, Johnson, Isopahkala, Winterton & Anthony, 2005). The European Union (EU), which Turkey is in the process of joining, prepared the "European Qualifications Framework for Lifelong Learning" in 2006 (EQF), and this reference framework was adopted by member countries in 2008 (European Commission, 2013). 8 competences determined within the framework are: communication in a native language, communication in foreign languages, competences of mathematics and basic science and technology, digital competences, learning how to learn, social and civic competences, an understanding of initiative and entrepreneurship, and cultural awareness and expression. EU member and prospective member states are requested to determine their own national competence frameworks while referencing the EQF (Barış, 2013).

In Turkey the first official work on teacher competences was conducted in 1999 with the collaboration of the Turkish Council of Higher Education and the World Bank, however the establishment and public release of the general competences accepted regarding the teaching occupation did not take place until 2006 (Turkish Ministry of Education Teacher Training and Development General Directorate (MEB ÖYGM, 2017). The competences determined were composed of six general competences, 31 sub competences, and 233 performance indicators used as evidence of these competences. The scope and content of the competences comply with internationally accepted competences, as evidenced by the systematic framework used to structure them under "competence scopes", "sub competences", and "performance indicators". In addition to the general competences of the teaching profession, special field competences for the teaching profession were developed for primary education in 2008, and secondary education in 2011. The general competences prepared were criticized for their inability to clearly discern the contents within their knowledge, skills, and attitude dimensions, evidenced by the long, tedious sub competences and their performance indicators with no concrete explanation of their measurement and evaluation (TED, 2009).

From 2006 to 2017, changes and updates were made to meet the requirements of society and individuals, address the criticisms of the 2006 teaching professional general competences, and comply with the EU harmonization process. During this period, the basic policy statements of organizations such as the European Commission, the World

Bank, OECD, and UNESCO along with the competence documentation of various nations such as Finland, Canada, and Singapore were revised and amended in accordance with shareholder feedback. As such, the general competences of the teaching profession revised in 2017 comprise of three fundamental competence fields: a) occupational knowledge, b) occupational skill, and c) values and attitudes. Under these three headings lie 11 sub competences and 65 performance indicators. The revised General Competences of the Teaching Profession consists of three fields of competences, namely occupational knowledge, occupational skill, and attitudes and values, with 11 competences beneath these and 65 indicators regarding these competences. These competence fields and those beneath them are provided in Table 1 (MEB ÖYGM, 2017, p. 8).

Table 1: General competences of the teaching profession

A Occupational Knowledge	B Occupational Skill	C Attitudes and Values
A1. Field Knowledge	B1. Planning Education and Instruction	C1. National, Intangible and Universal Values
Has advanced theoretical, methodological and factual knowledge of their field, including a questioning approach.	Effectively plans educational and instructional processes.	Pursues national, intangible and universal values.
A2. Educational Field Knowledge	B2. Establishing Learning Environments	C2. Approach to Student
Has mastery of the instructional program of the field and pedagogical field knowledge.	Prepares appropriate instructional materials and healthy, safe learning environments in which effective learning may take place for all students.	Portrays a supportive attitude for the development of students.
A3. Legislative Knowledge	B3. Managing the Teaching and Learning Process	C3. Communication and Collaboration
Behaves in accordance with regulations regarding their duty, rights, and responsibilities as an individual and a teacher.	Effectively executes the teaching and learning process.	Establishes effective communication and collaboration with Students, Colleagues, families and other stakeholders of education.
	B4. Assessment and Evaluation	C4. Personal and Professional Development
	Utilizes the methods, techniques and tools of assessment and evaluation in accordance with their purpose.	Participates in personal and occupational development work through self-evaluation.

In parallel with the General Competences of the Teaching Profession developed by the Turkish Ministry of Education, the Turkish Council of Higher Education updated their teacher training undergraduate programs in 2018. Another purpose of the update for the program was to comply with the Bologna process of the EU. Courses within the undergraduate teaching programs consist of three groups, namely Teacher Vocational

Knowledge, Field Training, and General Culture. In the updated programs, 30-35% of the courses are vocational knowledge, 15-20% are general culture, and 45-50% are field training courses. Additionally, the names and content of several courses were modified and the national and ECTS (European Credit Transfer System) credits were equalized for all programs. Considering the target students for undergraduate programs, it is indicated that the teaching programs are structured more on fundamental skills, attitudes, imbuing value, and adaptation (YÖK, 2018).

While general competences and classifications regarding the teaching profession exist in the literature, field specific competences unique to each area of teaching also need to be determined. Considering each discipline has unique fields of learning and applications, it becomes a prerequisite for effective teaching in each field that teachers possess certain competences exclusive to the field. Specifically, mathematics, science and technology competences which are also included in various disciplines are among the eight key competences expected from teachers by the European Commission (Crick, 2008). This distinction portrays the importance of mathematics and science disciplines as fields.

2.3. Science Teacher Competences

In the 21st century, innovative solutions based on scientific thought are required to deal with the economic, social and environmental challenges the world is facing. Therefore, the importance of societies having well education scientific personnel to undertake scientific and technological innovation is rising.

In Turkey, the science class foresees students growing up as scientifically literate individuals (MEB, 2018). A scientifically literate individual is expected to have knowledge of the concepts and ideas that are foundations for scientific and technological thought. The purpose of the science education in schools is not only to raise a new generation of scientists. Science education aids in overcoming the challenges that face all mankind, from climate change to genetic changes (Wieman, 2007), global warming and overpopulation (Osborne, 2007). The science class is very important in raising an informed and qualified society. The effective execution of the class is, for the most part, the responsibility of the science teacher. Therefore, the components that *establish* the competences of the science teachers who assume this important role are also of great importance.

Following the general teacher competences determined by the Turkish Ministry of Education in 2006, the ministry also released the special field competences required from primary education in 2008, with five special field competences developed for science and technology teachers. These field specific competences were presented with 24 sub dimensions and 132 performance indicators for the competences. The competence fields were (1) planning and organizing the learning-teaching process; (2) scientific, technological, and societal development; (3) tracking and evaluating development; (4) collaboration with the school, families and society; and (5) ensuring professional development. However, the Turkish Ministry of Education has stated that the need for determining separate field competences for each teaching field has been eliminated with

the addition of field knowledge and field training knowledge competences in the Teaching Occupation General Competences updated in 2017. The April 5th, 2018 announcement on the Turkish Ministry of Education Teacher Training and Development General Directorate website dictated the elimination of the separate determination of special field competences for each type of teaching.

A study of the literature reveals various research conducted on science teacher competences, both nationally and internationally. Kaptan (2001b), who tried to determine the competences required of a science teacher compiled the fields of competences under four headings. The competences determined were field knowledge, managing the learning and teaching process, student guidance services, and personal and guidance services. Green and Osah-Ogulu (2003) studied the professional competences of science teachers through three dimensions: environmental, cognitive, and pedagogical. Alake-Tuenter, Biemans, Tobi, Wals, Oosterheert and Mulder (2012) categorized science teacher competences under the three headings of field knowledge, attitude, and pedagogic design competences. In another study determining the competence fields of science teachers, Naumescu (2008) analyzed the competences of science teachers through the six dimensions of epistemologic, resource use (internet, books, libraries etc.), instructing and teaching, science teaching, use of teaching language, and evaluation.

It is indisputable that the sciences play an important role in the development and growth of countries. Therefore, countries expend significant effort to increase the quality of science education (Ayas, 1995). The science class itself is heavily influenced by the changes in science, technology and natural environment that take place in the 21st century. In the field of science, the inclusion of sudden changes on a global scale take time to implement in teaching programs prepared in accordance with long-term targets. It is therefore the responsibility of science teachers to follow these changes and transfer them to teaching environments (McFarlane, 2013). These changes not only change the content of science classes, but also the competences expected of science teachers. This is why the determination of science teacher competences is considered to be important. The purpose of this study is to determine the teacher competences required of science teachers using the Delphi technique. The opinions of academics serving in the Department of Science Teaching are consulted using the Delphi technique.

This study is thought to contribute to multiple aspects of the literature in the field. Primarily, it is expected to provide perspective in preparing teaching programs and course content for those responsible in training science teachers such as the Turkish Higher Education Council and education faculties. Secondly, it is believed that this study may contribute to the structuring of the oral and written examinations administered by the Turkish Ministry of Education for teacher placement and appointment. Lastly, it is expected to contribute to the personal and professional development of teachers.

3. Research Method

In this study, the Delphi technique was used within a mixed-method design (Creswell, 2008). During the first Delphi round, a group of experts were asked "What are the

competencies of a science teacher?" in order to reach a shared agreement (Dalkey & Helmer, 1962). Content analysis was conducted on the responses and an item list was created. The list was then presented to the Delphi participants in the form of a Likert-type scale. Descriptive statistical analysis was then applied to their responses.

3.1. Delphi Technique

The Delphi technique is a procedure to "*obtain the most reliable opinion consensus of a group of experts by subjecting them to a series of questionnaires in depth interspersed with controlled opinion feedback*" (Dalkey & Halmer, 1962, p.7). Although the technique is sometimes classified as qualitative and other times as quantitative, both qualitative and quantitative research skills are required in the application of the Delphi technique (Skulmoski, Hartman & Krahn, 2007). Therefore, this technique is considered to be a mixed-method research technique (Creswell, 2008; Kos & Aydın, 2013; Skulmoski, Hartman & Krahn, 2007).

The Delphi technique has four major features: anonymity, iteration, controlled feedback, and the statistical aggregation of a group response. Anonymity, throughout the Delphi process, refers to the fact that the group of experts are not aware of one another. Thus, these experts are able to present their own opinions without the feeling of group pressure. Without this pressure, they are also free to change their opinions as the Delphi rounds proceed (Nworie, 2011). Iteration refers to re-sending the questionnaire until a consensus is reached. Every time the questionnaire is sent, the experts are provided controlled feedback by being informed of the opinions of other experts. Feedback is generally provided in the form of a statistical summary of the group's response. Based on this feedback, the experts review their own opinions and may add previously unspecified opinions or change their decisions to align with the common group opinion (Mitroff & Turoff, 2002). In the final round, "*the group judgement is taken as the statistical average…of the panelists' estimates on the final round*" (Lindstone & Turoff, 2002, p. 3; Rowe & Wright, 2002, p. 22).

3.2. Delphi Panelists

One of the critical phases of the Delphi technique is determining the participants who will take part in the application of the technique. The adequacy of the experts involved in the implementation maximizes the quality of the responses, reduces prejudice, and increases the reliability of the study (Powell, 2003; Okoli & Pawlowski, 2004; Nworie, 2011). Therefore, purposive sampling is the most frequently used sampling method in the Delphi technique, which allows the researcher to specify criteria to determine the most suitable experts for the study (Fraenkel, Wallen & Hyun, 2015). Regarding expertise, the following criteria were utilized in panelist selection: Academics with a doctorate degree in science education with at least 5 years experience in this field as a lecturer.

To identify potential panelists in accordance with the criteria determined for selection, the academic curriculum vitaes of science education faculty members were accessed through the websites of the universities they were employed at. The CVs of the experts were reviewed, and a 50-candidate list of panelists was established. The

candidates were sent an invitation e-mail, and only 1 of the 50 prospective panelists agreed to participate in the study. The faculty members on the list were then contacted by phone to be invited to participate in the study. Eventually, 18 academics agreed to participate in the study voluntarily. The literature in the field does not specify a number of panelists required for Delphi studies, with suggestions ranging from 5-100 (Ager, Stark, Akesson, & Boothby, 2010; Clayton, 1997; Herring, 2007; McIlrath, Keeney, McKenna,& McLaughlin, 2009; Skulmoski et al., 2007; Torrance et al., 2010; Wilson, Koziol-Mclain, Garrett, & Sharma, 2010; Witkin & Altschuld,1995). During the first Delphi round of the study, all 18 panelists from 18 different universities participated. 13 of the 18 participants responded to the open-ended questionnaire of the second round. 11 panelists were involved in the third and final round of Delphi, which the literature indicates to be an acceptable level of participation. Table 2 portrays the number of questionnaires sent during each round, along with the response rates and the number of panelists in each group.

Table 2. Delphi panelist composition

	Round 1	Round 2	Round 3
Questionnaires delivered	18	13	11
Completed questionnaires	13	11	10
Response rate	%72,2	%84,6	%90,9

3.3. Procedure

In this study, a three-round Delphi technique was used. The procedure followed during the study is summarized below.

a. First Round

Within the scope of this study, a detailed determination of the competencies of science teachers was targeted, including everything related to the curriculum, the cognitive, affective and psychomotor characteristics and abilities of students, and effective instruction of science. As such, the categories in Table 3 were determined based specifically on the general competencies for teaching and special subject standards prescribed by the Turkish Ministry of Education, the elementary science curriculum, and literature on effective science education (Bass, Contant, & Carin, 2008; Hassard & Dias, 2008; Howe, 2002; Huyuguzel Çavaş & Kesercioglu, 2008; Kaptan, 1999; Kaptan & Korkmaz, 2001; MEB, 2006; MEB, 2008; MEB, 2017a; National Research Council, 2000; Tanel, Şengoren & Kavcar, 2009).The categories determined were shared with 5 academics in the field of science education, and they were requested to evaluate the understandability, compatibility, and possible merging of items for each category. They were also requested to point out any ambiguities, and merge items where necessary. The suggested corrections resulted in 10 categories being established. Panelists were asked to respond to the question "What are the competencies of science teacher" based on the categories listed in Table 3. Panelists were also given the option of adding new categories, subcategories, and comments in their response.

Table 3. Categories

Category	
1. Competencies for science curriculum	6. Competencies for the content of science curriculum
2. Competencies to improve students' cognitive characteristics	7. Competencies for learning-teaching process in science
3. Competencies to improve students' affective characteristics	8. Competencies for evaluation in science
4. Competencies to improve students' psychomotor abilities	9. Competencies for instructional technologies
5. Competencies for the objectives of the science curriculum	10. Competencies for effective communication

Following the first Delphi round, content analysis was conducted on the responses of the panelists (Creswell, 2007). Content analysis is a technique used to analyze many forms of communication including textual content such as essays, newspapers, novels, articles, pictures etc. (Fraenkel, Wallen & Hyun, 2015). In short, the process of content analysis includes organizing the data; reading the entire data with the aim of drawing a general meaning from it and taking notes; describing, classifying, and interpreting the data; and presenting the findings with or without predetermined categories. Codes are created during the description and classification of the data, and those codes are implemented. The coding process is "*reducing the data into meaningful segments and assigning names for the segments*" (Creswell, 2007, p. 148). Initially in this study, during the content analysis, two researchers worked independently on the whole data set to section the data into predetermined codes and create new categories depending on panelists' comments. At the end of the coding process, the researchers compared the codes they had established. During this process, all codes were evaluated both individually and in relation to other codes, and categories were reorganized accordingly. The results of the content analysis were used to finalize the categories of science teachers' competencies. Following this categorization, inter rater reliability was calculated using Miles and Huberman's (2016, p. 64) formula. They suggested that an inter-rater reliability of 80% consensus between coders on 95% of the codes is sufficient among multiple coders. For this study, 91% inter rater reliability was achieved. Lastly, each competency was rephrased as a sentence, resulting in a list of items portraying the competencies of a science teacher. The conclusion of the content analysis resulted in a Likert-type scale of 172 items under 10 categories.

b. Second Round

The Likert-type scale ranging from 1 (strongly disagree) to 5 (strongly agree) was sent to the 13 panelists, and they were requested to mark the appropriate degree of importance for each item. Descriptive statistical analysis was applied to their responses once they were collected at the end of the round.

c. Third Round

Questionnaires for this round were prepared specifically for each panelist with bespoke information regarding their own degree of agreement for each item in the second round along with the descriptive statistical findings for each item calculated from the responses of all panelists. The panelists were then asked to review the descriptive statistical results and comments for each item in order to re-evaluate their degree of agreement provided in the previous round. If they wished to change their degree of agreement, they were requested to mark their revised degree in the related field.

d. Ethical considerations

In Delphi studies, the researcher is ethically responsible for ensuring that the identity of the participants and the attributed responses are not disclosed to other participants. The decisions and opinions within the study remain anonymous throughout the process. Within the scope of this research, the necessary precautions were taken to adhere to these ethical considerations.

e. Validity and reliability

The selection of participants for the Delphi study is the critical initial phase of the technique. Participants knowledgeable on the subject being studied and experienced in the related field increase the content validity of the study (Rowe & Wright, 1999; Hasson, Keeney & McKenna, 2000). Poor expression, clarity, and fluency of the questions directed to the participants of the Delphi study may negatively influence validity and reliability (Keeney, Hasson & Mc Kenna, 2001). Reliability in such studies is obtained by explaining the process in detail to the participants. Having the same participants in each round of Delphi, where participants who expressed certain subjects during the first round take part in the evaluation of the following two rounds would increase the validity of the study (Seuring & Müller, 2008). In Delphi studies, the questionnaire prepared at the end of each round is sent back to the experts participating for their feedback and re-evaluation. Thus, construct validity is inherently ensured (Okoli & Pawlowski, 2004).

Taking into account the available literature regarding the validity and reliability dimensions of Delphi studies, the following precautions were exercised.

1) The opinions of five experts were sought regarding the open-ended questions prepared for distribution to the participants in the first round.
2) The requirements for participation were determined as follows:
   - Having a masters or doctorate degree in the Department of Science Education.
   - Having at least five years of work experience in the field of science education.
3) Content analysis was conducted on the data obtained in the first round and the coding of the data was conducted independently by two researchers. The reliability of the coding was determined to be 0.91.
4) All of the details of the Delphi process were explained to the participants prior to each stage of data gathering.

f. Consensus measurement

In Delphi studies, participants are expected and even preferred to have differing opinions. Thus, the data gathered during the first round is diversified, and the diverging points emerge clearly during the second and third rounds. Therefore, researchers conducting Delphi studies determine a measure for consensus (Keeney, Hasson & McKenna, 2006). There are no set rules in the literature regarding the measure of consensus and when it should be achieved (Keeney, Hasson & McKenna, 2011; Powell, 2013). Therefore differing statistical data (median, mean, percentage of agreement, interquartile deviation) and consensus measures are used in research (Franklin & Hart, 2007; Green, Jones, Hughes & Williams, 1999; Hasson, Keeney & McKenna, 2000, Korkmaz & Erden, 2013; Powell, 2003; Putman, Spiegel & Bruininks; 2013; Şahin, 2009).

In order to determine the competencies of science teachers as required in this study, the frequency values of the experts responding to the questionnaire items regarding their means, medians, agree (4), and strongly agree (5) responses were determined; participation frequency was calculated. The consensus measures determined for the second and third rounds of this study are portrayed in Table 4.

Table 4: Agreement criteria

Round 2 (n=11)	Round 3 (n=10)
Ortalama ≥ 3,7	Ortalama ≥ 3,9
Ortanca ≥ 4	Ortanca ≥ 4
Frekans 4+ frekans 5 ≥ 8	Frekans 4+ frekans 5 ≥ 8

Additionally, the measure for higher level competence was defined. As can be seen in Table 5, competence statements with a minimum average of "4.5", median of "5", and a minimum frequency of 9 for expert responses comprising of "agree" and "strongly agree" provided higher level consensus regarding competence statements.

Table 5: Higher level consensus measure

Round 3 (n=10)
Average ≥ 4,5
Median = 5
Frequency 4+ frequency 5 ≥ 9

4. Results and Discussion

In the first round of the Delphi study, panelists were requested to respond to questions based on the categories presented in Table 3. The content analysis conducted at the end of this round identified 172 items under 10 categories as competencies of a science teacher.

In the second round, the panelists responded to a Likert-scale questionnaire which was structured based on their responses to the previous round. Descriptive statistical analysis was applied to the responses of 11 panelists (of the 13 total participants of the first round) and the results were evaluated in accordance with the consensus measures

provided in Table 4. Following the second round, 5 items did not achieve the statistical value to meet the requirements of the consensus measure.

In the third round, each panelist received a 167 item questionnaire along with the individual and collective results of the statistical analysis conducted on the previous responses, and the participants were requested to compare these findings and make a final decision. 10 participants responded to the questionnaire, with statistical values indicating 8 items failing to achieve the consensus level required following the third round. Based on the literature of effective science education, the researchers removed 6 items from the competency list while judging based on the literature for the inclusion of the other two items.

Following the three Delphi rounds, 172 items were assessed based on the aforementioned measures, concluding with 161 items under 10 categories being identified as competencies of a science teacher. Table 6 compares the number of items obtained for each category between the first and third rounds. Additionally, an examination of the findings based on the criteria in Table 5 determined that 69 items provided in Table 7 had high levels of consensus among participants.

Given the space constraints of this article, the next section provides a comprehensive summary of the findings by considering high consensus level items for each category rather than a comprehensive list of items and related statistics. A complete listing and statistics are available from the authors upon request.

Table 6: Categories, and number of items

Category	Number of items at the end of the first round	Number of items at the end of the third round
1. Competencies for science curriculum	15	14
2. Competencies to improve students' cognitive characteristics	16	16
3. Competencies to improve students' affective characteristics	22	20
4. Competencies to improve students' psychomotor abilities	15	15
5. Competencies for the objectives of the science curriculum	17	17
6. Competencies for the content of science curriculum	14	14
7. Competencies for learning-teaching process in science	21	21
8. Competencies for evaluation in science	16	13
9. Competencies for instructional technologies	13	12
10. Competencies for effective communication	23	19

Table 7: High level agreement items

1. Competencies for science curriculum
Program literacy
Having the pedagogical knowledge to effectively apply the elements of the instructional program
Having the field knowledge to effectively apply the elements of the instructional program
Establishing relationships between the subjects within the instructional program
Paying attention to the warnings issued within the instructional program
Providing feedback to those responsible for improving the instructional program

2. Competencies to improve students' cognitive characteristics
Planning the learning-teaching process in accordance with individual differences
Providing various instruction methods and techniques during the learning-teaching process
Using supplementary/additional instructional materials
Associating subjects with real life
Arousing curiosity regarding the content
Portraying the interdisciplinary relationships between subjects
Being aware of students' cognitive readiness
Enabling the acquisition of thinking skills
Enabling the acquisition of problem-solving skills

3. Competencies to improve students' affective characteristics
Loving the teaching occupation
Respecting students
Respecting differing ideas
Providing students the responsibility of learning
Ensuring the development of self confidence in students
Teaching with practices that enable the comprehension of the role of science in life
Planning fun processes to enable students' love for the sciences
Taking advantage of interesting technological materials
Planning learning opportunities through practice and experience
Using instructional methods and techniques appropriate for the content

4. Competencies to improve students' psychomotor abilities
Loving applied sciences
Effectively using laboratories
Taking the necessary safety precautions for activities
Ensuring effective time management regarding balancing theory and practice

5. Competencies for the objectives of the science curriculum
Having the skills required of the scientific process
Having knowledge of the field
Have mastery of the terminology used in the instructional program
Believing in the importance of science education
Keeping track of current developments in the subject field
Associate subjects with daily life
Establishing the relationship between science-technology-society-environment
Being aware of the path to be taken in realizing goals
Being aware of the behavioral changes that will take place as a result of their acquisitions

6. Competencies for the content of science curriculum
Using current technology
Keeping track of current knowledge regarding content
Adopting lifelong learning
Sharing current knowledge regarding content with students
Foreseeing conceptual misunderstandings regarding subjects
Utilizing instructional methods and techniques appropriate for the content

7. Competencies for the learning-teaching process in science
Effectively using instructional strategies, methods, and techniques
Utilizing current instructional strategies, methods, and techniques
Utilizing instructional methods and techniques appropriate for the content
Planning the teaching-learning process in accordance with students' readiness
Following current developments
Sharing current developments with students
Accommodating scientific discussion
8. Competencies for evaluation in science
Utilizing process-centered evaluation methods (portfolios, projects etc.)
Providing feedback to students
Conducting unbiased evaluation
Taking into account individual differences during the assessment and evaluation process
9. Competencies for instructional technologies
Being willing to use instructional materials
Utilizing hardware based instructional materials (Smart boards, tablet computers etc.)
Directing students to safe internet environments throughout the learning process
10. Competencies for effective communication
Having effective communication skills
Being aware of students' interests and needs
Taking into account individual differences during communication
Addressing students by name
Providing the opportunity for students to express themselves
Loving students
Empathizing
Being cheerful
Being tolerant
Being patient
Being respectful

The findings of the "competencies for science curriculum" category indicate that a science teacher should be curriculum literate. In addition, it was stated that science teachers must have the pedagogical and field knowledge required to effectively apply the elements of the instructional program. Lastly, it was emphasized that science teachers must establish relationships between program subjects and pay attention to warnings while providing feedback to those responsible to improve the programs and applications.

Under the "competencies to improve students' cognitive characteristics" category, the competencies identified include planning the instructional process in accordance with individual differences of students, making use of various instructional methods and techniques, utilizing supplementary instructional materials, associating subjects with real life, and portraying interdisciplinary relationships. The additional competencies in this category required of science teachers are being aware of the cognitive readiness of students, inciting curiosity for the content, and enabling the acquisition of thinking and problem-solving skills.

The competencies that emerged under the "competencies to improve students' affective characteristics" category were loving their occupation, respecting students, respecting differing ideas, assigning the responsibility of learning to students, ensuring

the development of self confidence in students, teaching with practices that enable the comprehension of the role of science in life, planning fun processes to endear the sciences to students, utilize interesting technological materials, planning applied/practical learning experiences, and using instructional methods and techniques appropriate for the content.

"Competencies to improve students' psychomotor abilities" was a category that contained the following competencies: loving the applied sciences, effectively using the laboratory, taking the necessary safety precautions for activities, and effective time management regarding theory-practice balance.

Under the "competencies for the objectives of the science curriculum" category, the following competencies emerged: having scientific process skills and field knowledge, having mastery of the terminology used in the instructional program, belief in the importance of science education, keeping track of current developments in the field, associating subjects with daily life, and establishing the relationship between science-technology-society-environment. Additionally, science teachers were also expected to be aware of the behavioral changes that take place following the learning outcomes, and the path to achieve these goals.

Experts in the field achieved consensus regarding utilizing current technology, adopting lifelong learning, foreseeing misconceptions on the subjects, using instructional methods and techniques appropriate for the content, keeping track of current knowledge regarding the content, and sharing this knowledge with the students in the "competencies for the content of science curriculum" category.

The items that emerged under the "competencies for the learning-teaching process in science" category were effective use of instructional strategies, methods and techniques; taking advantage of current instructional strategies, methods and techniques; using instructional methods and techniques appropriate for the content; planning the learning-teaching process in accordance with students' readiness; following current developments and sharing them with students; and accommodating scientific discussion.

Under the "competencies for evaluation in science" category, the items that emerged were using process focused evaluation methods, providing feedback to students, taking into account individual differences during the assessment and evaluation process, and conducting unbiased evaluation.

The category with the lowest item count was "competencies for instructional technologies", with being willing to use instructional materials, using hardware based instructional materials, and guiding students to safe internet environments during the learning process.

The final category was "competencies for effective communication", with the following items emerging as competencies required of a science teacher: having effective communication skills, being aware of the interests and needs of students, taking individual differences into account during communication, addressing students by name, providing students the opportunity to express themselves, loving the students, empathizing with the students, and being cheerful, tolerant, patient, and respectful.

This study, which aimed to determine the competencies required of science teachers through expert opinions, conducted 3 rounds of Delphi, which started with 18 participants and resulted with the opinions of 10 experts providing 161 competencies under 10 categories.

Based on the consensus of the expert opinions, the first two categories that achieved the highest level of consensus through their competency items were "competencies to improve students' affective characteristics" and "competencies for effective communication". These categories were also present in previous research on teacher competencies (ACTEQ, 2003; EU, 2005; Selvi, 2010). A science teacher trying to teach their students affective characteristics must have already transformed certain affective characteristics into part of their personality. It may be stated that the most important characteristic is love for their occupation. Atalay (2005) and Pehlivan (2008) stated that teaching is a labor of love; individuals who do not love this occupation or do not respect it cannot perform it. Teachers respecting students as individuals, creating a democratic learning environment and caring about different ideas, and inciting responsibility for learning in their students were the other competencies expected from science teachers determined by the experts. Regarding effective teacher behaviors, Ornstein and Lasley (2004, p. 15) stated that "they assign responsibility and feel respect towards their students". Lavoie (2008,) indicated that even students who weren't adjusting to their learning environment may be motivated by responsibility. Nearly all of the research and literature in the field of effective science teaching and its components cite similar statements (Farmery, 2002; Hassard & Dias, 2008; Mercer-Mapstoneve Kuchel, 2017; Wellington, 1998). In addition to these statements the Council of Higher Education/World Bank National Education Development Project Preservice Teacher Training Improvement study conducted between 1994 and 1997 included statements such as effective science teacher characteristics being associating content with real world events that take place out of the classroom, and activating students in work that uses scientific processes, further supporting the findings of this study (Turgut, Baker, Cunningham & Piburn, 1997). Effectively implementing the aforementioned competencies may depend, as stated by the experts, on effective communication skills (European Commission, 2005; Selvi, 2005). As stated by other studies (Çavaş & Huyugüzel Çavaş, 2016; Ergin, 2014), learning cannot take place without effective communication.

Other statements regarding the expected competencies of science teachers emerged under categories regarding the science instructional program and the components of the program. One of the most fundamental competencies required of teachers with active roles in the application of programs was program literacy. This concept refers to how teachers understand their instructional programs, their attitudes towards their programs, their effective planning and execution of the application process, and their ability to evaluate their context and transform the program appropriately and in an adaptive manner (Keskin & Korkmaz, 2017; Nsibande & Modiba, 2012). Program literacy was also included in the 2017 update of the "Teaching Occupation General Competencies" with the statement "*Commands mastery of the teaching program of the field,*

and pedagogical field knowledge" (MEB ÖYGM, 2017, p. 13), and is considered an important competency required of science teachers, as with all disciplines (Akınoğlu & Doğan, 2012). The foremost competency statements are that science teachers will need the field knowledge and pedagogical knowledge required to execute learning experiences in accordance with the dimensions of their instructional program. The International Council for Science [ICS] (2011) also stated that the field knowledge and pedagogical knowledge of science teachers are important for effective teaching. In their work on how student learn science, Moreno and Tharp (20 bv05) emphasized establishing a connection between prior knowledge and new learning to initiate meaningful learning and thinking processes. In this regard, science teachers establishing as many relationships as possible between the content of the program rather than independent instruction would allow for meaningful coding and thereby effective learning by the students.

The warnings within the instructional program are important anecdotes that would enhance the functionality and effectiveness of the program for many stakeholders as a result of the evaluations that provide input to the program development process. When teachers are applying the program, attention to these warnings would make both their teaching and the students' learning more effective. As the executors of the instructional program, science teachers' feedback to the relevant persons is also an important competency statement. Programs are initiated by teachers, and the evaluations conducted by teachers play an important role in revealing the effectiveness of the program (Baş, 2016). Thus, it is possible for teachers to directly contribute to program development and evaluation studies.

When the competencies expected of science teachers regarding the purpose of the science teaching program are studied, certain commonalities emerged with the special goals of the 2018 science instruction program and these were summarized (MEB, 2018). The competency statements obtained indicate that science teachers must have the awareness of sustainable progress, scientific process skills, exemplify the interaction between science-society-technology, and establish the relationships between science-technology-society-environment. The science instruction program aims to incite awareness for sustainable progress, scientific process skills, and scientific thinking habits in socio-scientific subjects while raising awareness regarding the interaction between the individual, the environment, and society. It may be stated that these items present in the special goals of the science instructional program and the competency statements obtained as a result of this study are compatible.

One of the interesting results of this category is that while teachers are expected to establish a science-technology-society-environment relationship in accordance with program goals; and despite the fact that the necessity for emphasizing interdisciplinary connections between subjects under the "competencies for the objectives of the science curriculum" category was indicated as a required competency, a consensus was not achieved regarding the statement of science teachers having STEM education knowledge. STEM (Science, Technology, Engineering and Mathematics) education is an interdisciplinary approach that holistically integrates the fields of science, technology, engineering and mathematics (Karademir, 2017). Furner and Kumar (2007) stated that

STEM fields are at the forefront of this era, that these fields could not be considered independent, and that science teachers must have the competencies to teach these fields with an interdisciplinary approach. Studies determining that more meaningful learning takes place when the subjects of science classes are taught with more interdisciplinary relationships are established (Akpınar & Ergin, 2014; Gürdal, Şahin & Bayram, 1999) emphasize the importance of interdisciplinary teaching as a competency for today's science teachers. Recent studies indicate that the decision makers in the Turkish educational system have become aware of the importance of STEM education.

In this regard, the Turkish Ministry of Education and the General Directorate of Innovation and Educational Technologies (YİĞİTEK) published a STEM education report in 2016 (MEB, 2016). In 2017, MEB published a STEM training book to guide administrators and teachers (MEB, 2017a). Ensuring each discipline is considered a part of a whole (Çepni, 2018, p. III), and included in the 2018 science teacher program, the STEM understanding failed to achieve consensus due to the limited amount of time the concept of STEM education has had to influence the science instruction program. In this study, taking into consideration its significance in the literature, the statement regarding STEM education knowledge was not removed from the science teacher competency list.

Another competency statement that did not achieve consensus was regarding developing a measurement tool for acquisition. The acquisitions within the instructional program are prepared for learning products in different fields. In other words, some acquisitions are directed at the cognitive area while others may be directed at the affective. In this regard, a single type of measurement tool would not be able to measure behavioral changes for all acquisitions (Karadağ & Usta, 2015; Uluçınar & Karademir, 2017). Therefore, the development of acquisition measurement tools was considered important as a science teacher competency and was not removed from the science teacher competency list.

Another dimension of the program regarding content was science teachers keeping current with their knowledge and the necessity of sharing this knowledge with students. There are many studies indicating that in science instruction, associating content with daily life and presenting students with learning experiences compatible with life have positive influences on the permanence of learning, interest in science instruction, and academic achievement (Andrée, 2003; Cherestensen, 2007; Çoştu, Ünal & Ayas, 2007; Harlen, 2002). Another competency statement that stands out in this field of competency is teachers anticipating conceptual errors or misconceptions. It is paramount that teachers be aware of possible misconceptions students may have, take necessary precautions and plan their instruction accordingly (İnel Ekici, 2010, p. 393). One competency required of teachers is their adoption of lifelong learning. Lifelong learning is an important competency present in the general teacher competences (MEB, 2017a, p. 16), under the "personal and professional development" heading of the special field competences (MEB, 2008, p. 88), and among 21st century skills. All of the competency statements under the content dimension of the program may be considered competency statements agreed upon to date under the scope of general and special teacher competency studies (ACTEQ, 2003; EU, 2005; Selvi, 2010).

Various statements may be encountered in previous competency fields regarding science teachers in the learning-teaching process such as accounting for student readiness when planning, effectively using instructional strategy, methods and techniques, keeping track of current events and sharing them with students, and enabling scientific discussion. The current century has largely changed the role of the teacher. The role of teachers in the 21st century has evolved to their designing environments appropriate for students to ensure their own learning (Çolak, 2014).

Regarding the assessment and evaluation process, the foremost competency statements regarding science teachers were their use of process focused evaluation methods, providing students with appropriate feedback, conducting unbiased evaluation, and taking into consideration individual differences. In the science class, which targets the acquisition of multiple skills such as scientific process skills, life skills, analytic thinking skills, and logical thinking skills, it is believed that traditional assessment and evaluation methods that merely measure knowledge are insufficient (Şaşmaz Ören, 2016). The fundamental purpose of assessment and evaluation is to determine learning deficiencies, provide both students and teachers with feedback, and improve the learning-teaching process. It is therefore important that teachers have the competency to use feedback in order to ensure the effectiveness of the assessment and evaluation process (OECD, 2013). Additionally, it is also important that teachers are as transparent and fair as possible during the evaluation process, and as unbiased as possible by determining the measures of evaluation a priori (OECD, 2013).

Teachers are expected to plan the learning-teaching process while taking into account individual differences in order to develop the cognitive characteristics of students. In this regard, some of the expected fundamental processes of effective science teaching from science teachers are the use of a variety of instructional methods, techniques, and materials; associating subject matter with real life; and inciting curiosity (Schleicher, 2016; Selvi, 2005). In addition, science teachers must aim to teach thinking and problem-solving skills while being aware of students' cognitive readiness. An effective path for the instructional program to achieve its goals is by determining the instructional methods and techniques based on the individual differences of students, their cognitive readiness, their developmental stages, and the characteristics of their learning unit during science instruction (Güven-Yıldırım, Köklükaya & Aydoğdu, 2016; Martin, 2000).

Among the foremost competencies directed at developing students' psychomotor skills was the statement indicating teachers liking applied sciences. Teachers being enthusiastic about teaching, and portraying willingness and excitement towards the subject they are teaching will result in the students having similar feelings and promote more willing attitudes in the students (Lazarides, Gaspard & Dicke, 2019; Oprea, 2012). Among the competency statements regarding instructional technologies; willingness to use instructional materials, using hardware based instructional materials, and guiding students to safe internet environments during the learning process were the most significant competency statements. Under the "competencies for the content of the science curriculum" category, making use of current technologies was a statement that

indicates the importance of teachers integrating technological developments into instructional processes. Web 2.0 tools have an important role in the lives of individuals today. These new tools and technologies also change the way we think and learn (Trust, 2018). Various educational applications that may be used both in and out of classrooms, scientific content that can be shared through social networks, and communication with experts are all possible in the field of science (Aktay, 2016). The increasing importance of these developments in instructional technologies and the positive attitudes of students regarding technology use as a result of studies in this field (Aslan Efe, 2015; Abt & Barry, 2007; McKinney, Dyck. & Luber, 2009; Morris, 2010, Putman & Kingsley, 2009; Volman, 2005) support the findings of this study. For teachers to effectively use this unlimited potential, they must have technological pedagogical field knowledge, effectively use hardware and software based materials in instructional environments, and must be able to adapt the material to the content, as outlined in the European Union's published European Competencies Framework (European Commision, 2013). The high use rate of online services and social networks by students and the disadvantages as well as the advantages of the virtual realm assign teachers the responsibility to guide students (OECD, 2018).

6. Conclusion

A general interpretation of the findings of this research may be that emphasis was placed on affective acquisitions during the instructional process rather than the cognitive and psychomotor skill acquisitions of students. In addition, the necessity for association of subject matter with daily life was emphasized under multiple categories. A similar emphasis was placed on the need to account for individual differences when science teachers plan, select material, and structure the evaluation processes of teaching-learning processes.

As a requirement of the era we live in, one significant finding was regarding the use of technology. When arrangements are being made for instructional activities, it was stated that the maximized use of technology and the development of teachers' individual and professional competencies was mandatory in this regard.

7. Recommendations

The competency statements obtained as a result of this research are expected to provide perspective to teacher training institutions, instructional programs, and course content. Additionally, it may be helpful in the planning of in-service training for science teachers, especially regarding needs analysis. In addition to these possible uses of the findings, the competencies determined within the scope of this study may contribute to science teachers and prospective science teachers in their self-evaluation, providing awareness regarding their professional and personal development.

8. Limitations

Certain challenges were faced in this study, in which the researchers applied the Delphi technique for the first time. The primary challenge was that despite the fact that the experts participating in the study were informed of the importance of participating in all of the stages and processes of data gathering, they requested to withdraw from the study. As such, the study which began with 18 participants concluded with 10 participants. Clayton (1997); who stated that the number of participants in a Delphi study may vary based on the subject, purpose, scope, accessibility of participants, and national or international context, also indicated that 15-30 participants may be sufficient for homogenous communities, and 5-10 may be sufficient for heterogenous communities. Rowe and Wright (2001) stated that 5-20 experts were sufficient for Delphi groups, while Şahin (2009) indicated that an ideal Delphi group should consist of 10-20 experts. In conclusion, the number of experts participating in this study is sufficient based on the literature in the field. It may be stated that one of the contributing factors for experts being unable to complete the duration of the research was that the research data gathering process was initiated at the beginning of the summer vacation. A limitation that arose tangentially to this issue was that the data from the experts was often obtained much later than the dates/deadlines set for them.

This study is limited to the data obtained from the three stage Delphi application conducted. The literature states that a three round Delphi application is often sufficient to gather the required information and achieve a consensus. A fourth round may be applied if consensus is not achieved (Hsu & Sandford, 2007). The measure accepted to conclude the Delphi rounds is consistency in the feedback. Another method of defining consensus is to determine a consensus percentage. Sekayi and Kennedy (2017) state that if the number of participants responding "agree" or "strongly agree" are at least 80% of the total number of participants, consensus may be considered to be achieved. Taking into account these parameters, this study was concluded following the third round.

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