International Journal of Technology and Design Education
https://doi.org/10.1007/s10798-021-09713-2

Science teacher's perceptions of the nature of technology: a Q-methodology study

Ayse Yenilmez Turkoglu[1] · Fatih Aydin[2] · Huseyin Es[3]

Accepted: 22 October 2021

Abstract

The aim of the current study was to explore science teachers' perceptions of the nature of technology through the use of Q methodology. 17 science teachers were sampled as participants, and to explore their perceptions of the nature of technology, they ranked a Q-sort of 36 statements that constituted the following six categories: (i) definition of technology, (ii) the relationship between science and technology, (iii) the impact of society on technology, (iv) the impact of technology on society, (v) the impact of technology on environment, and (vi) the impact of technology on economy. As the participants completed their Q-sort, they were interviewed. Analysis of the participants' Q-sorts resulted in a three-factor solution, i.e. three distinct patterns of perception about the nature of technology. The three perspectives included teachers who are (i) equally aware of the benefits and drawbacks of technology and the relation of it to science, (ii) optimist about technology and aware of its dependence on society, and (iii) optimist about technological innovations but tempered by technology-driven environmental and social issues. Findings indicated gender and years of professional experience as potential determiners within these perspectives, which needs further research.

Keywords Nature of technology · Q methodology · Science teachers · Technology education · Science education

Introduction

When it comes to technology, one can find related studies in all fields. This situation can be considered as an indicator of the penetration of technology in our lives, our environment and even our understanding of the future. At this point, as Cullen and Guo (2020) states,

✉ Ayse Yenilmez Turkoglu
ayse.yenilmez@alanya.edu.tr

[1] Faculty of Education, Department of Mathematics and Science Education, Alanya Alaaddin Keykubat University, Alanya, Antalya, Turkey

[2] Faculty of Education, Department of Mathematics and Science Education, Bolu Abant Izzet Baysal University, Bolu, Turkey

[3] Faculty of Education, Department of Mathematics and Science Education, Sinop University, Sinop, Turkey

the nature of technology becomes important as we develop our way of knowing and use technology to find solutions in the fields of science, engineering and mathematics. It is, on the other hand, difficult to think on technology since people often look at it from different perspectives. For instance, Rose and Dugger (2002) state that *computers* and *the Internet* come to minds rather than the meaning of technology as changing the natural world to meet our needs. Defining technology as *applied science*, on the other hand, has occupied people for many years and debates on this subject lasted for years (de Vries, 2005). In a study conducted with teacher candidates (Yalvaç et al., 2007), for example, it is seen that nearly half of the participants viewed technology as the application of science, while others as new processes, tools, machines, devices, gadgets, computers or practical tools for daily use, and some as ideas and techniques that help society move forward. The current paper focuses on technology as an ongoing dynamic process. Therefore, we assume that reaching the exact nature of technology have difficulties despite known about technology. We think that the complex structure of technology is also at the root of these difficulties.

Similar to the nature of science, views on technology are shaped by experiences and culture as well (Cullen & Guo, 2020). The role of technology is not only closely related to people's lives, but there are also important implications in the field of education. At this point, the discourse about the nature of technology and how these understandings relate to students' technology knowledge becomes important. If educators are able to understand students' perceptions of the nature of technology, they can assist them to become aware of their personal thoughts and improve their technology literacy (Liou, 2015). In fact, it is stated that in order for teaching it effectively, teachers should have a well-developed understanding of technology (de Vries, 2012; Forret et al., 2011). Herein, the necessity of teachers to have a realistic/true perception of the nature of technology comes up.

The nature of technology

The nature of technology can be found in the philosophical writings of Idhe (1983), who attributes to the work of the existential philosopher Heidegger. Heidegger (1977) defined technology as a mode of revealing the world (Compton & Jones, 2004). In 1990s, on the other hand, academicians discussed technology in the contexts of design, artefacts, engineering, and applied tools rather than information technology (Kim & Roth, 2016). Even, from Science-Technology-Society (STS) curriculum efforts that began in the 1980s (Ramsey 1993; Yager 1996) to the latest emphasis of Science-Technology-Engineering-Mathematics (STEM), there are plenty of efforts to improve both science and technology understandings (Pleasants et al., 2019). Although such STS interventions contributed to the increasing importance of the term *technology* in education, the true nature of technology is still widely unknown (de Vries, 2018).

As Collier-Reed (2008) argues, in order for people to be considered technologically literate, they should be able to think critically about technology-related issues and understand the nature of technology (Liou, 2015). Undoubtedly, there is a wide-ranging literature and discussion on the technologies that would make societies more sustainable, but there is almost no explanation about the nature of technology and what it means for the development of sustainable technologies and societies (Paredis, 2011). Mitcham (1994) states that philosophy of technology has developed in four main dimensions of interest. These dimensions are (i) technology as object, (ii) technology as knowledge, (iii) technology as activities, and (iv) technology as volition. Fernandes, Rodrigues, and Ferreira (2017), on the other hand, provide four dimensions to describe concepts related to the nature of technology which are similar to Mitcham's. The dimensions are (i) instrumental concepts characterized as tools, artifacts, and machines; (ii) cognitive concepts characterized as the practice of theoretical knowledge; (iii) systemic concepts characterized as components of a complex system; and (iv) value-based concepts characterized as the personal value and judgment of science. The similarity of the dimensions herein indicates that over years, the explanations are still similar. Arthur (2009) states that one of the most important issues to be conceptualized about technology is its evolution. He defines the principles for the nature of technology in three ways: (i) technology is a way of achieving human purpose, (ii) technology is a collection of practices and components, and (iii) technology is the collection of all devices and engineering practices available to a culture. According to him, adopting these definitions can help people think about how technologies emerge and how they evolve. Kruse (2013a) states that discussions on the nature of technology cover the following questions: What is technology? How valuable are technologies? What are the benefits and drawbacks of using technology? What are the limitations of technology? In what ways are new technologies linked to the past? How do the practices of technology linked to wider contexts (society, classrooms, etc.) and how does it affect them?

When we consider the nature of technology, it is obviously difficult to make clear deductions. For example, Schuster (2016) suggests that technologies form complex interdependent-networks, as different species in a food web in an ecosystem do. Coccia (2019) argues that the long-term behavior of any technology is not independent from living systems (human and other animal species) and other interrelated technologies. In particular, when analogous technologies are available, each technology tends to affect the character and evolutionary path of others (Coccia, 2019). Shepard (1995) states that the negative consequences of technology should not be attributed solely to its ill-usage (Pleasants et al., 2019). In other words, technologies develop together with societies (Saviotti, 2005), but the intertwining of society and technology is not neutral. Values shape technologies and technologies also have a significant impact on the values realized in a society (Johnson & Wetmore, 2009). Unfortunately, the negative consequences are difficult to spot, given the many benefits of technological advancement (Kruse and Buckmiller, 2015). According to Huesemann and Huesemann (2011), it is meaningless to hope that negative environmental consequences of technology can be eliminated through more technology since new technologies will create new problems (Pleasants et al., 2019). With all of these, Harwood and Eaves (2020) offer a conceptual projection about how technology can evolve in the future. They draw attention to the potentially disruptive nature of technology and state that this is not necessarily due to incremental developments, but to the emergence of unpredictable new configurations. Kott and Perconti (2018) also state that if an unpredictable technology emerges, which is particularly disruptive, it can have serious consequences. Ultimately, as offered by Utterback, Pistorius, and Yilmaz (2019), it is necessary to abandon the approach that technology and innovation only emerge and develop in pure competition between new and existing ones.

Problem of research

Over the past 50 years, public attitude towards technology has been largely shaped by the print media, and more recently by online and social media (Harwood & Eaves, 2020). At this point, educators' perceptions about the nature of technology is of importance.

Teachers who do not have the desired/expected perceptions about the nature of technology will inevitably lead students negatively. Jones and Moreland (2004) suggest that in order to develop and maintain learning in technology, focus should be on specific and detailed technological learning outcomes, together with appropriate pedagogical approaches. Moreover, they propose *nature of technology and its characteristics* as one of the seven structures of technological pedagogical content knowledge. In addition, according to Kruse and Buckmiller (2015), understanding the nature of technology will help educators to consider decisions about technology in a more attentive way. Pleasants et al. (2019) state that their purpose in identifying and clarifying the key nature of technology structures is to encourage more informed views on the nature of technology among educators, so that they will be able to develop more knowledgeable and developmentally appropriate nature of technology understandings among their students. Evidence from some studies (i.e., Compton & Harwood, 2003; Jones & Moreland, 2003) clearly shows that if students are provided with opportunities to develop their increasingly complex understanding of the nature of technology, their learning about technology generally increases. This is accomplished by teachers who engage and speak openly with their students about the nature of technology (Jones & Moreland, 2003) and critical analysis of technological applications (Compton & Harwood, 2003).

In this study, it was aimed to determine *science* teachers' perceptions about the nature of technology both in terms of revealing their existing perceptions and contributing to educational practices about this issue. If we look at the history of the science curriculum studies in Turkey, we see that they date back to mid-twentieth century as a result of the rapid changes in science and technology after World War II. Systematic innovations in curriculum development studies were done in line with the reform movements in other countries (especially in the United States) and with the support of organizations like World Bank. As a result of these efforts, the science curriculum in Turkey was considerably revised in 2000 and aimed to raise individuals who know the importance of scientific developments and realize the effects of these developments on technology, society and the environment (MoNE, 2000). Right after these developments, in 2003, new curriculum studies were initiated, and science, technology, society and environment interactions were defined as a learning area in the next curriculum (MoNE, 2006). The name of the course was also updated as *Science and Technology* and the teachers were named as *Science and Technology Teachers*. Since 2013, with the new revisions in the curriculum, the name of the course has been updated to *Science* again but the Science-Technology-Society-Environment (STSE) education retained its place in the science curricula (MoNE, 2013, 2018). At this point, it can be obviously deducted that science teachers' perceptions of the nature of technology is of importance.

Although there are studies in the related literature focusing on students' (e.g., Constantinou et al., 2010; DiGironimo, 2011; Fernandes et al., 2017; Kruse, 2013b) and teacher candidates' (e.g., Koç, 2013; Leatham, 2007) understanding of the nature of technology, studies examining teachers' understanding is rare (e.g., Waight, 2014). The nature of technology perceptions of students at different grade levels are important. Along with that, science teachers' perceptions are also problems of research that need to be investigated, since they are the most significant factor that bring science and technology and their education to students. At this point, the present study describes an investigation of a sample of science teachers' perspectives of technology through the use of a methodological alternative—that is, the Q methodology. Accordingly, the research questions proposed for the study are as follows:

1. What are the different perspectives of science teachers concerning the nature of technology?
2. What are the descriptions associated with the perspectives that science teachers posit about the nature of technology?

Methodology

This study was conducted by using Q methodology—a method that examines self-referenced perspectives of individuals by revealing the similarities and differences of these perspectives in a holistic structure. (Brown, 1993; Stainton Rogers, 1995; Watts & Stenner, 2012). In this method, interpersonal factor analysis is done through replacing the variables by individuals (Stephenson, 1953). That is, the variable is a survey item and the subject is the person in the traditional factor analysis, while in Q method, the variable is the Q-sort made by the participant and the subject is the Q statement (Webler, Danielson, & Tuler, 2009, as cited in Young & Shepardson, 2018). Traditional factor analysis identifies correlations between variables across the sample of participants; whereas Q methodology identifies the patterns in the placement of Q statements across all Q-sorts made in the study and these patterns show that there is an "inter-subjective orderings of beliefs" that groups of people share (Webler et al., 2009, p.8, as cited in Young & Shepardson, 2018). Through the method, the social perspectives are revealed.

The procedure includes presenting participants with a number of statements about a topic and asking them to sort these statements according to a guideline [e.g., agree/disagree, like/dislike, regard/disregard] (Van Exel, & De Graaf, 2005). Each statement is ranked relative to every other statement in Q methodology and unlike Likert scales where individual statements are rated according to participants' rate of agreement and a partial picture of the perspectives is revealed, relative rankings of the statements in Q methodology give a more complete picture of the perspectives that participants have about the issue (McKeown, 2001). In this study, for example, participants ranked a Q-sort of 36 statements. In a Likert scale with 36 statements, for example, there are only 36 choices. In Q methodology, on the other hand, a person has to make ½N(N–1) choices (Brown & Ungs, 1970), where N is the number of statements (the number of choices is calculated as 630 for 36 statements).

Participants

The participants consisted of a total of 17 science teachers who were voluntarily participated in the study. The sample was purposive and science teachers from different gender and years of experience were recruited in the research for the purpose of creating a heterogeneous group. In Q methodology, a high number of participants is not expected since the focus of the method is the sequence of statements (Brown, 1993). Essentially, the subject of Q studies is the Q statements and the purpose is to determine the patterns formed in Q statement configurations (Webler et al., 2009, as cited in Young & Shepardson, 2018). In Q methodology, a 3:1 ratio of statements to the number of participants is offered but a ratio of 2:1 is also accepted (Webler et al., 2009, as cited in Young & Shepardson, 2018). For a Q-sort with 36 statements, the optimal number of participants is 12, but an acceptable number of participants is between 12 to 18 (Young & Shepardson, 2018). Throughout the study, no identifying information about the participants is given but the participants are coded depending on their year of experience as a teacher and their gender. That is, for example, a male teacher with one-year experience is coded as ST01M and a female teacher with ten-year experience is coded as ST10F. Namely, ST means 'Science Teacher', numbers (01, 06 etc.) are the years of professional experience, and M means male and F means female. When there are two or more teachers with the same characteristics, on the other hand, it is indicated in parenthesis as (01), (02) or (03), referring to first, second and third. Of the 17 participants, eleven (65%) were female, and six (35%) were male. Two of the participants had 1-year, two 2-years, one 3-years, one 4-years, one 5-years, one 7-years, four 8-years, one 10-years, two 13-years, one 21-years and one 26-years of professional experience (see Table 1 for participant demographics).

Q-sort design

In this study, participants sorted a number of 36 statements (see Table 3 for the list of the statements). The statements constituted the following six categories: (i) definition of technology, (ii) the relationship between science and technology, (iii) the impact of society on technology, (iv) the impact of technology on society, (v) the impact of technology on environment, and (vi) the impact of technology on economy (see Table 2).

The statements in Q methodology are supposed to represent a wide range of views held by a community (McLain, 2021). Therefore, in this study, the statements in each category originated from well accepted research in the related literature (see Table 3 for the references); and a pilot study was carried out with 10 science teachers before conducting the main study. These statements were selected because they provided a picture of how science teachers think about the nature of technology. Having multiple categories that focus

Table 1 Participant's demographic information

	Q-sort	Gender	Years of experience
1	ST02M	Male	2
2	ST02F	Female	2
3	ST13F	Female	13
4	ST21M	Male	21
5	ST08F(1)	Female	8
6	ST03F	Female	3
7	ST01F(1)	Female	1
8	ST05M	Male	5
9	ST04F	Female	4
10	ST07F	Female	7
11	ST13M	Male	13
12	ST01F(2)	Female	1
13	ST08M	Male	8
14	ST08F(2)	Female	8
15	ST26F	Female	26
16	ST08F(3)	Female	8
17	ST10M	Male	10

Table 2 Categories and the corresponding statements

	Categories	Statements
1	Definition of technology	1, 11, 20, 26,
2	The relationship between science and technology	2, 12, 21, 27,
3	The impact of society on technology	3, 13, 22, 32, 36
4	The impact of technology on society	4, 5, 9, 10, 14, 15, 19, 23, 28, 33, 34
5	The impact of technology on environment	6, 16, 29, 30
6	The impact of technology on economy	7, 8, 17, 18, 24, 25, 31, 35

on different aspects of a discipline better measures how individuals feel about a subject (Molina et al., 2011).

Data collection and analyses

The Q-sort

The Q set in this study included 36 statements, which were sorted based on participants' level of agreement with each statement relative to the other statements. Sorting is not based on *correctness* but on *the degree of agreement*; that is, how strongly the participant agrees or disagrees with each statement relative to the others. This type of sorting allows the process to be totally subjective since it characterizes each participant's specific perspective (Brown, 1993). It also leads to a normal distribution of the statements, which is a standard practice in Q methodology (Webler et al., 2009, as cited in Young & Shepardson, 2018). In this study, there were 11 levels of agreement, and each level has a set number of spaces in which to place the statements: one + 5; two + 4 s; three + 3 s; four + 2 s; five + 1 s; six 0 s; five -1 s; four -2 s; three -3 s; two -4 s; and one -5 (see Fig. 1). Participants were given the statements and place one statement in each box. In Q methodology, the way that a participant places the statements in the vertical column does not matter since they are at the same level of agreement. That is, a participant can agree more with one statement than the other(s) ranked at that same level but the Q-sort board does not reflect that difference.

The data collection process was carried out online due to the COVID-19 pandemic constraints. A spreadsheet file with the Q-sort board (Fig. 1) and the statements (Table 3) was created and sent to the participants via e-mail. The participants were informed about the process with an information form sent through e-mail (and on the phone, when needed) and were first asked to read all the statements and group them as they agreed with the statement, disagreed with the statement, or if it was neutral or not applicable to them. They were then asked to focus on the statements they agreed with and sort them from the most in + 5, then + 4, + 3, + 2 and + 1, respectively. Following that, they were asked to focus on the statements they disagreed with and follow the same procedure for these statements as -5, -4, -3, -2 and -1 this time. Finally, they were asked to place the statements for which they were neutral in 0. The participants were told that there was no 'correct' sorting and that they were free to ask questions regarding the statements. They were also given the opportunity to move any of the statements if they chose to do so. Data obtained through Q-sorts were analyzed through using PQ Method 2.35 software (Schmolck, 2014). Each

Table 3 Statements and Q-sort values for the three perspectives

No	Statement	Q-sort value		
		P1	P2	P3
1	Technology consists of all the modifications humans have made in the natural environment for their own purposes (Dugger, 2001)	−1	+3	0
2	Although technology has important relations with science, it is different from science (Britton et al., 2005)	+4	−5	−1
3	As in the past our future depends on good technologists (Aikenhead, Ryan, and Fleming, 1989)	+1	+5	−5
4	Technology can help you make some moral decisions by making you more informed about people and the world around you (Aikenhead, Ryan, and Fleming, 1989)	0	+4	−1
5	New technologies change people's lives in both expected and unexpected ways (Solomon, 1997)	+5	+1	+1
6	Technology can definitely help solve problems such as pollution (Aikenhead, Ryan, and Fleming, 1989)	−1	0	−2
7	Technology increases the wealth of countries since it generates more efficiency, production, and progress (Aikenhead, Ryan, and Fleming, 1989)	+2	+3	−1
8	While technology searches for 'development' for someone, it also creates winners and losers (Kimbell, Stables and Gren, 2002)	+2	−2	0
9	Among the effects of technology, things that benefit some people can be harmful to someone else (Aikenhead, Ryan, and Fleming, 1989)	+3	0	−3
10	Technology is problematic and contradictory for individuals and society (Petrina, 2007)	−3	−4	−3
11	Technology is a collection of ideas and techniques for designing and manufacturing things, for organizing workers, business people and consumers, and for the progress of society (Aikenhead, Ryan, and Fleming, 1989)	−2	+4	+2
12	There is a dynamic information flow between science and technology (Chaves & Moro, 2007)	+4	+1	0
13	Technological developments can be controlled by citizens. because technology serves the needs of consumers (Aikenhead, Ryan, and Fleming, 1989)	0	+3	−2
14	Scientists cannot predict the long-term effects of new technological developments, in spite of careful planning and testing (Aikenhead, Ryan, and Fleming, 1989)	−2	−1	−3
15	More technology would make life easier, healthier and more efficient but more technology would cause more pollution, unemployment and other problems (Aikenhead, Ryan, and Fleming, 1989)	−1	+1	−1
16	Technology will result in irreversible and ever-increasing effects. Extinction of species, depletion of the ozone layer, and the greenhouse effect are notable aspects of its consequences (Petrina, 2007)	−2	0	0
17	The decision to use a new technology mainly depends on several things, such as its cost, its efficiency, its usefulness to society, and its effect on employment (Aikenhead, Ryan, and Fleming, 1989)	+2	+2	+2

Table 3 (continued)

No	Statement	Q-sort value		
		P1	P2	P3
18	Technological activities require resources such as energy (ITEA, 1996)	+1	+2	+1
19	There is always a balance between the positive and negative effects of technology since every new development has at least one negative consequence (Aikenhead, Ryan, and Fleming, 1989)	−3	0	+3
20	Technology is a technique for doing things, or a way of solving practical problems (Aikenhead, Ryan, and Fleming, 1989)	−1	+2	+3
21	Technology advances mainly on its own. It doesn't necessarily need scientific discoveries (Aikenhead, Ryan, and Fleming, 1989)	−4	−3	0
22	The more students learn about technology the more informed the future public will be (Aikenhead, Ryan, and Fleming, 1989)	0	+1	+1
23	Technology can help resolve some social problems but not others (Aikenhead, Ryan, and Fleming, 1989)	+1	0	0
24	Technological activities form the basis of a country's economy (ITEA, 1996)	+1	+2	+2
25	Most of the technological practices are directed towards designing and creating new products, technological systems and environments (ITEA, 1996)	0	−3	+5
26	Technology is a collection of techniques that include man-made artificial products, tools, and systems throughout the ages (Dumestre, 1999)	−1	−2	+4
27	Scientific research leads to practical applications in technology, and technological developments increase the ability to do scientific research (Aikenhead, Ryan, and Fleming, 1989)	+2	−3	+1
28	One cannot get positive results without first trying a new idea and then working out its negative effects (Aikenhead, Ryan, and Fleming, 1989)	−2	−2	+1
29	Various technological processes or abuses can create ecological dilemmas and create environmental crises (ITEA, 1996)	+3	−4	+4
30	Environmental problems arise from advanced technology, and this can again be solved with advanced technology (Des Jardins, 2013)	−3	−1	+3
31	Technological developments will occur in areas of high demand and where profits can be made in the market place (Aikenhead, Ryan, and Fleming, 1989)	−4	−1	−4
32	Technological developments will occur in areas of high demand and where profits can be made in the market place (Aikenhead, Ryan, and Fleming, 1989)	0	−1	−1

Table 3 (continued)

No	Statement	Q-sort value		
		P1	P2	P3
33	Technology can help people make legal decisions by improving ways of collecting evidence and proving the physical facts of a situation (Aikenhead, Ryan, and Fleming, 1989)	+1	−2	−2
34	Technology offer a great deal of help in resolving such social problems such as overpopulation (Aikenhead, Ryan, and Fleming, 1989)	−5	−1	−4
35	Technology will increase the wealth of our country because our country will be able to sell new ideas and technology to other countries for profit (Aikenhead, Ryan, and Fleming, 1989)	0	+1	+2
36	Making decisions with a sense of responsibility requires understanding the relationship between technology, society and the environment (ITEA, 2000)	+3	0	−2

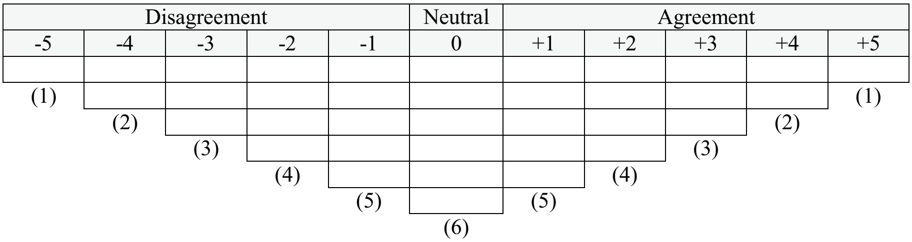

Fig. 1 The Q-sort layout used in this study

sort was entered into the program, and the program correlated each Q-sort with every other Q-sort and produced an inter-correlation matrix. Principal component analysis and Varimax rotation were then made to maximize the variance explained on minimum number of factors possible.

Interviews

In Q methodology, it is recommended that a Q-sort be followed by an interview (Brown, 1993). A standard interviewing procedure, however, is not defined for this process but in order for better understanding participants' views, asking questions about the statements that were ranked at most (that is, +5 and -5 in this study) is a common practice (Brown, 1993). In this study, participants were interviewed through six questions. Statements 2, 3, 10, 21 and 29 constituted the first five questions, while the last question focused on taking an overall opinion of the teachers about the nature of technology. The first five statements were chosen from the ones either (i) made a statistically significant difference between the three perspectives (that is, the distinguishing statements), (ii) shared between the three perspectives (the consensus statements), (iii) ranked at most (+4, +5, -4 or -5) or (iv) represented information from all categories (so that, overall information about the categories is provided). Statement 2, for example, is an identifying statement for all three perspectives. The statement is under the category of 'the relationship between science and technology' and has Q-sort values of +4, −5 and -1 for perspectives 1, 2 and 3, respectively. Similarly, statement 3, an identifying statement for the three perspectives, is under the category of 'the impact of society on technology' by having Q-sort values of +1, +5 and −5 for perspectives 1, 2 and 3, respectively. Statement 10, on the other hand, is a shared statement under the category of 'the impact of technology on society', and has Q-sort values of −3, −4, and −3.

Findings and interpretation

Analysis of the participants' Q-sorts resulted in a three factor solution, i.e. three distinct patterns of perception about the nature of technology (see Table 4). As seen in the Table, the three perspectives were loaded with more than one person defining himself/herself in that perspective, and all of the participants (100%) were defined with a perspective (that is, no one is left behind). The perspectives had between three and eleven defining variables (i.e. responses significantly associated with the perspective). Together, they accounted for

Table 4 Factor loadings of Q-sorts for the three perspectives

	Q-Sort	Perspectives:		
		P1	P2	P3
1	ST02M	0.4428 X	−0.3019	−0.1145
2	ST02F	−0.0884	−0.3339	0.6967 X
3	ST13F	0.6640 X	0.0829	−0.0632
4	ST21M	0.6701 X	0.0221	−0.4395
5	ST08F(1)	0.7353 X	−0.2406	0.1376
6	ST03F	0.3226	0.3643	0.6073 X
7	ST01F(1)	0.3514	0.7176 X	−0.1771
8	ST05M	0.4081 X	−0.0174	0.1722
9	ST04F	0.5726	0.6044 X	0.1727
10	ST07F	0.4219	0.6777 X	0.0058
11	ST13M	0.5948 X	0.0016	0.0658
12	ST01F(2)	0.2008	−0.0158	0.4976 X
13	ST08M	0.6753 X	−0.0485	0.3480
14	ST08F(2)	0.6160 X	−0.2859	−0.3447
15	ST26F	0.4966 X	−0.1960	−0.1718
16	ST08F(3)	0.6397 X	−0.1494	0.0984
17	ST10M	0.6985 X	0.2757	−0.1390
% expl.Var.: 51% (Total)		29%	12%	10%

51% of the variance in the Q-sorts. The Q-sorts and corresponding factor loadings on each of the three perspectives are shown in Table 4.

When Table 4 is analyzed, it is seen that eleven participants are in the first perspective, three are in the second and another three are in the third perspective. It is also seen that participants' gender and years of experience seem to be influential on their distribution to the perspectives. For example, it is seen that all males in the sample are in the first perspective and the female participants who hold this perspective have at least 8 years of teaching experience. It is observed that the participants in the second perspective, on the other hand, are all women and have a maximum of 7 years of experience, and the participants in the third perspective are again all women but have a maximum of 3 years of teaching experience.

Comparisons between perspectives

It is possible to compare the perspectives graphically (Young & Shepardson, 2018). Figures 2, 3 and 4 present the comparisons of each two factors with respect to the loading sco res.

Figures 2, 3, and 4 compare how strongly the participants correlate with their own perspective and with the other two perspectives. Loading scores range from −1 to + 1; and scores close to 1 show complete agreement, while scores close to −1 show complete disagreement and 0 shows no agreement (Webler et al., 2009, as cited in Young & Shepardson, 2018). For example, Fig. 3 shows that ST01F(2), ST02F and ST03F have a slight correlation with factor 3, while ST01F(1), ST04F and ST07F correlate with factor 2 (see loading

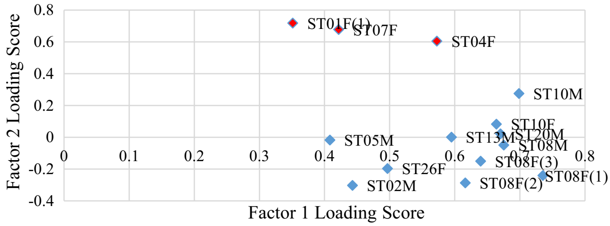

Fig. 2 Factor loadings for factors 1 and 2

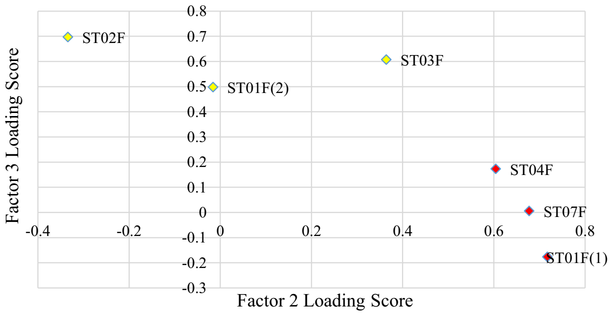

Fig. 3 Comparison between factors 2 and 3

Fig. 4 Comparison between factors 1 and 3

scores on the axes). In other words, by loading on factor 3, ST01F(2), ST02F and ST03F share more characteristics with this factor.

Shared (consensus) statements

Shared statements are also valuable in defining the three perspectives. The three perspectives shared eight statements in common (see Table 5 for these statements, with the Q-sort values for each perspective). As seen in Table 5, statement 17 was common in sort for the three perspectives (+2). It says that the decision to use a new technology mainly depends on many things such as its cost, efficiency, benefit to society and its impact on employment. The remaining seven statements, on the other hand, can be considered as "key statements" and their Q-sort values help to determine the perspective they define (Young & Shepardson, 2018, p.205).

When Table 5 is examined, it is seen that while Perspective 2 is neutral for statement 6, Perspectives 1 and 3 are slightly negative, meaning that Perspective 2 is more optimist about technology in solving problems such as pollution (see the statement), in comparison to the other perspectives. Similarly again, Perspective 2 has a Q-sort value of −4 for

Table 5 Shared statements for the perspectives (1, 2 and 3)

No	Statement	Q-sort Value		
		P1	P2	P3
6	Technology can definitely help solve problems such as pollution	−1	0	−2
10*	Technology is problematic and contradictory for individuals and society	−3	−4	−3
15*	More technology would make life easier, healthier and more efficient but more technology would cause more pollution, unemployment and other problems	−1	+1	−1
17*	The decision to use a new technology mainly depends on several things, such as its cost, its efficiency, its usefulness to society, and its effect on employment	+2	+2	+2
18*	Technological activities require resources such as energy	+1	+2	+1
22*	The more students learn about technology the more informed the future public will be	0	+1	+1
23*	Technology can help resolve some social problems but not others	+1	0	0
32*	Technological developments will occur in areas of high demand and where profits can be made in the market place	0	−1	−1

All listed statements are non-significant at $p > .01$, and those flagged with an * are also non-significant at $p > .05$

statement 10, which states that technology is problematic and contradictory for individuals and society. Interpretation of statement 15 results in a similar inference about Perspective 2, that is participants holding this perspective are optimist about technology when compared to others.

The three perspectives

The three perspectives emerged from the Q-sorts included teachers who are (i) equally aware of the benefits and drawbacks of technology and the relation of it to science, (ii) optimist about technology and aware of its dependence on society, and (iii) optimist about technological innovations but tempered by technology-driven environmental and social issues.

The statements that distinguish each perspective and the characteristics of the participants that define each perspective are highlighted below. Any overlap among the perspectives, as well as any differences, are also discussed (see Table 3 for the Q-sort values of the statements not discussed in detail).

Perspective 1: equally aware of the benefits and drawbacks of technology and the relation of it to science

Eleven participants (6 males and 5 females) loaded significantly onto Perspective 1. As stated above, all males in the sample were defined in this perspective and all females sharing this perspective had at least 8 years of professional experience. The perspective accounted for 29% of the variance among the sorts.

The participants of the perspective emphasized both positive and negative aspects of technology and they were aware of the relation between technology and science (see Table 6 for identifying statements for this perspective). They recognized the dynamic flow of information between science and technology (S12: +4) but were aware of the difference between them as well (S2: +4). Participants loading on this factor were in favor of the idea that new technologies can change human life in both expected and unexpected ways (S5: +5). They thought that technological things that benefit some people can be harmful to others (S9: +3), and in search of 'development', technology can create both winners and losers (S8: +2).

Interviews provided more and supportive information about the perspective. Participants holding this perspective revealed both positive and negative aspects of technology. They pointed out some drawbacks of technology such as environmental problems and problems with human health and psychology like addiction. Some sample excerpts are below.

> While a product designed with developing technology can be effective in the development of societies and attaining the desired level of welfare, it can also bring some environmental problems like pollution, and therefore technology can be used to eliminate this problem again. [ST08F(3), interview]
> Some of the developments that seem beneficial in the short term can cause great damage to the environment in long term. Micro-plastics, waste batteries, heavy metals, etc. are among the examples. [ST26F, interview]
> In developing a technology, if the needs of society and financial interests are solely taken into consideration, we may have benefits in the short term but may

Table 6 Identifying statements for perspective 1

No	Statement	Grid position	Nature of Technology Categories:					
			Definition of technology	Rel. betw, science & technology	Impact of society on technology	Impact of technology. on society	Impact of technology on environment	Impact of technology on economy
5*	New technologies change people's lives in both expected and unexpected ways	+5				x		
12*	There is a dynamic information flow between science and technology	+4		x				
2*	Although technology has important relations with science, it is different from science	+4		x				
9*	Among the effects of technology, things that benefit some people can be harmful to someone else	+3				x		
29	Various technological processes or abuses can create ecological dilemmas and create environmental crises	+3					x	
8	While technology searches for 'development' for someone, it also creates winners and losers	+2						x
30*	Environmental problems arise from advanced technology, and this can again be solved with advanced technology	−3					x	
19*	There is always a balance between the positive and negative effects of technology since every new development has at least one negative consequence	−3				x		
21	Technology advances mainly on its own. It doesn't necessarily need scientific discoveries	−4		x				

($p < .05$; asterisk (*) indicates significance at $p < .01$)

> have to deal with problems such as environmental pollution, anti-sociality, psychological problems or the threat of natural life in long term. [ST26F, interview]
> Technological studies can provide benefits, but there are also damages.... For example, Robot vacuum cleaners are highly efficient technological tools, but after a while they push people to laziness and can go up to obesity as a result of inactivity. [ST10M, interview]
> In my opinion, technology has many positive and negative effects on the environment. For example, with the development of technology, environmentally friendly, energy-saving white goods and automobiles can be designed or studies for sustainable development can be supported; but on the other hand, the pesticides or the new generation seeds used in agriculture can cause the deterioration of the ecological balance and serious damage to the environment in long term. [ST08F(1), interview]
> The technological product range is developing with the developing technology. There will useful ones for society, as well as harmful ones. The product developed for the health sector will undoubtedly be useful; however, it also creates individuals who are TV-, telephone- or technology-addicts. [ST20M, interview]

In the interviews, participants offered solutions to the problems caused by technology. Among these solutions were the conscious use of technology. One participant, on the other hand, introduced technological literacy as a valuable trait for people to utilize technology. Below is the related excerpt.

> It is obvious that technology has both benefits and drawbacks in almost every field. Technological literacy is very important in this regard. It is necessary to be able to use and benefit from technology appropriately. [ST08F(2), interview]

The participants holding this perspective gave point to the interconnection between technology and science. They pointed out that both are strongly connected to each other and there is a strong interaction between them. Below are sample excerpts stressing the interconnection.

> I think they benefit each other as a complementary factor even though they are different from each other. [ST02M, interview]
> Thanks to scientific studies, technology advances. However, information is then released for profit. That is why, although the starting point is science, their paths diverge. [ST10M, interview]
> Technology has important links to science, and advances in science contribute to the advancement of technology. Progress in technology contributes to the change and development of scientific knowledge. [ST08F(1), interview]
> Technology is a tool for advancing science and making new discoveries. New discoveries in science also guide the advancement of technology [ST10F, interview]

Although the participants prioritized the relationship between science and technology, a point that is not taken into consideration in terms of this relationship draws attention (see S21). It is seen that participants emphasized the relationship in a way but the idea that technology can progress without scientific knowledge is not seen, although it is now accepted that technological knowledge has some certain features that make it different from scientific knowledge (de Vries, 2005). This idea may be a result of the fact that technology and science are now intertwined so much that, no meaning has been developed for how they can be separate from each other.

Perspective 2: optimist about technology and aware of its dependence on society

Three participants loaded significantly onto Perspective 2; all female and had a maximum of 7 years of professional experience. This perspective accounted for 12% of the variance among the sorts and it is distinguished from the other perspectives by the idea that teachers emphasized the role of society in the development of technology. In other words, the participants were in favor of technology and were aware of its dependence on society (see Table 7 for identifying statements for this perspective).

Participants loading on this factor thought that, 'as it is in the past, future depends on professionals of technology as well' (S3: + 5). According to them, technological developments are directed by human since technology serves the needs of societies (S13: + 3). They defined technology as a technique to do something or a way of solving problems (S20: + 2) and as the changes human make in the natural environment for their own purposes (S1: + 3).

Interviews provided supportive information about the perspective. The participants were in favor of technology but also indicated its dependence on society. Sample excerpts from the interviews are as follows.

> Life without technology seems impossible. Society adapted to technology. The problem is that it provides solutions but it also creates problems. But I think, it is very easy to solve problems with technology. [ST01F(1), interview]
>
> As long as technology is in the hands of unconscious and reckless people, the damage we do to the environment will show its effect much more harshly in the coming years. The technology we use consciously will take our society forward, of course. The ones who use technology is as important as the technology's purpose. [ST04F, interview]
>
> Technological developments are often shaped by the demands of individuals, but it is wrong to generalize this idea. While some individuals accept new technologies without any doubt, some individuals need to rate it first. [ST07F, interview]
>
> Technology must also adapt to the cultural structure of the society; otherwise, it cannot take a place in that society. Society's needs and expectations shape technology. [ST07F, interview]

Participants holding this perspective drew attention to the interaction between society and technology. They believed that life depends on technology, and the needs, expectations and demands of society shape it. The participants did not rigorously discourse on the possible problems with technology, but rather they defined it as a way of solving problems (see S20 and interview excerpts).

Perspective 3: optimist about technological innovations but tempered by technology-driven environmental and social issues

Three participants loaded significantly onto Perspective 3; all female and had a maximum of three years of professional experience. This perspective accounted for 10% of the variance among the sorts and it is similar to the second perspective in terms of optimism about technology. The perspective is distinguished from the others in that the participants were

Table 7 Identifying statements for perspective 2

No	Statement	Grid position	Nature of technology categories					
			Definition of technology	Rel. betw, science & technology	Impact of society on technology	Impact of technology on society	Impact of technology on environment	Impact of technology on economy
3*	As in the past our future depends on good technologists	+5			x			
13*	Technological developments can be controlled by citizens. because technology serves the needs of consumers	+3			x			
1*	Technology consists of all the modifications humans have made in the natural environment for their own purposes	+3	x					
20	Technology is a technique for doing things, or a way of solving practical problems	+2	x					
31	Technological developments will occur in areas of high demand and where profits can be made in the market place	−1						x
25*	Most of the technological practices are directed towards designing and creating new products, technological systems and environments	−3						x

($p < .05$; asterisk (*) indicates significance at $p < .01$)

tempered by technology-driven environmental and social issues (see Table 8 for identifying statements for this perspective).

Participants loading on this factor were in favor of the idea that most technological activities are directed towards designing and creating new products, technological systems and environments (S25: +5). However, they also mentioned about a balance between the positive and negative effects of technology since every new development has at least one negative consequence (S19: +3). For example, they believed that several technological processes can create ecological dilemmas or environmental crises (S29: +4).

In the interviews, participants' dissatisfaction about the drawbacks of technology came out once again. Below are sample excerpts.

> Technology facilitates our lives, but we see that it also has negative effects. By using technological devices, we harm our ecology. I think, it harms to the extent that it is beneficial. We should analyze those products and develop them in a way that they cause less damage. Taking it out of our lives is not a solution. [ST02F, interview]
>
> Technology facilitates our lives, but we see that it also has negative effects. By using technological devices, we harm our ecology. I think, it harms to the extent that it is beneficial. We should analyze those products and develop them in a way that they cause less damage. Taking it out of our lives is not a solution. [ST02F, interview]
>
> While technology develops, old technological product wastes, -as one of the results of new developments-, create major environmental problems. For example, I think space pollution is one of today's important problems. … I think, current problems like pollution and global warming should be prevented by more environmentally friendly technologies. [ST01F(2), interview]

Participants also made comments about the use of technology beyond its purpose and the unpredictability of its results. Below are sample excerpts.

> When technology goes beyond its intended use, some problems are likely to arise. These problems can reach a level that disrupts the structure of the society if they reach a wide audience, and this situation creates serious problems. [ST02F, interview]
>
> The rapid development of technology and its increasing effect in every field cause concern, even though it provides convenience and benefit. A chess game that we cannot predict the next move; it can be dangerous. [ST02F, interview]
>
> I think, the uncertainty of the course of technological developments started to make people uneasy. … I think we are in a great conflict, both financially and in terms of looking ahead. In addition, the number of people in the world who think that technological products replace people's workforce is quite high. That's why people think technology is a bad thing. [ST01F(2), interview]

Participants of this perspective underlined the negative effects of technology but they did not leave it. They pointed out to the balance between the potential negative and positive effects, that is, *the dilemma of technology*. To state in a different way, we may say that the dilemma about the unpredictable consequences of technology is clearly seen in the perceptions of these participants. Interviews pointed out that, participants do not find it possible to remove technology from their lives and find it necessary to use technology with the least harmful effects (see interview excerpts).

Discussion

Findings showed that the participants in the study had three different perspectives towards the nature of technology. Teachers holding Perspective 1 characterized technology as having both positive and negative effects. In other words, they had a two-way (dualistic) perception about the nature of technology. This finding coincides with the complex nature and unpredictability of technology as stated in the literature (Harwood & Eaves, 2020; Schuster, 2016; Utterback et al., 2019). However, the striking element here is hidden in the statements defining this perspective. That is, most of the statements defining this perspective had positive Q-sort values except for statements 30 and 19. It is understood from this statements with negative Q-sort values that teachers did not agree with the complex structure and unpredictability of the technology for these two statements. Moreover, although teachers holding this perspective had positive perceptions about the relationship between technology and science, it is understood that they had insufficient perceptions about the advancement of technology without a need for scientific discoveries. However, as Britton et al. (2005) states, technology benefits from science, but its scope is wider than serving as the practice of science. This finding emerges the need to train teachers in line with the fact that technology has its own knowledge structure and can develop independently from science. In addition, in comparison to other perspectives, teachers holding this perspective attached more importance to technology-science relationship in the context of the nature of technology. Another point to address about this perspective is that all males in the sample of this study were defined in this perspective and all females sharing this perspective had at least 8 years of professional experience. It is not possible, of course, to attribute this case to gender or professional experience with such a small sample but the case obviously points out to further research on these grounds.

Regarding the nature of technology, teachers in Perspective 2 showed positive perceptions, and it is seen that they shared the idea that technology is dependent on society for advancement. These findings coincide with the related literature which states societies as having positive perspectives towards technology and shaping it (Johnson & Wetmore, 2009; Kruse, 2013a; Saviotti, 2005; Waight, 2014). In Waight's (2014) study, for example, science teachers' conceptions about the nature of technology was examined through interviews, and findings resulted in three main themes: (a) technology improves and make life easier; (b) technology is the artifacts which function to accomplish tasks; and (c) technology is the representations of advances in civilization, indicating that they had an optimistic view of technology in terms of its purpose, function, and outcomes. When evaluated within the framework of the statements defining Perspective 2, it is clear that the dependence of technology on society emerges in the context of shaping the future, meeting needs and solving problems. Another point is that the teachers in this perspective had 1 to 7 years of professional experience. As stated previously, the science curriculum in Turkey was renovated in 2006 by putting emphasis on STSE education. Although it is again not suitable to attribute the perspective to professional experience, the renovation in the curriculum may be a cause of shaping the perceptions of the teachers in this direction. It appears that further research elaborating on this case is needed, as well.

Similar to Perspective 2, teachers in Perspective 3 showed positive perceptions about technology but they were tempered by technology-driven environmental and social issues. This finding is consistent with the findings in the related literature which states that technology is not independent of environmental and social issues and is unpredictable (Coccia, 2019; Kott & Perconti, 2018). The findings also showed that teachers in this perspective were confused about technological innovations. The examples they gave during the interviews varied on a number of different topics (i.e. devices, electric cars, workforce), and this can be considered as an explanation for their confused minds. This finding shows the need for a more detailed research of the relevant perspective on different innovative technologies (Tables 7 and 8).

The findings of this study provided some common insights that the participants held. When evaluated in terms of shared statements, for example, it was seen that teachers mostly focused on the effects of technology (i.e. on society, environment and economy; statements 6, 10, 15, 17, 18 and 23) and partly on the impact of society on technology (statements 22 and 32). This finding shows that, regardless of the perspective, teachers' perceptions about the nature of technology developed mostly by prioritizing technology. Similarly, in the related literature, definitions and studies related to the nature of technology are done from the technology perspective (Fernandes et al., 2017; Johnson & Wetmore, 2009; Jones et al., 2013; Kruse, 2013a).

Overall, the current study showed that teachers had perceptions that are compatible with the related literature, but based on different perspectives. This finding supports the idea stated by de Vries (2018) that, the true nature of technology is still largely unavailable. However, the findings also give an important clue for the education about the nature of technology. According to Waight and Abd-El-Khalick (2012), the nature of technology has direct implications for technological application in the science classroom. First, the role of context, culture, and values is unique in integrating technology into the science classroom. Second, technological disclosure should be evaluated within the science classroom as opposed to external domains. And third, the nature of technology exemplifies how both benefits and challenges are rather messy, and technologies do not always succeed on their own merit (or of themselves). Technological systems are complex and they do not act on their own. Namely, as many researchers dealing with the nature of technology (de Vries, 2012; Forret et al, 2011; Kruse & Buckmiller, 2015; Pleasants et al., 2019) have stated, a well-developed understanding of the nature of technology will aid in learning, practice and decisions in this area.

Conclusion

This study was an exploration of science teachers' perceptions about the nature of technology. The study was performed through the use of Q methodology and the findings revealed three diverse perspectives: (i) teachers who are equally aware of the benefits and drawbacks of technology and the relation of it to science, (ii) teachers who are optimist about technology and aware of its dependence on society, and (iii) teachers who are optimist about technological innovations but tempered by technology-driven environmental and social issues. The findings revealed that there was no single line of vision about the nature of technology among the science teachers, and provided typical descriptions about the perspectives. Together with these descriptions, the study also indicated *gender* and *professional experience* as potential determiners among the perspectives. Actually, the ongoing dynamic nature of technology clearly requires the continuity of research on this subject. However, to confirm the validity of the perspectives (and the potential determiners and possible others, as well), replication of the study is needed particularly with other teachers from different regions or countries. Using the characterizing and distinguishing statements revealed for the perspectives in this study, survey research with larger samples may be conducted and

Table 8 Identifying statements for perspective 3

No	Statement	Grid position	Nature of technology categories					
			Definition of technology	Rel. betw, science & technology	Impact of society on technology	Impact of technology on society	Impact of technology on environment	Impact of technology on economy
25*	Most of the technological practices are directed towards designing and creating new products, technological systems and environments	+5						x
29	Various technological processes or abuses can create ecological dilemmas and create environmental crises	+4					x	
19*	There is always a balance between the positive and negative effects of technology since every new development has at least one negative consequence	+3				x		
28*	One cannot get positive results without first trying a new idea and then working out its negative effects	+1				x		
21*	Technology advances mainly on its own. It doesn't necessarily need scientific discoveries	0		x				
13*	Technological developments can be controlled by citizens. because technology serves the needs of consumers	−2			x			
14	Scientists cannot predict the long-term effects of new technological developments, in spite of careful planning and testing	−3				x		
3*	As in the past our future depends on good technologists	−5			x			

($p < .05$; asterisk (*) indicates significance at $p < .01$)

demographic factors associated with the perspectives can be identified. As is known, many models for technology education (STS, STEM, TPCK etc.) have been designed in the last 30 years. Technology emphasis lies at the heart of all of these models, and in this context, teachers who know the nature of technology will be able to play a more effective role. At this point, besides quantitative research, qualitative others may be done through in-depth analysis of the effect of the perspectives of science teachers on teaching processes. The underlying causes of the emergence of the identified perspectives may also be a concern of study. Education includes many variables such as student, teacher and environment, and addressing the nature of technology within the framework of all these variables will positively affect the development in this area. To state briefly, we think that the findings of this study are promising in terms of making more informed decisions for technology applications in educational environments and to direct studies on these applications.

Author's Contributions All authors contributed to the design and implementation of the research, to the analysis and interpretation of the findings and to the writing of the manuscript. The authors also reviewed and approved the final version of the manuscript.

Data availability The data that supports the findings of this study are available from the authors upon reasonable request.

Declarations

Conflicts of interest The authors declare that they have no conflict of interest.

References

Aikenhead, G. S., Ryan, A. G., & Fleming, R. W. (1989). *Views on science-technology-society* (form CDN.mc.5). Saskatoon, Canada, S7N OWO: Department of Curriculum Studies, University of Saskatchewan.

Arthur, B. W. (2009). *The nature of technology*. Allen Lane-Penguin Books, London.

Britton, E., Long-Cotty, B. D., & Levenson, T. (2005). *Bringing technology education into k-8 classrooms: A guide to curricular resources about the designed world*. Corwin Press. A Sage Publications Company.

Brown, S. R. (1993). A primer on Q methodology. *Operant Subjectivity, 16*(3/4), 91–138.

Brown, S. R., & Ungs, T. D. (1970). Representativeness and the study of political behavior: An application of the Q technique to reactions to the Kent State incident. *Social Science Quarterly, 51*, 514–526.

Chaves, C. V., & Moro, S. (2007). Investigating the interaction and mutual dependence between science and technology. *Research Policy, 36*(8), 1204–1220.

Coates, D., & Rose, N. (2002). Social, moral, spiritual and cultural issues in design and technology. In G. Owen-Jackman (Ed.), *Aspects of teaching secondary design and technology: Perspectives on practice* (pp. 245–253). Routledge-Falmer.

Coccia, M. (2019). A Theory of classification and evolution of technologies within a generalized Darwinism. *Technology Analysis and Strategic Management, 31*(5), 517–531.

Compton, V., & Jones, A. (2004). The nature of technology: Briefing paper prepared for the New Zealand Ministry of Education Curriculum Project. https://nzcurriculum.tki.org.nz/content/download/854/6044/file/nature-techn.doc (Available: 20.02.2021)

Compton, V. J., & Harwood, C. D. (2003). Enhancing technological practice: An assessment framework for technology education in New Zealand. *International Journal of Technology and Design Education, 13*(1), 1–26.

Constantinou, C., Hadjilouca, R., & Papadouris, N. (2010). Students' epistemological awareness concerning the distinction between science and technology. *International Journal of Science Education, 32*(2), 143–172. https://doi.org/10.1080/09500690903229296

Cullen T.A., & Guo M. (2020). The nature of technology. In: Akerson V.L., Buck G.A. (eds) *Critical questions in STEM education. Contemporary trends and issues in science education*, vol. 51. Springer, Cham. https://doi.org/10.1007/978-3-030-57646-2_2

De Vries, M. (2012). Philosophy of technology. In P. J. Williams (Ed.), *Technology education for teachers* (pp. 15–34). Sense Publishers.

DesJardins, J. R. (2013). *Environmental ethics: An introduction to environmental philosophy* (5th ed.). Wadsworth.

DiGironimo, N. (2011). What is technology? Investigating student conceptions about the nature of technology. *International Journal of Science Education, 33*(10), 1337–1352. https://doi.org/10.1080/09500693.2010.495400

Dugger, W. E. (2001). Standards for technological literacy. *Phi Delta Kappan, 82*(7), 513–517.

Dumestre, M. J. (1999). The impact of technology on u. s. chigher education: A philosophical approach. *Journal of Information Technology Impact, 1*(2), 63–72.

Fernandes, G. W. R., Rodrigues, A. M., & Ferreira, C. A. (2017). Conceptions of the nature of science and technology: A study with children and youths in a non-formal science and technology education setting. *Research in Science Education*, 1–36.

Forret, M., Fox-Turnbull, W., Granshaw, B., Harwood, C., Miller, A., O'Sullivan, G., & Patterson, M. (2011). Towards a pre-service technology teacher education resource for New Zealand. *International Journal of Technology and Design Education*. https://doi.org/10.1007/s10798-011-9199-8

Harwood, S., & Eaves, S. (2020). Conceptualizing technology, its development and future: The six genres of technology. *Technological Forecasting & Social Change, 160*, 120174.

International Technology Education Association (1996). *Technology for All Americans: A rationale and structure for the study of technology.* Reston, VA: International Technology Education Association.

International Technology Education Association (2000). *Standards for technological literacy: Content for the study of technology*. Reston, VA: International Technology Education Association.

Johnson, D., & Wetmore, J. (Eds.). (2009). *Technology and society. Building our sociotechnical future*. MIT Press.

Jones, A., Buntting, C., & de Vries, M. J. (2013). The developing field of technology education: A review to look forward. *International Journal of Technology and Design Education, 23*, 191–212. https://doi.org/10.1007/s10798-011-9174-4

Jones, A., & Moreland, J. (2003). Developing classroom-focused research in technology education. *Canadian Journal of Science, Mathematics and Technology Education,*. https://doi.org/10.1080/14926150309556551

Jones, A., & Moreland, J. (2004). Enhancing practicing primary school teachers' pedagogical content knowledge in technology. *International Journal of Technology and Design Education, 14*, 121–140. https://doi.org/10.1023/B:ITDE.0000026513.48316.39

Kim, M., & Roth, W. M. (2016). Re/thinking the nature of technology in science classrooms. *Interchange, 47*, 169–187.

Kimbell, R., Stables, K., & Green, R. (2002). The nature and purpose of design and technology. In G. Owen-Jackson (Ed.), *Teaching design and technology in secondary school* (pp. 19–30). Routledge.

Koç, M. (2013). Student teachers' conceptions of technology: A metaphor analysis. *Computers & Education, 68*, 1–8.

Kott, A., & Perconti, P. (2018). Long-term forecasts of military technologies for a 20–30-year horizon: An empirical assessment of accuracy. *Technological Forecasting and Social Change, 137*, 272–279.

Kruse, J. (2013a). Implications of the nature of technology for teaching and teacher education. In Clough, M.P., Olson, J.K., & Niederhauser, D. (Eds.), *The nature of technology: Implications for learning and teaching*. Boston, MA: Sense Publishers.

Kruse, J. (2013b). Promoting middle school students' understanding of the nature of technology. In Clough, Olson, & Niederhauser (Eds.), *The nature of technology: Implications for learning and teaching.* Boston, MA: Sense Publishers.

Kruse, J., & Buckmiller, T. (2013). Making the shift from school manager to instructional leader: Using the nature of technology framework as a tool for analysis. *International Journal of Education, 7*(1), 75–94.

Leatham, K. R. (2007). Pre-service secondary mathematics teachers' beliefs about the nature of technology in the classroom. *Canadian Journal of Science, Mathematics and Technology Education, 7*(2–3), 183–207. https://doi.org/10.1080/14926150709556726

Liou, P. Y. (2015). Developing an instrument for assessing students' concepts of the nature of technology. *Research in Science & Technological Education, 33*(2), 162–181. https://doi.org/10.1080/02635143.2014.996542

McKeown, B. (2001). Loss of meaning in Likert scaling: A note on the Q methodological alternative. *Operant Subjectivity, 24*(4), 201–206.

McLain, M. (2021). Developing perspectives on 'the demonstration' as a signature pedagogy in design and technology education. *International Journal of Technology and Design Education, 31*, 3–26. https://doi.org/10.1007/s10798-019-09545-1

Ministry of National Education [MoNE] (2000). İlköğretim okulu fen bilgisi dersi (4, 5, 6, 7, 8. sınıf) öğretim programı [Elementary school science curriculum (grades 4–8)]. MEB Tebliğler Dergisi, 63, 2518, Kasım 2000.

Ministry of National Education [MoNE] (2006). İlköğretim fen ve teknoloji dersi (6, 7 ve 8. sınıflar) öğretim programı [Elementary school science and technology curriculum (grades 6–8)]. Ankara, Turkey: MoNE.

Ministry of National Education [MoNE] (2013). İlköğretim kurumları (ilkokullar ve ortaokullar) fen bilimleri dersi (3, 4, 5, 6, 7 ve 8. sınıflar) öğretim programı [(Elementary School Science Curriculum (grades 3–8)]. Ankara, Turkey: MoNE.

Ministry of National Education [MoNE] (2018). Fen bilimleri dersi öğretim programı (ilkokul ve ortaokul 3, 4, 5, 6, 7 ve 8. sınıflar) [Science course curriculum (Primary and secondary school curriculum (grades3–8)]. Retrieved from http://mufredat.meb.gov.tr/ProgramDetay.aspx?PID=325

Mitcham, C. (1994). *Thinking through technology: The path between engineering and philosophy*. The University of Chicago Press.

Molina, M. F., Carriazo, J. G., & Farías, D. M. (2011). Actitudes hacia la química de estudiantes de diferentes carreras universitariasen Colombia. *Química Nova, 34*(9), 1672–1677.

Paredis, E. (2011). Sustainability transitions and the nature of technology. *Foundations of Science, 16*, 195–225.

Petrina, S. (2007). *Advanced teaching methods for the technology classroom*. Information Science Publishing.

Pleasants, J., Clough, M. P., Olson, J. K., & Miller, G. (2019). Fundamental issues regarding the nature of technology. *Science and Education, 28*, 561–597. https://doi.org/10.1007/s11191-019-00056-y

Rose, L.C., & Dugger, W.E. (2002). *ITEA/Gallup poll reveals what Americans think about technology*. Reston, VA: International Technology Education Association.

Saviotti, P. P. (2005). On the co-evolution of technologies and institutions. *Towards environmental innovation systems* (pp. 9–32). Springer.

Schmolck, P. (2014). PQPethod (version 2.35) [software]. Available at http://schmolck.userweb.mwn.de/qmethod/index.htm. Accessed 28.12.2020.

Schuster, P. (2016). Major transitions in evolution and in technology. *Complexity.* https://doi.org/10.1002/cplx.21773

Solomon, J. (1997). Teaching STS: Games, simulation and role-play. In F. Banks (Ed.), *Teaching technology* (pp. 152–160). Routledge.

Stainton Rogers, R. (1995). Q methodology. J. A. Smith, R. Harré ve L. van Langenhove (Ed.). In *Rethinking methods in psychology,* (pp. 178–192). London: Sage Publications.

Stephenson, W. (1953). *1953*. Q-technique and its Methodology, University of Chicago Press, Chicago.

Utterback, J.M., Pistorius, C., & Yilmaz, E. (2019). The dynamics of competition and of the diffusion of innovations. *MIT Sloan School Working Paper* 5519–18. Last Revised February 20, 2019.

Van Exel, J. & De Graaf, G. (2005). *Q methodology: A sneak preview*. Retrieved 15 October 2019 from https://bit.ly/2n9ruW6

De Vries, M. (2005). Teaching about technology: An introduction to the philosophy of technology for non-philosophers. *Science & Technology Education Library*, volume 27, Published by Springer.

De Vries, M. (2018). Technology education: An international history. In Marc J. de Vries (Ed.), *Handbook of technology education*. Springer International Publishing AG

Waight, N. (2014). Technology knowledge: High school science teachers' conception of the nature of technology. *International Journal of Science and Mathematics Education, 12*(5), 1143–1168.

Waight, N., & Abd-El-Khalick, F. (2012). Nature of technology: Implications for design, development, and enactment of technological tools in school science classrooms. *International Journal of Science Education, 34*(18), 2875–2905. https://doi.org/10.1080/09500693.2012.698763

Watts, S., & Stenner, P. (2012). *Doing Q methodological research: Theory, method & interpretation*. Sage Publications.

Webler, T., Danielson, S., & Tuler, S. (2009). *Using Q method to reveal social perspectives in environmental research.* Greenfield, MA: Socialand Environmental Research Institute.

Yalvaç, B., Tekkaya, C., Çakıroğlu, J., & Kahyaoğlu, E. (2007). Turkish pre-service science teachers' views on science–technology–society issues. *International Journal of Science Education, 29*(3), 331–348.

Young, J. M., & Shepardson, D. P. (2018). Using Q methodology to investigate undergraduate students' attitudes toward the geosciences. *Science Education, 102*(1), 195–214.