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An Examination of Science Teachers' Knowledge Structures towards Technology

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The purpose of the study was to examine science teachers' knowledge structures on technology, who participated in a TPACK-based Professional Development (PD) program. The PD program was executed in the summer of 2015-2016 academic year with 24 science teachers. Data was collected with the Word Association Test (WAT). A holistic case study approach was followed throughout the study. The stimulus words used in WAT can be stated as; *technology, information and communication technologies, computer, instructional materials, Web 2.0 tools, and Technological Pedagogical Content Knowledge (TPACK)*. Cut-off points were identified by the frequency tables of response words towards stimulus words. The cut-off points helped create the concept networks on technology. At the end of the PD program, progress in science teachers' knowledge structures toward technology was observed. The results showed that the 21st century technologies included in the PD program such as Web 2.0 tools, Algodoo, animoto, probeware, and student response systems were found to be prominent in teachers' responses.

Keywords: professional development program, science teacher, technological pedagogical content knowledge, word association test.

INTRODUCTION

The 21st century brought along a shift from an industrial society to a knowledge society with improvements in information and communication technologies (ICT). Preparing students for daily life problems, for professional life and for usage of ICT to trigger learning and productivity is more prevalent in this new model of society (Zhao, 2003). Accordingly, projects that aim to a) set up and improve technology in schools, and b) bring the innovations in ICT to schools are increasing in number. In Turkey, there have been attempts towards to increase the access and usage of technology in educational settings in the recent years. The Turkish Ministry of National Education (MoNE) initiated projects in connection with international companies and institutions such as the World Bank, Europe Investment Bank, Intel, and Microsoft to set up a substructure of technology in schools in the early 1980s,

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and these projects are still in progress (Topuz & Göktaş, 2015).

In the early beginning of these highly-invested and costly projects, the main goal was to prepare the infrastructure of technology. However, currently these projects also aspire to generalise technology access and usage. The large-scale FATIH Project (The Movement for Enhancing Opportunities and Improving Technology), provides smartboards and internet infrastructure to K-12 schools; that is approximately 570,000 classrooms. In the scope of this project, each student and teacher is supported with tablets. The teachers receive professional development programs on how to use the technology infrastructure and the technological tools (MoNE, 2016). As stated in the content of FATIH Project, both preparing teachers to meet the 21st century needs, and continuously revising and improving technology infrastructure are critical factors for a succesful technology integration (Akıncı, Kurtoğlu, & Seferoğlu, 2012; Kurt, 2013). In line with these findings, the question "What do teachers need to know to use technology?" (Zhao, 2003) should be answered well while structuring the content of technology based professional teacher development programs. This brings the concept of Technological Pedagogical Content Knowledge (TPACK) to the forefront. Koehler &Mishra (2009) defined TPACK as the following:

The basis of effective teaching with technology, requiring an understanding of the representation of concepts using technologies; pedagogical techniques that use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face; knowledge of students' prior knowledge and theories of epistemology; and knowledge of how technologies can be used to build on existing knowledge to develop new epistemologies or strengthen old ones (p.66).

In order to structure and improve teachers' TPACK, high-quality professional development programs are required. These programs should include the usage of technologies that are content-specific. How these technologies can be paired with proper pedagogical methods within instruction should be the focus of such programs (Angeli & Valanides, 2009; Baran, Canbazoglu Bilici, Uygun, 2016). In the TPACK-based professional development programs, various strategies such as direct instruction (Graham et al., 2009), technology demonstrations (Angeli &Valanides, 2008), designing lesson plans (Akkoç, 2012; Guzey &Roehrig, 2009; Özmantar et al., 2010; Sancar Tokmak et al., 2013), teacher design teams (Kafyulilo, Fisser, &Voogt, 2014), and microteaching (Akkoç, 2012; Ozmantar et al., 2010) are used. Teachers' self-efficacy on TPACK and TPACK components (Angeli & Valanides, 2008; Shin et al., 2009), and the change in teachers' TPACK levels (Guzey & Roehrig, 2009; Graham et al., 2009; Niess, 2005; Terpstra, 2009) have recently been investigated in these TPACK-based PD programs.

In the current study, science teachers' knowledge structures on technology who participated in a TPACK-based PD program were examined. Frequently, the concept technology reminds people of the concepts computer and internet (Rose & Dugger, 2002). But, accordingly MoNe reported (2006):

Technology is not the mere electronic devices like computers and their applications. Technology is a form of knowledge that uses concepts and tools of other disciplines' such as science, mathematics and culture. Providing people with information to meet their needs or to solve their problems with the necessary materials, energy and tools is also a part of technology. Technology is a process where tools, structures and systems are built and improved to meet the demands and needs of people (p.8).

In line with the human needs, technology is constantly evolving (Basalla, 1988). Technologies such as smartphones, e-mails, and Web 2.0 tools are becoming an inevitable part of students' lives who are now defined as digital natives. However, digital native students tend to use the meaning and features of technological concepts without a full understanding. This necessiates teachers to have an awareness and a knowledge of technology and technological products (Özsevgeç et al., 2014). In this respect, presenting visual knowledge structures toward the stimulus words is essential in evaluating knowledge of the concepts (Tsai, 2001; Kurt, 2013; Nakiboglu, 2008).

Some strategies that are often used in presenting knowledge structures are concept maps, flow maps, tree construction, structural communication grids, Vee Diyagrams, and word association tests (Özatlı & Bahar, 2010; Tsai & Huang, 2002). In the Word Association Test (WAT), "the subject is asked to give a series of one-word responses in a fixed time to the given stimulus words" (Bahar & Hansell, 2000, p.351). Carl Jung, who is one of the theorists of WAT, reported that the WAT can be used to identify knowledge structures by way of associations between ideas, feelings, and experiences (Kostova & Radoynovska, 2008). WAT are used for multiple purposes in the literature; to understand whether associations between concepts are meaningful and to reveal knowledge structures (Bahar, Johnstone, & Sutchliffe, 1999; Kaya &Akış, 2015; Işıklı, Taşdere, Göz, 2011; Kostova & Radoynovska, 2008), to determine misconceptions (Ercan, Taşdere, & Ercan 2010; Özata Yücel & Özkan, 2015; Timur, 2012), and to evaluate conceptual changes (Hovardas & Korfiatis, 2006). These tests are particularly implemented before and after instruction, to examine changes in knowledge structures on a certain topic (Öner Armağan, 2015; Bahar, Johnstone, & Sutchliffe, 1999; Gulacar et al., 2015; Nakiboglu, 2008).

In this study, the purpose was to investigate the knowledge structures of science teachers on technology, who participated in a TPACK-based PD program. WAT was used for examination of teachers' knowledge structure. The findings of the study can support the existing research base by presentation of teachers' knowledge structures created with WAT, and by inclusion of a TPACK-based PD program example.

METHOD

Case study (Stake, 1995) was used in this study that focused on science teachers' knowledge structures on technology, who participated in a TPACK-based PD program. How teachers' knowledge structures on technology changed following the activities in the PD program was investigated. In this research, the 'how' question mostly sought to be answered in case studies was the focus. A holistic case study approach (Yin, 2003) guided the study in analyzing the knowledge structures of science teachers towards technology.

Context: TPACK-based professional development program

In the eight-day-long TPACK-based PD program, 24 different activities were implemented. These activities are shown below in detail Table 1. All activities in the program were scheduled between 9 am and 7 pm. In the design of these activities, the focus was on the integration of technologies, both the domain-specific technologies (e.g. simulations, animations, and probeware), and the general technologies (e.g. mobile applications, Web 2.0 tools).

The time range of the activities was between 90 minutes and 180 minutes. The activities all began with an introduction by the lecturer. This introduction included the topic of the activity and the technologies particular to that activity. An individual or a collaborative group work session followed this introduction. The participants had the chance to design technology-rich materials that reflected the application of a technology in a certain science content with the appropriate pedagogical methods. The lecturer of the gave information on the ASSURE model and provided example lesson plans. The participants worked in collaborative groups of four to prepare an ASSURE model-based lesson plan and related instructional materials that comprised a certain technology and a science content. The time given to the participants to prepare their lesson plans following the activities was 90 minutes. The groups presented their products on the last day of the PD program and continued by making revisions with the peer feedback they received.

Participants

Twenty-four science teachers participated in the TPACK-based PD program that was implemented in 2015-2016 summer period. The participants were carefully selected from seven geographical regions of Turkey to represent variety across a) schools of different socioeconomic status levels, b) gender (12 males and 12 females), c) professional experience, and d) age. The average age of the participants was 30.8, and the average professional experience was 7.25 years. Table 2 below gives detailed personal information on the participants. The participants had filled out an application form prior to the PD program. The responses to the questions in this form helped shape the selection of the teachers. Teachers who wanted to integrate technology to their lessons but did not know how to use technology in their instruction and the ones who only used technology in a very limited way were included in the participant group. All participants had a B.S. degree from the faculties of education in Turkey.

Table 1. TPACK-based PD Program

Day	09:00-12:30	12:30-13:30	13:30-17:30	17:30-19:00
1	• Creative drama: Meeting activity • What is TPACK: TPACK Game	Lunch	• Evaluation of educational software • ASSURE model based lesson plan and design projects	Practice: Preparing ASSURE model based lesson plan and technology riched instructional materilas
2	• Using smartboard and student response systems in science classroom		• What is Web 2.0 tools?	
3	• Using Youtube in science education • Using cloud-based applications (e.g., Google Drive and Dropbox) in science classrooms		• Creating science blogs, and using blogs in science education • Mobile learning in science education • QR code based science activities	
4	• Preparing effective presentations: Animoto and Prezi		• Preparing online science puzzles • Using concept and mind maps in science education: Inspiration	
5	• Using probeware in chemistry		• Using probeware in physics • Using probeware in biology	
6	• Using simulations in astronomy • Using simulations in chemistry		• Using simulations in physics • Using simulations in biology • Designing simulations via Algodoo	
7	• City Sightseeing and Nature Tour: Ihlara Valley -Cappadocia		• Preparing public service science announcement and slowmotion animation through systemic thought method	
8	• How can digital learning environments be used in science lessons?		• Presenting group ASSURE model based lesson plan and design projects	

Table 2. Demographic Characteristics of Science Teachers (n=24)

Demographic characteristics	
Professional experience (years)	**n**
1-5	12
6-10	7
11-15	3
Above 16	2
Age	
23-27	9
28-32	7
33-37	6
Above 38	2

Data collection tool

Word association test (WAT)

The WAT was implemented both on the first and last days of the PD program as a pre-post measure. The WAT was developed with the identification of six stimulus words reflecting technology as the broad concept. These stimulus words were; *computer, technology, information and communication technologies, instructional materials, Web 2.0 tools, and TPACK.* The content and purposes of the PD program was helpful in the specification of these stimulus words. The stimulus words were finalized by expert opinion. These experts were two professors; one was from the field of science education, and the second was from computer and instructional technologies field. The participants were asked to write 10 words for each stimulus word on separate pages. Each stimulus word was written 10 times in a row to avoid the participants withdrawing from the stimulus words (Yüce & Önel, 2015). An example of such presentation is provided in Figure 1.

Technology

Technology...................................

Technology...................................

Technology...................................

Technology...................................

Technology...................................

Technology...................................

Technology...................................

Figure 1. Example page of WAT form

Prior to the PD activities, participants received an introduction on the usage of WAT which enabled them to have prior knowledge on this alternative assessment tool. The WAT literature shows that participants may receive different time limits to respond to the stimulus words. For each concept in the WAT; 30 seconds (Güneş & Gözüm, 2013) was provided to high schools' students and 60 seconds was given to elementary school students (Ercan, Taşdere, & Ercan 2010; Öner Armağan, 2015) for each WAT stimulus word. For the studies conducted with pre-service teachers, two different time limits were noticed; 30 seconds (Bahar, Johnstone & Sutcliffe, 1999; Nakiboğlu, 2008; Kaya & Akış, 2015) and 40 seconds (Kurt, 2013). In the current study, the same time limit to respond that was provided for each stimulus word was 30 seconds. This enabled the teachers to spend the same amount of time for each word. The application lasted three minutes in total, including the six stimulus words.

Data analysis

The responses to the stimulus words were carefully examined in order to evaluate the data obtained by WAT. A frequency table was created in Excel that displayed the number of times the responses were repeated. This was calculated for each stimulus word. A concept network was also generated based on this frequency table. The cut-off point technique (Bahar et al., 1999) was used to clearly demonstrate the knowledge structures towards technology. Following this technique, for each stimulus word in the WAT, a cut-off point was identified that was three-five points below the number of response words given for that stimulus word. The responses that were above this response frequency were noted on the first part of the concept network. To illustrate, in the pre-implementation, there were 21 response words for the concept *computer*. So the first cut-off point was calculated by subtracting five from 21 and it was set set as '16 and above'. The same procedure was performed for all response words until all stimulus words appeared on the concept networks (Ercan, Taşdere & Ercan, 2010).

FINDINGS

Table 3 shows the number of responses created in the pre and post implementation. The pre-implementation was conducted on the first day of the TPACK-based PD program with 497 total calculated response words. Ultimately, the post-implementation was executed on the final day of the eight-day PD program, and the number of response words recorded 946.

As seen in Table 3, there was an increase in the number of response words associated with the stimulus words after the PD program. The stimulus words with the greatest increase were *Web 2.0 tools, computer, TPACK, ICT, technology,* and *instructional materials.* An interpretation of this can be that with the activities promoting the use of Web 2.0 tools in this PD program, teachers developed their knowledge structures especially towards Web 2.0 tools. Teachers were also asked to state the three most repeated response words in their minds associated with each stimulus word. These findings are displayed below in Table 4.

As seen in Table 4, the post-implementation results indicated that science teachers included concepts that they did not previously mention in the pre-implementation phase. In particular, it was identified that 21st century technologies that were highlighted in the PD program such as, *Web 2.0 tools (e.g. prezi, edmodo) Algodoo, Animoto, probeware,* and *student response systems* were prominent in the WAT. The cut-off point was set to be 16 because it was five points below the concept *'computer'* in the pre-test. Accordingly, Figure 2 given below is prepared.

Table 3. Total number of response words to each stimulus word in pre- and post implementation

	Response words	
Stimulus words	**Pre-implementation**	**Post-implementation**
Technology	119	170
ICT	93	149
Computer	76	161
Instructional materials	109	143
Web 2.0 tools	37	182
TPACK	63	144
Total	497	946

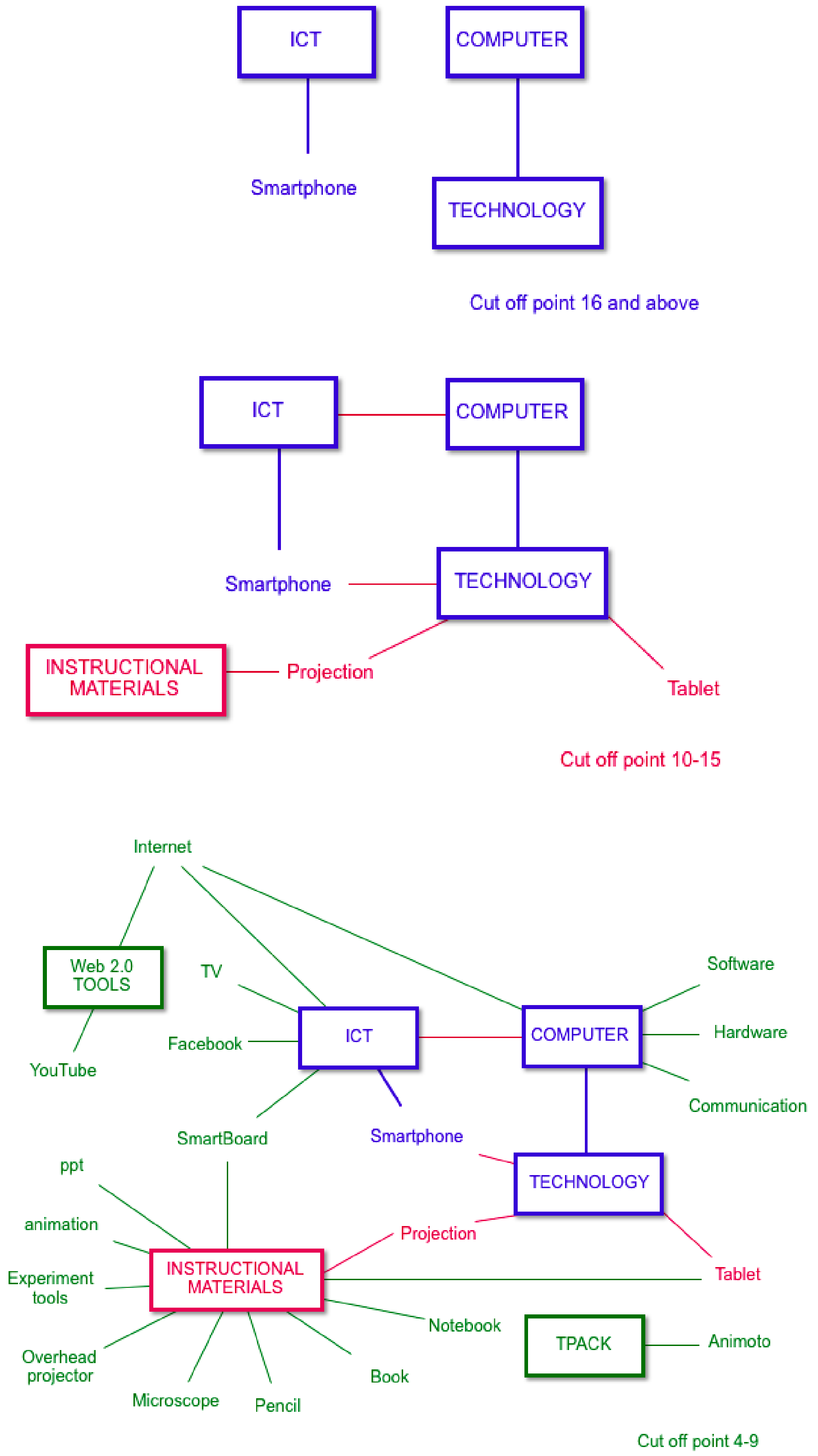
Table 4. Three most repeated response words to stimulus words on the WAT in pre and post implementation

Stimulus Word	Response Words					
	Pre-implementation			Post-implementation		
	1	2	3	1	2	3
Technology	Computer (n=21)	Smart phone (n=13)	Tablet , projection (n=12)	Computer (n=12)	Web 2.0 tools (n=11)	Smartboard (n=9)
ICT	Smart phone (n=17)	Computer (n=11)	Internet (n=9)	Easyclass (n=11)	Computer (n=10)	Edmodo (n=9)
Computer	Software, Microsoft Office Programs (n=7)	Hardware, Internet (n=6)	Communication (n=5)	Internet, Software(n=10)	Prezi (n=8)	Hardware, Communicatio n(n=7)
Instructional Materials	Projection (n=12)	Smartboard (n=9)	Computer, book (n=7)	Smartboard (n=16)	Computer (n=11)	Probeware, Student response system (n=10)
Web 2.0 Tools	Youtube, Internet (n=5)	Facebook, Twitter, Prezi (n=3)	Computer, Blog, Microsoft Office Programs (n=2)	Prezi (21)	Algodoo (n=13)	Youtube, Facebook (n=12)
TPACK	Animoto (n=5)	ProbewareIn spirationEdu cation (n=3)	Smartboard, Computer, Internet, Intersection, Pedagogy, Software, Youtube (n=2)	Web 2.0 tools (n=10)	Prezi (n=8)	Algodoo, Animoto, Technology (n=7)

The stimulus words were analyzed to create associated concept networks, and comments on these networks appear below in Figure 2, representing the pre-implementation phase.

Cut off point 16 and above; for the stimulus words '*instructional materials, Web 2.0 tools and TPACK'* that are provided in WAT, the teachers made no associations. Participants associated the stimulus word *ICT* with the concept of *smart phone*. Also as seen in Figure 2, the two stimulus words *technology* and *computer* were associated among themselves. In other words, it is revealed that for technology, the concept *computer* appeared in the participants' knowledge structures.

Cut off point 10-15; different than cut-off point of 16 and above, the teachers made an association with the stimulus word *instructional materials*. In this frequency range, the participants associated *tablet, smart phone,* and *projection* with the stimulus word *technology* in their knowledge structures. And in terms of *instructional materials*, they had *projection* in their knowledge structures as seen in Figure 2.


ICT
COMPUTER
Smartphone
TECHNOLOGY
Cut off point 16 and above
ICT
COMPUTER
Smartphone
TECHNOLOGY
INSTRUCTIONAL MATERIALS
Projection
Tablet
Cut off point 10-15
Internet
Web 2.0 TOOLS
TV
Software
Facebook
ICT
COMPUTER
Hardware
YouTube
Communication
SmartBoard
Smartphone
ppt
TECHNOLOGY
animation
Projection
Experiment tools
INSTRUCTIONAL MATERIALS
Tablet
Notebook
TPACK
Animoto
Overhead projector
Book
Microscope
Pencil
Cut off point 4-9

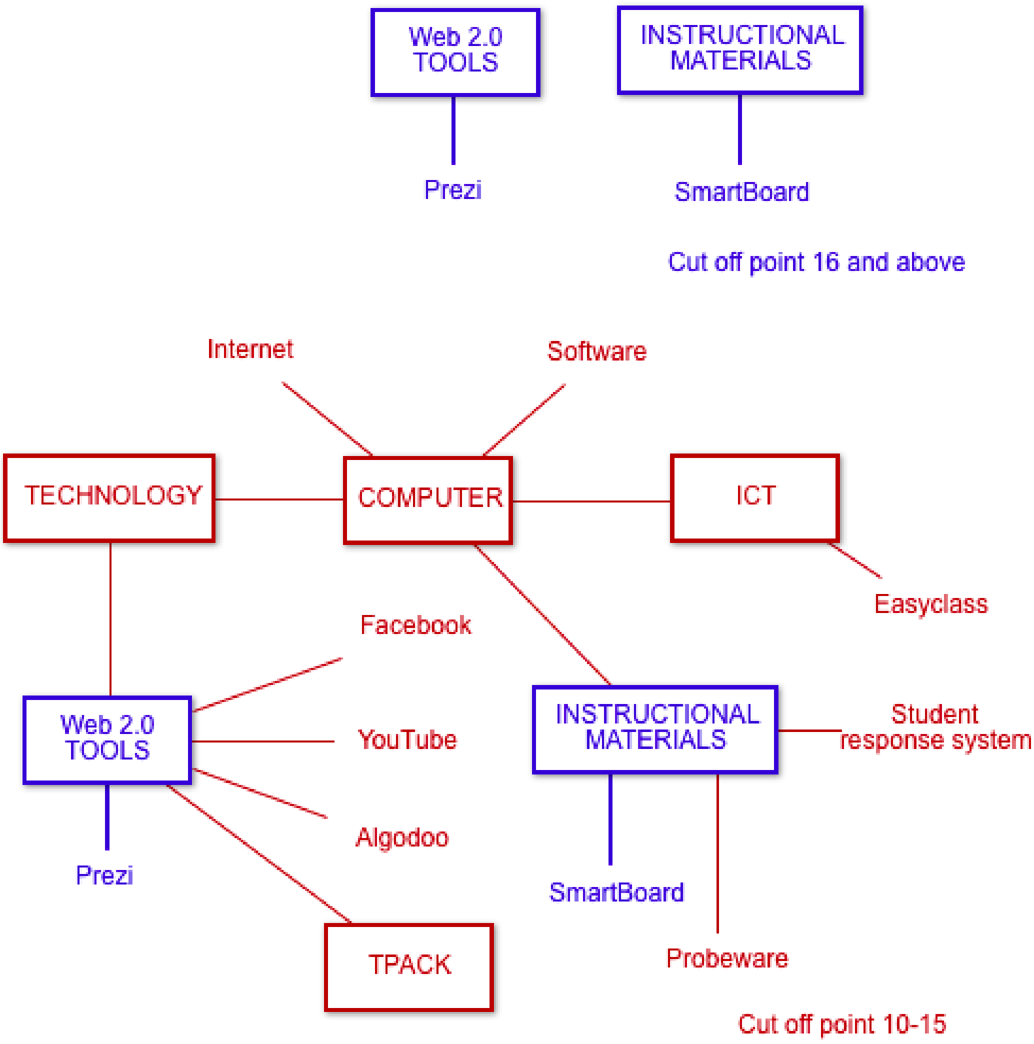


Figure 2. Concept networks for pre-implementation

Cut off point 4-9; a notable increase occured in the number of both the stimulus words and the words associated with the stimulus words. All the stimulus words provided appeared in this frequency range. But, Figure 2 shows that the concepts associated with the stimulus words were traditional technologies. In science teachers' knowledge structures, the concept *computer* was linked with *hardware, software, internet, Microsoft Office programs,* and *instructional materials*. And the concept *instructional materials* was connected to traditional technologies such as *notebook, book, powerpoint, projection,* and *microscope.* Teachers linked the concept *Facebook* to *ICT*, and even though it is a *Web 2.0 tool,* they did not make any association between *Facebook* and *Web 2.0 tools.* Figure 2 shows very limited knowledge structures of the participants around the two concepts; *Web 2.0 tools* and *TPACK*. The pre-service teachers did not make any associations between the concepts *Web 2.0 tools* and *instructional materials*. The concept networks on stimulus words and the associated concepts are demonstrated in Figure 3.

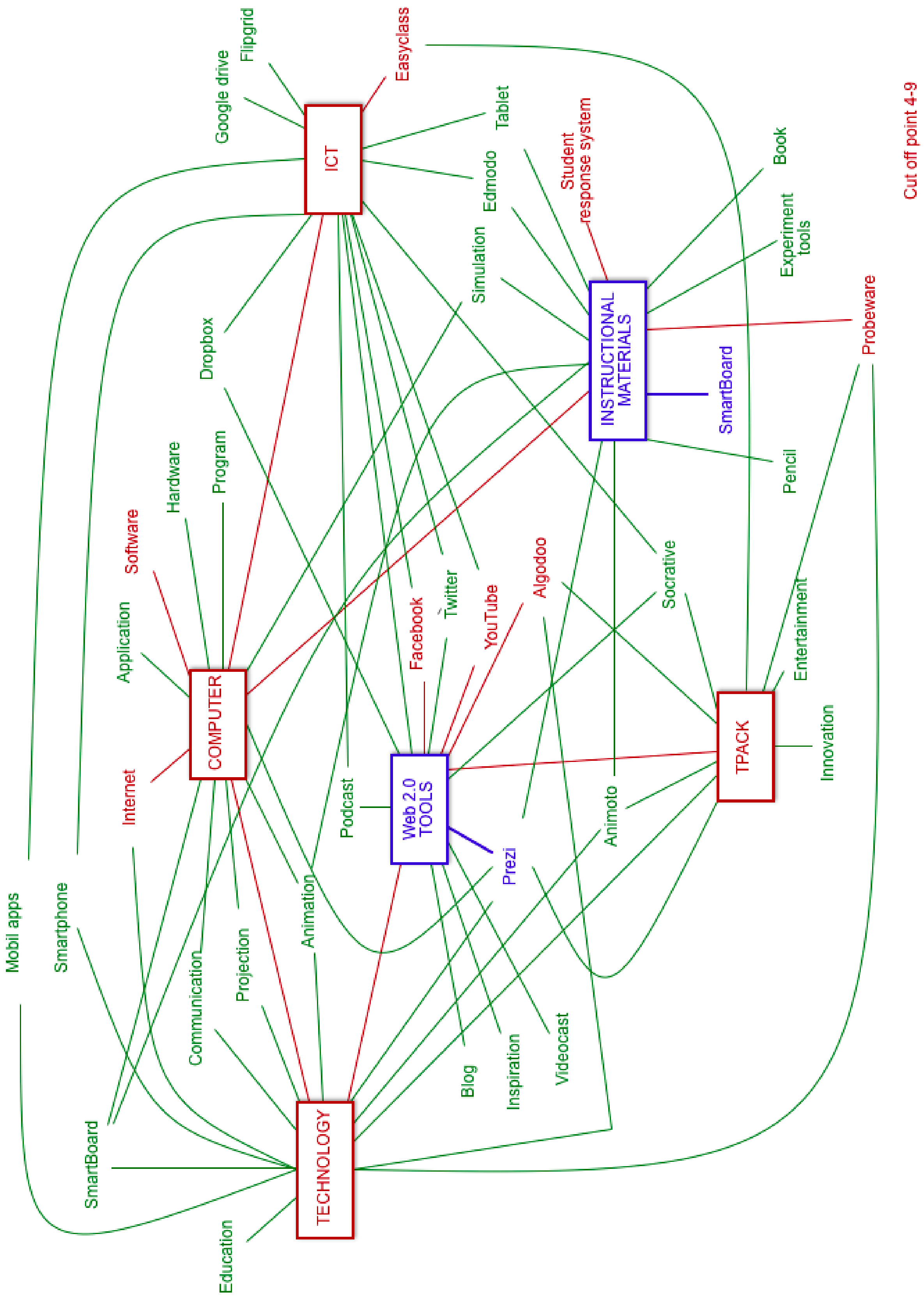


Figure 3. Concept networks for post-implementation

When Figure 3 is examined, **for cut-off point 16 and above**, the concept, *prezi* is recognized in science teachers' knowledge structures that is connected with the *Web 2.0 tools.* The concept '*smartboard'* appeared under the stimulus word *instructional materials*. As in the pre-implementation phase, there was not an association created for every stimulus word. In the pre-implementation, the participants had knowledge structures towards technology knowledge with stimulus words like *technology*, *ICT,* and *computer*, and concepts such as *smartphone*. In the post-implementation, the participants had an association of *Web 2.0* with *instructional materials, prezi*, and *smartboard*. This can be interpreted as the participant teachers having constructed educational technologies following the PD program.

Cut-off point 10-15; different than the pre-implementation, all stimulus words appeared in the concept networks. In the pre-implementation, all the stimulus words were formed between the cut-off point of 4-9. In this range, again different than the pre-implementation, an increase occured in both the link between stimulus words themselves and in associated concepts that fall under them. In the pre-implementation, for the *instructional materials* stimulus word, only the concept *projection* was detected. Whereas in the post-implementation, as also seen in Figure 3, the concepts *student response systems* and *probeware* were noticed.

Cut-off point 4-9; a concept network was generated that all stimulus words in the WAT can be found. Figure 3 puts forward that almost all implications in the PD program were revealed in teachers' knowledge structures that are associated with stimulus words. When this frequency is compared with the one created after pre-implementation, a significant increase was recognized in the number of concepts associated with stimulus words. When these concepts that are found under stimulus words are further examined, it can be concluded that the progress in teachers' knowledge structures is also meaningful from a theoretical perspective. For example, in the pre-implementation for this frequency range, teachers' knowledge structures linked with instructional materials included *pencil, notebook, powerpoint, projection, microscope, experiment tools* and *animation*. However, in the post-implementation, the same category covered the concepts *prezi, animoto, mobile applications, edmodo, simulation*, and *easyclass* and the stimulus word *Web 2.0 tools.* Similarly, in the pre-implementation, the concepts *youtube and internet* can be found in teachers' knowledge structures linked with the stimulus word *Web 2.0 tools.* And in the post-implementation for the same stimulus word, the concepts *blog, podcast, videocasts, dropbox,* and *twitter* are noticed. It should also be noted that the teachers associated the stimulus word, *Web 2.0 tools* with the stimulus words *computer, instructional materials, and ICT*. In the pre-implementation, the participants tended to state 'I have no information' as a response to the items on *Web 2.0 tools.* Whereas in the post-implementation, the strong links towards topics included in the PD program is showing the progress in participants, particularly knowledge structures for these concepts.

CONCLUSION

In this study, a WAT was used to examine science teachers' knowledge structures on technology before and after participating in a TPACK-based PD program. The findings showed that the number of response words in WAT (technology, information and communication technologies, computer, instructional materials, Web 2.0 tools, and TPACK) was increased substantially after PD program. Güneş (2013) reported that the number of response words given to stimulus words in the WAT can give clues to the extent that the keywords are remembered and understood. Accordingly, the increase in the number of response words can point to the fact that teachers progressed in their understanding of the keywords.

The study made further investigation for the association between the stimulus words and the response words via concept networks. All stimulus words in WAT are identified between the cut-off point of 4-9 in the pre-implementation. However, they are noticed between cut-off point 10-15 in the post-implementation. Another finding is that some of the keywords in the WAT did not appear in concepts networks for cut-off point 16 and above following the pre and post implementations. A possible reason for this can be the short range of frequency between cut-off points (Güneş, 2013).

When the concept networks revealed in this study are analyzed, it can be concluded that the participants had naive concept networks of the keywords on WAT before the PD program. This might have resulted in the appearance of all keywords between cut-off point 4-9 in the pre-implementation. Another point to note following the pre-implementation is that the participants had a very weak knowledge structure especially on Web 2.0 tools. The participants associated *Facebook,* one of the Web 2.0 tools, with ICT, yet did not include the concept *Facebook* under *Web 2.0 tools.*

The findings showed that prior to the PD program, only a few science teachers stated concepts associated with Web 2.0 tools and that they had *Youtube* and *Internet* in the knowledge structures. After the PD program, teacher made associations with *Web 2.0 tools* such as *blog, podcast, dropbox, Twitter, and prezi.* These might indicate that the teachers did not have knowledge on Web 2.0 tools before the PD program, and that their familiarity with Web 2.0 tools increased. Although the participants had a variety of teaching experiences, all of them had weak knowledge structures on Web 2.0 tools. This finding might indicate the insufficiency of technology training during teacher education programs. The study conducted by Baltaci- Goktalay and Ozdilek (2010) has findings in this direction as well. More than half of the pre-service teachers in their study reported that they never used blogs and social bookmarks in a course they had taken on Web 2.0 tools. They explained their plan to use these technologies as they start the teaching profession. An interpretation can be that the teachers did not have a meaningful association of TPACK in their knowledge structures in the pre-implementation.

Before the PD program, a few participants had a limited number of concepts on TPACK in their knowledge structures. But with the implementation of the program, the participants associated the concepts they learned with TPACK. TPACK is still in its infancy in Turkish context; TPACK-focused studies in Turkey began to emerge after 2010 (Baran & Canbazoğlu Bilici, 2015). So the concept is still unfamiliar to teachers. In this study, before the PD program, teachers had difficulty writing concepts related to TPACK. Following the program, the teachers started perceiving TPACK as an innovation that involves both domain-specific technologies (e.g. probeware, Algodoo), and general technologies (e.g. socrative, prezi, edmodo). The theoretical framework of TPACK was explained to the participants throughout the PD program. In addition, the TPACK game played on the first day of the program included examples to applications of knowledge related to TPACK. Despite these efforts, the participants focused on technology in their knowledge structures. With the examination of concept networks related with keywords in the WAT, it can be interpreted that following the PD program, the teachers started to see technology as more embedded and complementary with TPACK.

During the pre-implementation, the concept networks showed associations between *computer* and *software, hardware,* and *Microsoft office program*. After the post-implementation, associations were found between *computer* and educational technologies such as *animations, student response systems*, and *smartboards*. In a similar way, the teachers made associations between Web 2.0 tools and instructional materials. All of these can address the fact that the teachers evaluate the technologies from a pedagogical perspective. The responses given to the stimulus words might suggest a shift in teachers' knowledge structures on technology from traditional technologies to up-to-date technologies.

Two studies conducted recently in Turkey helps interpret our findings better. Aydin (2009) examined pre-service science teachers' knowledge structures on technology with various technology-focused activities similar to WAT. His findings showed that the responses given for technology changed direction from general technologies (e.g. computer, cell phone, informatics) towards technologies underlined in their activities (science, design, industry). This might be related to the fact that the knowledge structures revealed in WAT are related to the content of the activities in the PD programs implemented. Likewise Timur (2011) revelaed that pre-service science teachers had associations between educational technologies-computer and computer-ICT, ICT-smartboard and tablet before the implementation of technology supported activities. Subsequent to the implementation, the associations included ICT-mobile applications. This finding indicated that smartboards and tablets that came to the forefront with the FATIH project revealed themselves in the knowledge structures on mobile applications used frequently in daily life. An overall conclusion might be that the advancements on technology in the recent years had a direct effect on the knowledge structures of teachers on technology.

RECOMMENDATIONS

A progress emerged in science teachers' knowledge structures towards technology following the TPACK-based professional development program. This progress can be further investigated by qualitative data collection methods such as interviews or classroom observations. Also various tools, concept maps, and mind maps can be used along with WAT to better identify the knowledge structures of the participants.

New stimulus words might be added to WAT (e.g. probeware, simulations, mobile applications) to understand the knowledge structures of teachers related to a particular technology. Further research can emphasize the FATIH Project that has a key role in addressing technology integration in Turkey. New stimulus words can be created for WAT in relation with this project such as FATIH Project, smart board, and tablet.

In the pre-implementation, the science teachers' knowledge structures seemed to include mainly the traditional technologies and more generalized associations. Whereas in the post-implementation, their knowledge structures reflected a progress. This outcome points out the popularization of TPACK-based PD programs in other contexts. These TPACK-based PD programs should include activities that will allow teachers practice the integration of both domain-specific technologies and general technologies to their science lessons.

Although half of the participant group included teachers with 1-5 years of experience, the pre-implementation resulted in a very limited association with current technologies such as Web 2.0 tools. This might be related to the fact that the teachers received a very limited education on educational technologies in their teacher education programs. In accordance with this, further research might design TPACK- based courses for pre-service science teachers and examine their knowledge structures with WAT.

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