TÜRK FEN EĞİTİMİ DERGİSİ
Yıl 17, Sayı 1, Mart 2020

Journal of
TURKISH SCIENCE EDUCATION
Volume 17, Issue 1, March 2020

http://www.tused.org

Examining Pre-Service Science Teachers' Number and Space Relation Skills*

Nisa YENİKALAYCI[1], Türkan Aybike AKARCA[2]

[1] *Res. Asst. Ondokuz Mayıs University, Science Education, Samsun-TURKEY, ORCID ID: 0000-0002-5676-1488*
[2] *Res. Asst. Ondokuz Mayıs University,* Science Education, *Samsun-TURKEY, ORCID ID: 0000-0003-2155-7011*

Received: 01.08.2018 **Revised:** 16.01.2019 **Accepted:** 31.12.2019

The original language of article is English (v.17, n.1, March 2020, pp.1-10, doi: 10.36681/tused.2020.9)

Reference: Yenikalayci, N. & Akarca, T. A. (2020). Examining Pre-Service Science Teachers' Number and Space Relation Skills. *Journal of Turkish Science Education, 17*(1), 1-10.

ABSTRACT

One of the basic science process skills, number and space relation, is used to transform a two-dimensional object into a three-dimensional shape or express symmetry axis of the objects. The aim of this research was to determine the number and space relation skills of pre-service science teachers in order to train more qualified science teachers equipped with 21st century skills. The participants were 60 pre-service science teachers, first year students studying in a science education program in a state university located in the Black Sea region of Turkey. The study was conducted in the 2017 fall semester. Integrative Perception Test (IPT) was prepared by researchers to collect data. Within the scope of the IPT, textbooks specific to the field of science were scanned. Then, textbooks' visuals without symmetrical structure in physics, chemistry, and biology subfields were identified and listed. During the application, participants were asked to complete the missing half of the visual images by using their imagination and three-dimensional perceptions from their visual memories. The data obtained from the test with 30 images (i.e., 10 physics images, 10 chemistry images, and 10 biology images) were descriptively analyzed. Participants received two points for completed images, one point for images with missing parts, and zero points for incorrect/empty images. Results showed that the chemistry test average of the participants was the highest. Furthermore, it was observed that pre-service science teachers were especially successful on the topics of diffraction of waves and formation of shadow in physics, states of matter and acid-base indicators in chemistry, and the structure of DNA in biology, but it was also evaluated that their general number and space relation skills were in an average level. Results suggest that new studies with different age groups or using symmetrical images in teaching new concepts can be useful.

Keywords: Integrative perception, number and space relations, science education, science process skills.

INTRODUCTION

In science education, students need to gain number and space relationships and three-dimensional thinking skills to understand concepts. Students with science-based knowledge

*This study was presented as an oral presentation at the "1st International Congress on Social Sciences, Humanities and Education" held in 22-23 December 2017.

Correspondence author e-mail: aybike.akarca@omu.edu.tr © ISSN:1304-6020

and ability to think in three dimensions can transform two-dimensional shapes into three-dimensional shapes in the simplest form, use visual memory at an optimum level, and succeed in physics, chemistry, and biology concepts where all three-dimensional skills are required. Students with these three-dimensional skills have the potential to transform innovation and productivity into practice in their everyday life.

Science students need to acquire science process skills in a qualified way for successful science education. Science process skills are the skills that facilitate learning in science teaching, enable students to take responsibility, keep students active, and result in permanent learning. Basic science processes are simply classified as observing, measuring, classifying, data recording, and establishing number and space relations (Çepni, Ayas, Johnson & Turgut, 1996). The use of three-dimensional models or visuals in the teaching of science concepts can contribute to the spatial visualization and mental rotation skills of the students. In curriculum preparation, mental levels of students should be considered and activities should be developed according to the mental processes that students need in their age (Demirbaş & Ertuğrul, 2012). Three-dimensional thinking skills include rotation of objects, mental folding, and scaling skills (Vander Heyden, Huizinga, Kan & Jolles, 2016). In the "Learning to think spatially" report prepared by the National Research Council (NRC, 2006), spatial thinking is defined as the ability to understand and use the space concepts, spatial notation, and spatial reasoning processes.

Demirkaya and Masal (2017) aimed to reveal the effects of activities based on geometric-mechanical games "applied in the Elective Intelligence Games lesson" on secondary school students' spatial thinking skills and found a significant difference showing that students increased their spatial visualization skills as a result of the implementation. In addition, in their study investigating the relationship between geometric objects and geometric and spatial thinking, Ergin and Türnüklü (2015) documented that spatial thinking of 8th grade students is effective on geometric objects. In order to reveal the symmetry information of the 8th grade primary school students in mathematics, Köse (2012) pointed out that students were successful in determining the symmetry according to vertical and horizontal orientations of the line when shapes did not intersect with the symmetry line. In a study about evaluation of three-dimensional thinking skills in the concepts of "distance" and "magnitude," Bolat and Yenikalaycı (2017) claimed that pre-service science teachers could not perceive the three-dimensional space because they stated the appearance of a constellation did not change from different points of view. Also, Sarı (2016) found that pre-service male teachers' spatial skills were more higher than the females in a research study on the relationship between spatial skills and spatial anxiety levels of primary school teacher candidates. Turgut and Yenilmez (2012) indicated that primary and secondary school pre-service mathematics teachers' spatial visualization skills were relatively low. Likewise, Bulut and Köroğlu (2000) examined spatial skills of pre-service mathematics teachers by using cards, cube comparison, paper folding, and surface formation tests. As a result of the study, researchers found that 11th grade students and pre-service mathematics teachers' average scores obtained from tests were low.

The ability to use number and space relations from the science process skills includes the competencies such as spatial arrangements, arrangements of time and speed, and symmetry (Abruscato, 2000, as cited in Aydoğdu, 2014). If an image can be folded along one line so that the two halves match each other, then it is called as the symmetry line (mirror symmetry). Topics such as rotation, reflection, and symmetry are included mostly in mathematics curriculum (Aktaş et al., 2009; Aygün et al., 2009a, 2009b; Canpekel, 2014; Dörttepe et al., 2009; Mamaç, Ünsal & Yavuz, 2009; Van de Walle, Karp & Bay-Williams, 2012). In this context, through an examination of curriculum, in the unit of Wonderland of Images, which is the first unit of third grades in Turkey, it was mentioned regarding the concept of symmetry in the context of geometric forms that planar forms can also be defined as symmetrical and they create symmetrical shapes (Mamaç et al., 2009). In this curriculum, some examples of symmetry of a reflected image were found as sea surface, a leaf or a butterfly (Dörttepe et al., 2009).

Symmetry in geometric shapes is easy to find, especially for the research groups as in this study. For this reason, this study was based on shapes that do not show symmetrical structure. Examples of symmetry axes in some of the figures are given in Figure 1.

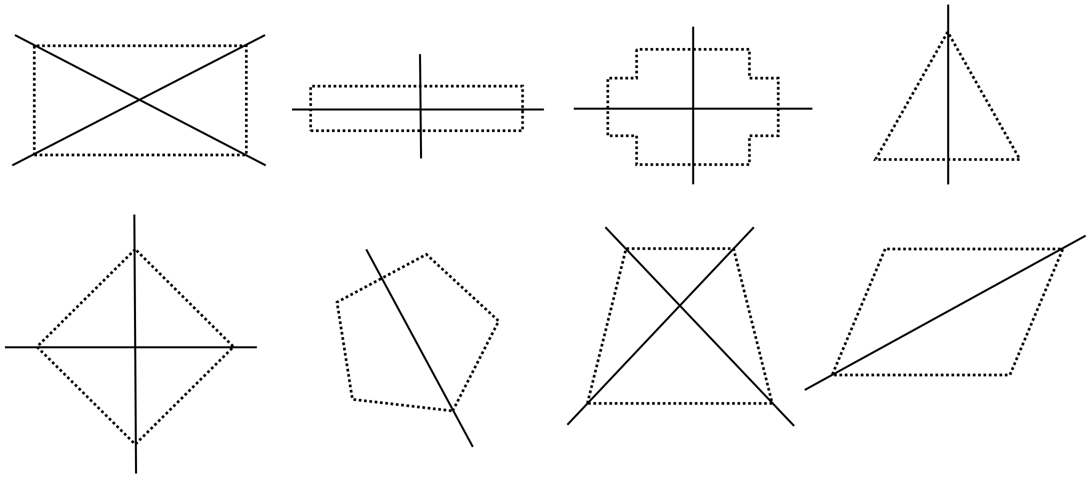


Figure 1. Symmetry axes in some geometrical shapes (Mamaç et al., 2009)

It was considered that establishing number and space relations, which is a dimension of science process skills, can be necessary for students to develop reasoning, thinking, and research skills. It was also thought that this study might contribute to the development of pre-service science teachers' scientific drawing skills. For this purpose, in this research study, it was aimed to determine the number and space relation initiation skills of pre-service science teachers to have more qualified science teachers equipped with 21st century skills.

METHODS

a) Research Design

In this research, the perceptions of students about visuals they encountered in science and the high school curriculum of physics, chemistry, and biology have been tried to be determined through case studies. In integrative multiple case studies, which is a type of case study, independent cases are chosen and each case is perceived as a whole. Comparisons can be made between cases if necessary (Yin, 1984, as cited in Çepni, 2007).

b) Participants

The participants in this study were 60 pre-service science teachers, first year students studying in a science education program in a state university located in the Black Sea region of Turkey. The study was conducted in the 2017 fall semester. Participants were chosen randomly.

c) Data Collection Tool

In order to teach new information successfully, a teacher should investigate what preliminary information is to support or contradict the new knowledge (Şimşek, 2014). In doing so, drawings can be used when determining the preliminary information of students.

Drawing is an open-ended technique that allows teachers to guide the learning process and reflect students' learning (Atasoy, 2002). The data obtained from this technique can give clues to design ideal teaching environments.

Researchers in this study prepared Integrative Perception Test (IPT) to collect data. Within the scope of the IPT, textbooks specific to the field of science were scanned. Then, textbooks' visuals without symmetrical structure in physics, chemistry, and biology subfields were identified and listed. While choosing visuals with no symmetrical structure, attention was driven to the fact that the concepts in the pool were from different subject areas, and there were equal number of problems from each subfield.

During the application, a test including half of unsymmetrical science images was given to participants. Then, the participants were asked to complete other unsymmetrical half of science images by using their imagination and three-dimensional perceptions from their visual memories.

d) Data Analysis

The data obtained from the test with 30 images (i.e., 10 physics images, 10 chemistry images, and 10 biology images) were descriptively analyzed. Participants received two points for completed images, one point for images with missing parts, and zero points for incorrect / empty images. The highest score that can be received from each test was 20, and the lowest score was zero.

The data were evaluated via content analysis method, a qualitative research analysis method. In terms of reliability, the data were independently analyzed by researchers and the results were combined. In the scanned sources, the topics that did not contain visual items or based on theory and those of containing symmetrical visuals were removed. The topics included in the study are given in Table 1.

Table 1. *The topics included in the IPT*

Question	Physics	Chemistry	Biology
1	voltmeter	states of matter	anatomy of the eye
2	Earth's motion around the Sun	chemistry laboratory glassware	internal view of the heart
3	pendulum	electrochemical battery cell	the structure of the kidney
4	fluid pressure	manometers	the structure of the lungs
5	diffraction of waves	distillation	anatomy of an animal cell
6	image formation in convex mirrors	acid-base indicators	anatomy of a plant cell
7	RLC circuit	energy resources	parts of a light microscope
8	dispersion of white light through a prism	safety symbols	the structure of DNA
9	formation of shadow	models of the atom	the energy pyramid
10	phases of the Moon	periodic table	the life cycle of a frog

FINDINGS

The data obtained from the study were scored by researchers in this study. The IPT analysis results obtained from physics are given in Table 2.

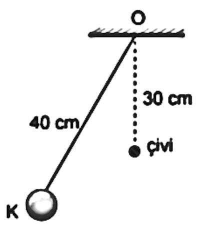
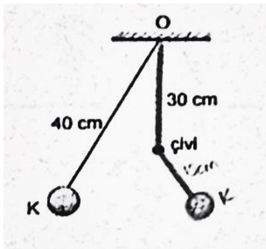
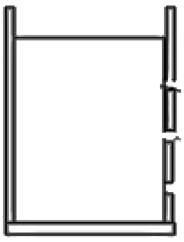
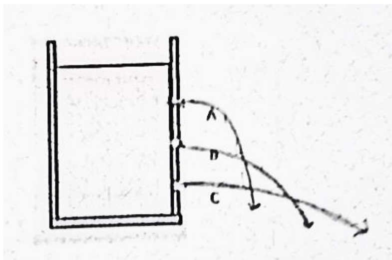
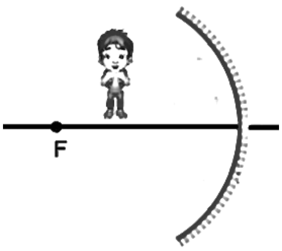
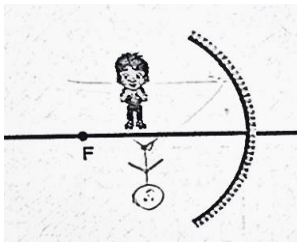
Table 2. *The IPT analysis results for physics*

Category	q_1	q_2	q_3	q_4	q_5	q_6	q_7	q_8	q_9	q_{10}
Complete	2	6	7	7	9	2	0	6	9*	1
Missing	18	13	12	10	9	16	16	13	11	16
Incorrect / Empty	0	1	1	3	2	2	4	1	0	3
$\bar{X}_{physics}$	1.1	1.25	1.3	1.2	1.35	1	0.8	1.25	1.45	0.9

q_9: formation of shadow

As seen in Table 2, participants were successful at the 9th question (i.e., formation of shadow, $\bar{X}$=1.45), their ability to establish number and space relations in other subjects were relatively less successful. Some examples of participants' drawings for the physics test are given in Table 3.

Table 3. *Some examples of participants' drawings for the physics test*

Concept	**The Question**	**The Drawing**
pendulum		
fluid pressure		
image formation in convex mirrors		

When Table 3 is examined, it is seen that complete drawings for pendulum and fluid pressure, and missing drawing for image formation in convex mirrors. The IPT analysis results obtained from chemistry are shown in Table 4.

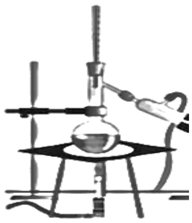
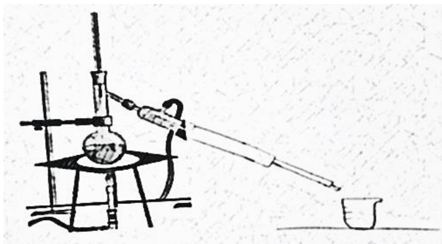
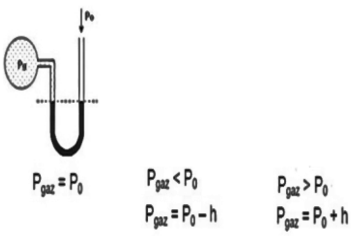
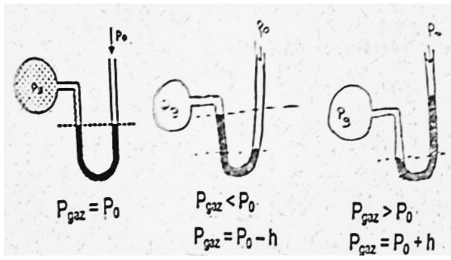
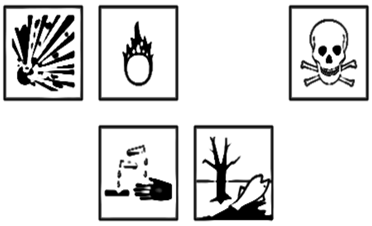
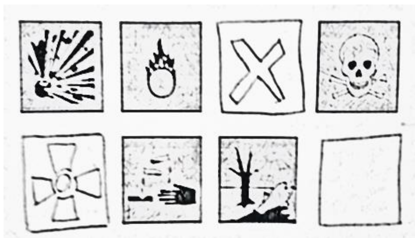
Table 4. *The IPT analysis results for chemistry*

Category	q_1	q_2	q_3	q_4	q_5	q_6	q_7	q_8	q_9	q_{10}
Complete	20*	0	0	13	5	20*	3	1	3	2
Missing	0	20	19	7	10	0	16	17	15	18
Incorrect /Empty	0	0	1	0	5	0	1	2	2	0
$\overline{X}_{chemistry}$	2	1	0.95	1.65	1	2	1.1	0.95	1.05	1.1

q_1: states of matter; **q_6:** acid-base indicators

As seen in Table 4, participants were successful at the 1st (i.e., states of matter, $\overline{X}$=2) and 6th (i.e., acid-base indicators, $\overline{X}$=2) questions and their ability to establish number and space relations in other subjects were relatively less successful. Some examples of participants' drawings for the chemistry test are presented in Table 5.

Table 5. *Some examples of participants' drawings for the chemistry test*

Concept	The Question	The Drawing
distillation		
manometers		
safety symbols		

When Table 5 is examined, it is seen that missing drawings for distillation and safety symbols, and complete drawing for manometers. The IPT analysis results obtained from biology are given in Table 6.

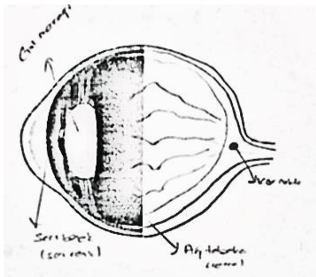
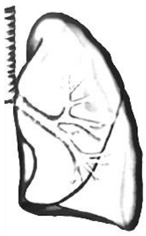
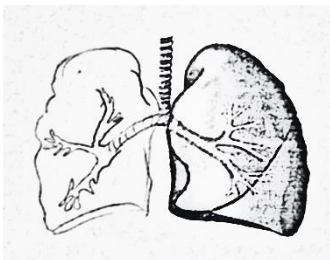
Table 6. *The IPT analysis results for biology*

Category	q_1	q_2	q_3	q_4	q_5	q_6	q_7	q_8	q_9	q_{10}
Complete	5	0	2	1	3	2	2	8*	4	3
Missing	14	16	17	19	16	17	13	11	15	12
Incorrect / Empty	1	4	1	0	1	1	5	1	1	5
$\bar{X}_{biology}$	1.2	0.8	1.05	1.05	1.1	1.05	0.85	1.35	1.15	0.9

q_8: the structure of DNA

As seen in Table 6, participants were successful at the 8th question (i.e., the structure of DNA, $\bar{X}$=1.35), and their ability to establish number and space relations in other subjects were relatively less successful. Some examples of students' drawings for the biology test are given in Table 7.

Table 7. *Some examples of participants' drawings for the biology test*

Concept	The Question	The Drawing
anatomy of the eye		
the structure of the kidney		
the structure of the lungs		

When Table 7 is examined, it is seen that complete drawings for the anatomy of the eye and the structure of the lungs, and missing drawing for the structure of the kidney. The graph based on the average scores of the participants from the tests is provided in Figure 2.

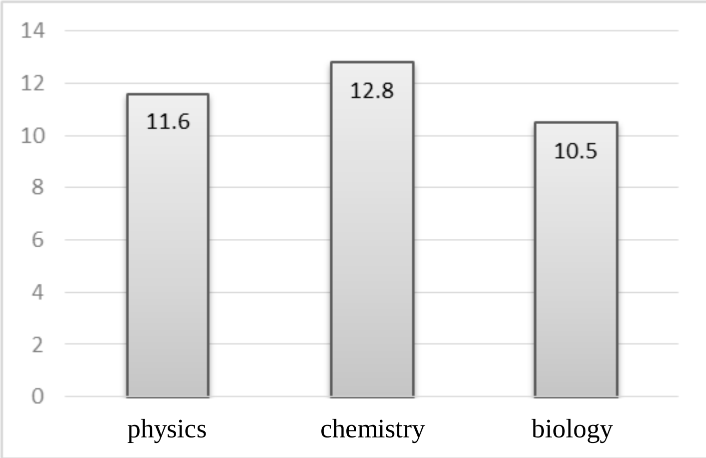


Figure 2. Average scores obtained from tests

When Figure 2 is examined, it is seen that the mean of the participants' physics test was $\bar{X}$=11.6, the mean of the chemistry test was $\bar{X}$=12.8, and the mean of the biology test was $\bar{X}$=10.5.

DISCUSSION and CONCLUSION

In science education, students need to gain number and space relationships and three-dimensional thinking skills to understand concepts. In this research study, it was determined that the average score of participants in chemistry test was higher than the other fields (i.e., physics and biology) aimed to examine the ability of pre-service science teachers to establish number and space relations. Similarly, Koray, Bahadır and Geçgin (2006) found that science process skill percentage for chemistry was 10.14% based on the 9th grade textbook and 12.12% in the 12th grade curriculum. Likewise, when the educational achievements in the 2007 curriculum were examined by Şen and Nakiboğlu (2012) to investigate the level of sufficiency of 9th, 10th, 11th, and 12th grade chemistry textbooks to develop science process skills, these gains were observed as measuring, inferring, predicting, communicating and number and space relation skills. In addition, Tekin (2007) examined the spinning and spatial visualization abilities of high school students to demonstrate the adequacy of the high school geometry curriculum and found that the current high school geometry program was insufficient to contribute to students' abilities of transformation. On the other hand, there is also another supporting study about the importance of online visualization tools, implying that these tools help to improve molecular and continuous symmetry perception of experienced chemistry teachers and they found that a basic knowledge of symmetry and continuous symmetry opens up new ways to think and perceive molecules. With the contribution of visualization tools, a deeper understanding of the learning processes can occur (Tuvi-Arad & Blonder, 2010). Similarly, Bulf (2010) focused on the exploration of French secondary school students' symmetry perception, and asked the effect of symmetry on the learning process and if this effect was supportive or prohibitive. Moreover, he found out that *"Different crossings are not so obvious for students, and the difficulty of these crossings are underestimated by teachers and curricula."* (Bulf, 2010, p. 734).

In a different aspect, Kim and Cho (2015, p. 12) claimed "*Integrated education along with the subjects of mathematics and science should not focus on the content of knowledge, but pay more attention to process skills or inquiry methods*" while researching Korean children's symmetry skills in mathematics and science lessons. The results of the study support the idea of this research by saying that the symmetrical structures can be used to develop the skills in lower grades. Finally, Turgut, Yenilmez and Anapa, (2014) found that 32 pre-service Turkish elementary mathematics teachers can determine the symmetry axis when a rotation axis was provided but failed in case of absence of an axis.

As a suggestion, we recommend that similar visuals or applications for young age groups with visuals of symmetrical structure can be used in teaching new concepts. It is also suggested that curricula and textbooks should be prepared to improve the visualization skills of the learners and the basic science processes of the learners. Using examples that support learners' number and space relations and three-dimensional thinking skills in the lessons should also be taken into consideration.

REFERENCES

Aktaş, Ş., Atalay, A., Aygün, S. Ç., Aynur, N., Bilge, O., Çelik, M., Çuha, S. S., Karaman, U., Öcal, İ., Öncü, F., Özçelik, U., Ulubay, M. & Ünsal, N. (2009). *İlköğretim matematik 6 - Öğrenci çalışma kitabı*. MEB Devlet Kitapları (4. Baskı). Ankara: Dergah Yayıncılık.

Atasoy, B. (2002). *Fen öğrenimi ve öğretimi*. (15. Bölüm: Çizimler), Ankara: Gündüz Yayıncılık.

Aydoğdu, B. (2014). *Fen bilimleri öğretimi. (4. bölüm: Bilimsel süreç becerileri).* (Ed. Şengül Saime Anagün & Nil Duban), (1. Baskı). Ankara: Anı Yayıncılık.

Aygün, S. Ç., Aynur, N., Coşkuntürk, N., Çuha, S. S., Karaman, U., Özçelik, U., Ulubay, M. & Ünsal, N. (2009a). *Öğretmen kılavuz kitabı matematik 8*. MEB Devlet Kitapları (2. Baskı). İstanbul: İhlas Yayıncılık.

Aygün, S. Ç., Aynur, N., Coşkuntürk, N., Çuha, S. S., Karaman, U., Özçelik, U., Ulubay, M. & Ünsal, N. (2009b). *İlköğretim matematik 8 - Öğrenci çalışma kitabı*. MEB Devlet Kitapları (2. Baskı). İstanbul: İhlas Yayıncılık.

Bolat, M. ve Yenikalaycı, N. (2017). The determination of science students' three-dimensional thinking skills on the basis of constellation sample, 26. Uluslararası Eğitim Bilimleri Kongresi - ICES UEBK, 20-23 Nisan 2017, 1856-1858, Antalya, Türkiye.

Bulf, C. (2010). The effects of the concept of symmetry on learning geometry at french secondary school, *Proceedings of CERME 6*, January 28th-February 1st 2009, 726-735, Lyon France.

Bulut, S. & Köroglu, S. (2000). Onbirinci sınıf ögrencilerinin ve matematik ögretmen adaylarının uzaysal yeteneklerinin incelenmesi. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi, 18*, 56 -61.

Canpekel, M. (2014). *İlköğretim matematik 4. sınıf ders kitabı - Öğrenci çalışma kitabı* (1. Kitap). Ankara: Tutku Yayıncılık.

Çepni, S. (2007). *Araştırma ve proje çalışmalarına giriş (*Genişletilmiş 3. Baskı). Trabzon: Celepler Matbaacılık.

Çepni, S., Ayas, A., Johnson, D. & Turgut, M. F. (1996). *Fizik öğretimi.* Ankara: Milli Eğitimi Geliştirme Projesi Hizmet Öncesi Öğretmen Eğitimi Deneme Basımı.

Demirbaş, M. & Ertuğrul, N. (2012). Fen ve teknoloji dersine ilişkin Piaget'in soyut işlemler döneminde kazanılması beklenen becerilerin gerçekleşme durumunun incelenmesi. *Kalem Eğitim ve İnsan Bilimleri Dergisi*, *2*(2), 123-164.

Demirkaya, C. & Masal, M. (2017). Geometrik-Mekanik Oyunlar Temelli Etkinliklerin Ortaokul Öğrencilerinin Uzamsal Düşünebilme Becerilerine Etkisi. *Sakarya University Journal of Education*, *7*(3), 600-610.

Dörttepe, C., Göğün, Y., Ocak, H., Oruç, A., Şandır, Y., Şenyurt, C., Ulubay, N. H., Ünsal, N. & Yavuz, F. D. (2009). *İlköğretim matematik 4 öğretmen kılavuz kitabı*. MEB Devlet Kitapları (5. Baskı). Ankara: Evren Yayıncılık.

Ergin, A. S. & Türnüklü, E. (2015). Ortaokul öğrencilerinin cisim imgelerinin incelenmesi: Geometrik ve uzamsal düşünme ile ilişkiler. *Eğitim ve Öğretim Araştırmaları Dergisi*, *4*(2).

Kim, M. K. & Cho, M. K. (2015). Design and implementation of integrated instruction of mathematics and science in Korea, *Eurasia Journal of Mathematics, Science & Technology Education*, *11*(1), 3-14.

Koray, Ö., Bahadır, H. & Geçgin, F. (2006). Bilimsel süreç becerilerinin 9. sınıf kimya ders kitabı ve kimya müfredatında temsil edilme durumları. *Zonguldak Karaelmas Üniversitesi Sosyal Bilimler Dergisi*, *2*(4), 147-156.

Köse, N. Y. (2012). İlköğretim öğrencilerinin doğruya göre simetri bilgileri. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi*, *42*, 274-286.

Mamaç, H. N., Ünsal, N. & Yavuz, F. D. (2009). *İlköğretim matematik 3 öğretmen kılavuz kitabı*. MEB Devlet Kitapları (5. Baskı). Ankara: İmaj Yayıncılık.

National Research Council (NRC) (2006). *Learning to think spatially*. Washington, DC: National Academy Press.

Sarı, M. H. (2016). Uzamsal Beceri ve Uzamsal Kaygı Arasındaki İlişki: Sınıf Öğretmeni Adayları Üzerine Bir Araştırma. *Turkish Journal of Computer and Mathematics Education*, *7*(3), 646-658.

Şen, A. Z. & Nakiboğlu, C. (2012). Ortaöğretim Kimya Ders Kitaplarının Bilimsel Süreç Becerileri Açısından İncelenmesi. *Ahi Evran Üniversitesi Kırşehir Eğitim Fakültesi Dergisi (KEFAD)*, *13*(3), 47-65.

Şimşek, A. (2014). *Eğitimde bireysel farklılıklar. (5. Bölüm: Önbilgi)*, (ed. Yıldız Kuzgun & Deniz Deryakulu) (3. Baskı). Ankara: Nobel Yayıncılık.

Tekin, A. T. (2007). Dokuzuncu ve on birinci sınıf öğrencilerinin zihinde döndürme ve uzamsal görselleştirme yeteneklerinin karşılaştırmalı olarakincelenmesi. *Yüksek Lisans Tezi*, Ankara Üniversitesi Eğitim Bilimleri Enstitüsü, Eğitim Programları ve Öğretim Bilim Dalı, Ankara.

Turgut, M. & Yenilmez, K. (2012). Matematik öğretmeni adaylarının uzamsal görselleştirme becerileri. *Eğitim ve Öğretim Araştırmaları Dergisi*, *1*(2).

Turgut, M., Yenilmez, K. & Anapa, P. (2014). Symmetry and rotation skills of prospective elementary mathematics teachers, *Bolema, Rio Claro (SP)*, *28*(48), 383-402. DOI: http://dx.doi.org/10.1590/1980-4415v28n48a19

Tuvi-Arad, I. & Blonder, R. (2010). Continuous symmetry and chemistry teachers: Learning advanced chemistry content through novel visualization tools. *Chemistry Education Research and Practice, 1*, 48-58. DOI: 10.1039/C001046B

Van de Walle, J. A., Karp, K. S. & Bay-Williams, J. M. (2012). *İlkokul ve ortaokul matematiği- Gelişimsel yaklaşımla öğretim*. (çev. ed. Soner Durmuş), (7. baskıdan çeviri). Ankara: Nobel Yayıncılık.

Vander Heyden, K. M., Huizinga, M., Kan, K. J. & Jolles, J. (2016). A developmental perspective on spatial reasoning: Dissociating object transformation from viewer transformation ability. *Cognitive Development*, *38*, 63-74.