




Is Scientific Creativity Possible in Early Childhood?

Cansu Yıldız Taşdemir*

* Department of Preschool Education,
Hacettepe University, Ankara, Turkey
E-mail: cytasdemir@gmail.com

 10.46303/tpicd.2021.6

How to cite

Yıldız Taşdemir, C. (2021). Is Scientific
Creativity Possible in Early Childhood?

Theory and Practice in Child

Development, 1(1), 71-82.

<https://doi.org/10.46303/tpicd.2021.6>

Copyright license

This is an Open Access article
distributed under the terms of the
Creative Commons Attribution 4.0
International license (CC BY 4.0).

ABSTRACT

It can be stated that scientific creativity is a fairly new research topic for early childhood. Although creativity is one of the skills that are frequently discussed in early childhood research, studies dealing with scientific creativity, a type of creativity specifically related to science, are very limited regarding this period. In this review study, scientific creativity was conceptually examined and research conducted on scientific creativity with children attending primary and secondary school were included. Whether scientific creativity is possible in early childhood was examined according to a limited number of studies examining scientific creativity in this period. Additionally, based on previous studies, suggestions were given on how to support scientific creativity in early childhood.

KEYWORDS

Scientific creativity; early childhood; science education; creativity.

INTRODUCTION

There are many definitions of creativity, which has been the subject of many studies for many years on early childhood. According to San (1985), creativity is the ability to establish relationships that have not been established before between events and phenomena, and thus to present new experiences, ideas and products within a new framework of thoughts. In another definition, creativity is an attitude, a process and a skill, a way of seeing a world from different perspectives, where there are only possibilities instead of right or wrong (Fox & Schirmacher, 2014). Torrance (1962), who is known as the father of creativity, defines creativity as the process of being sensitive to problems, lack of knowledge, incompatibility, identifying difficulties, searching for solutions, making predictions, developing hypotheses about deficiencies, testing the hypotheses and presenting the result. According to Torrance (1962), some of the characteristics that distinguish creative people from less creative people are being aware of themselves and others, courage, determination, sentimentality, sensitivity, being curious, being open to external stimuli and ideas of others. In the literature, four dimensions of creative thinking skills have been discussed. These are fluency, originality (uniqueness), elaboration (detailing), and flexibility (Guilford, 1967; Torrance, 1969). According to Torrance (1964, as cited in Artut, 2013), fluency is the generation of many different thoughts on a problem situation; originality is having a thought that is not like any other, so it is unique; elaboration is expanding the thought by making it more detailed, interesting or complex; flexibility is the change of direction of thought or the ability to think in another way.

When the literature is reviewed, it is seen that many studies have been done on creativity in early childhood. Examining the effect of different variables on children's creative thinking skills (Alsrour & Al-Ali, 2014; Baer & Kaufman, 2008; Barbot et al., 2016; Yildiz & Guler Yildiz, 2021), examining the effect of some programs and practices (Cheung, 2010; Dikici Sigirtmac, 2016; Garaigordobil & Berrueco, 2011; Hui et al., 2015) examining the effect of preschool education (Can Yasar & Aral, 2010; Dere, 2019; Karlidag & Gonen, 2019) and examining the effects of educators on children's creative skills (Huang et al., 2019; Leggett, 2017; Tok, 2021) has always been a focal point of researchers working in the field of early childhood. Scientific creativity, which is a type of creativity specifically related to science, is a fairly new concept for early childhood. Although there are studies on scientific creativity with children attending primary school and higher education levels, studies dealing with this issue in early childhood are limited. In this review, studies on scientific creativity and scientific creativity in early childhood were reviewed and how to support scientific creativity in young children was discussed.

Scientific Creativity

Today, the key role of scientific knowledge and creativity is emphasized for the continuous development of societies (Sternberg, 2010). From this point of view, scientific creativity is considered among the important skills of the 21st century in order to solve the problems brought by globalization and development and to progress (de Vries & Lubart, 2019).

Scientific creativity, which consists of two factors, creativity and scientific knowledge, is explained as creativity in a field that includes a scientific infrastructure (Hu & Adey, 2002; Huang & Wang, 2019). Raj et al. (2016) defined scientific creativity as the ability to conduct creative science experiments and to find and solve creative science problems and working on science activities. Scientific creativity includes scientific knowledge and questioning skills as well as creative thinking skills (Park, 2004). In a broader sense, scientific creativity is to produce or the potential to produce a specific product designed for a specific purpose, with original, social or personal value, using the given information (Hu & Adey, 2002).

Scientific creativity is different from other creativity as it is about creative science experiments, creative problem solving and creative science activity and should be based on scientific knowledge and skills. Doing science is much more than comprehending existing knowledge or following established procedures. Scientific creativity requires doing scientific research with using creativity to go beyond existing knowledge and techniques and to create new perceptions. Solving a scientific problem, even at an early age, requires the child to explore their repertoire, imagine various paths to a solution and often come up with new combinations of knowledge or new techniques for a solution (Hu & Adey, 2002). Scientific creativity has become one of the issues that need to be emphasized today, since the goal is to raise individuals with 21st century skills. The importance of scientific creativity in various countries has been explicitly emphasized in national science education curriculum and government policies and it has been emphasized that science education content should foster students' scientific creativity (Bi et al., 2020).

Hu and Adey (2002) designed a theoretical structure for scientific creativity. This structure, shown in Figure 1, consists of product, trait, and process dimensions.

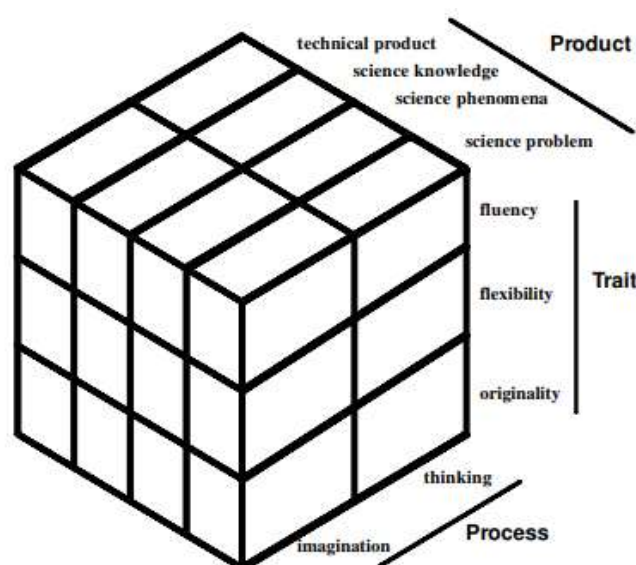


Figure 1. The scientific creativity structure model.

In this model, the product dimension of scientific creativity includes the ability to create or improve technical products, to make advances in science or scientific knowledge, to understand scientific phenomena and to solve scientific problems. The trait dimension of scientific creativity includes three characteristics of the creative person: fluency, flexibility and originality. According to Torrance (1964, as cited in Artut, 2013), fluency is the generation of many different thoughts on a problem situation, and the important thing here is the quantity of generated thoughts. In other words, individuals who can think fluently can put forward many different ideas in the face of problem situations. Flexibility is the ability of a person to adapt easily to events, situations and their environment, to think multi-dimensionally and to change their thoughts. Flexibility is the opposite of rigidity and dependence on thought patterns. Creative people are flexible in their thoughts and attitudes, and their rules and boundaries are not as rigid and impassable as non-creative people (Yolcu, 2009). According to Torrance (1964, as cited in Artut, 2013), flexibility is the change of direction of thought or the ability to think in another way. Originality, according to Torrance (1964, as cited in Artut, 2013), is that a thought does not resemble any other thought, is not imitated. In short, it is unique. In other words, originality is the opposite of conforming to social expectations or social influence in thought, expression or attitude (Yolcu, 2009). Finally, while imagination in the process dimension of scientific creativity is the ability to create new images, creative thinking is the process of generating new or innovative thoughts (Siew et al., 2015).

Research on scientific creativity is relatively new compared to research on creativity (Wiyanto et al., 2020). When the literature is reviewed, it is seen that there are studies examining the effects of various programs and educational practices on the scientific creativity of secondary school students (Aktamis & Ergin, 2008; Dogan & Kahraman, 2021; Hu et al., 2013; Lin et al., 2003; Siew et al., 2015; Siew & Ambo, 2020; Smyrniou et al., 2020). In addition, studies examining the relationship between scientific creativity and attitude towards science lessons (Usta & Akkanat, 2015), scientific creativity and home environment (Philip, 2008), scientific creativity and scientific process skills (Aktamis & Ergin, 2007; Dhir, 2014) were carried out. There are also scale studies on the subject developed for primary and secondary school students (Ategoz & Sak, 2021; Ayas & Sak, 2014; Hu & Adey, 2002; Mohamed, 2006; Sak & Ayas, 2013; Siew et al., 2014).

Children's scientific creativity is cultivated when they are engaged in activities where they can use their scientific process skills and make discoveries (Aktamis & Ergin, 2008; Gupta & Sharma, 2018). Since such science activities model the way scientists work and research, they can encourage the use of various scientific process skills by children and contribute to the emergence of creative ideas and the development of scientific creativity (Gupta & Sharma, 2019). In addition to the relationship between students' scientific process skills and scientific process skills (Aktamis & Ergin, 2007; Dhir, 2014; Dikici et al., 2020; Ozdemir & Dikici, 2017), the research show that there is a relationship between scientific creativity and the students' attitudes towards science lessons (Usta & Akkanat, 2015), home environments (Philip, 2008),

and academic achievement in science (Ayverdi et al., 2012; Baysal et al., 2013). Hu and Adey (2002), who studied the relationship between age and scientific creativity, stated that scientific creativity may increase as scientific knowledge, experience and skills increase with increasing age but there was no linear relationship between age and scientific creativity. In another study examining the nature of scientific creativity, Kozhevnikov et al. (2021) stated that visual and spatial abilities can be a predictor of scientific creativity. In addition to cognitive and affective factors, environmental effects such as teachers' and parents' scientific creativity perceptions and attitudes may also affect scientific creativity (Park & Jee, 2015). For instance, the teacher has an important part to support scientific creativity in the classroom because the teacher's attitudes and beliefs are important indicators of the learning environment in the classroom (Liu & Lin, 2014). Studies showed that teachers and parents think that divergent thinking, autonomy (independence), areas of curiosity and interest, experimentation, asking questions, logical thinking and sharing ideas to solve problems are important for scientific creativity (Liu & Lin, 2014; Lee & Park, 2021; Park & Jee, 2015).

Limited scientific knowledge may lead to poor scientific creativity (Ayverdi et al., 2012; Yang et al., 2016). Therefore, curriculum and science activities should be carefully planned to encourage scientific creativity (Yang et al., 2016). Interdisciplinary learning or integrated practices are crucial to develop scientific creativity. According to Hadzigeorgiou et al. (2012), scientific creativity can be developed by solving problems, incorporating scientific process skills into the problem-solving process, performing creative writing activities, creating analogies to understand facts and ideas, trying to find connections between seemingly unrelated facts and ideas, and integrating science and art. In the research that supports this view by Smyrnaiou et al. (2020), which integrates science and stories with creative thinking styles, it was found that digital storytelling increases students' scientific creativity. The students justified the choices they made in their own stories with scientific explanations, so they produced both original and scientifically correct stories. Similarly, studies in the field of STEM reveal that this approach, which integrates more than one discipline, creates effective opportunities to support scientific creativity (Dogan & Kahraman, 2021; Siew & Ambo, 2020).

Scientific Creativity in Early Childhood

Although studies on scientific creativity with primary, secondary and high school students are frequently encountered, it is conspicuous that there are not many studies concerning this subject in early childhood. Chin and Siew (2015) developed a six-item Scientific Creativity Test for preschool children based on Hu and Adey's (2002) The Scientific Structure Model. Chin and Siew (2015) developed a six-item Scientific Creativity Test for preschool children based on Hu and Adey's (2002) The Scientific Structure Model and presented a scientific creativity model for preschool children. Figure 2 shows Chin and Siew's (2015) scientific creativity model.

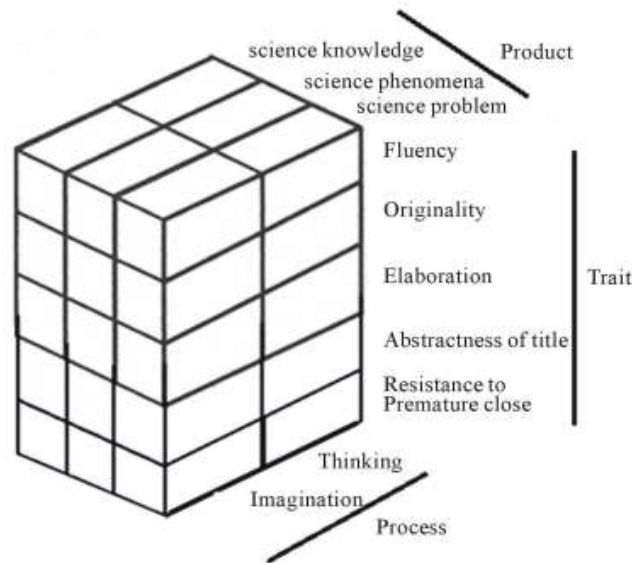


Figure 2. The improved scientific creativity structure model for Figural Scientific Creativity Test for Preschool Children

While developing this scale, Chin and Siew (2015) removed the "technical product" dimension in Hu and Adey's (2002) model, considering that the product dimension is less included in the preschool science curriculum. In this model, the product dimension of scientific creativity has sub-dimensions of making progress in science or scientific knowledge, understanding scientific phenomena and solving scientific problems. The trait and process dimensions of scientific creativity are the same as the scientific creativity model created by Hu and Adey (2002).

Early childhood studies on scientific creativity has shown that the Problem-Based Learning and Cooperative Learning (PBLCL) model can encourage children's scientific creativity (Siew et al., 2017; Siew & Chin, 2018). In another study involving children attending second and third grade, it was determined that the STEM program positively affected children's scientific creativity (Ece Genek & Doganca Kucuk, 2020). Majid et al. (2020) stated in their study that science fiction stories or cartoons integrate science and creativity, and thus they can be used to support the scientific creativity of preschool children. In addition to these studies, there are scientific creativity scales developed for preschool children (Chin & Siew, 2015; Hou, 2013).

As it was mentioned above, there is limited research on this subject in early childhood. The development of scientific creativity is possible in early childhood. Because both creativity and science-related skills begin to develop in the early years. (Fox & Schirrmacher, 2014; Trundle, 2010). Ignoring scientific creativity in early childhood may have negative impacts for children in the following periods of their education life. So, it is necessary to shift the discussions on scientific creativity to the preschool period. Exploring scientific creativity in preschool can help children reach their full potential. Therefore, educators can better serve the needs of children by providing appropriate teaching methods and learning opportunities that encourage scientific creativity (Chin & Siew, 2015).

What can be done to support the scientific creativity of young children?

Based on the research on the subject, some suggestions are given below to support scientific creativity in early childhood.

- When the studies are examined, it is seen that the use of the problem-based cooperative learning model in early childhood science teaching supports the scientific creativity of children (Siew & Chin, 2018). Similarly, studies conducted with older children show that problem-based activities can improve children's scientific creativity (Siew et al. 2015). Therefore, including problem situations suitable for the age and developmental levels of children in activities to be planned in the preschool period may be a way to support scientific creativity. In the problem-based learning process, preschool children use their imaginations as well as scientific knowledge to solve real-world problems. They also help each other learn new ideas based on their existing scientific knowledge through cooperative learning (Siew & Chin, 2018). In order to support the scientific creativity of children in early childhood, learning environments based on the problem-based cooperative learning model can be organized.
- STEM activities or activities integrating different disciplines also contribute to the development of scientific creativity (Dogan & Kahraman, 2021; Ece Genek & Doganca Kucuk, 2020; Siew & Ambo, 2020). Therefore, instead of activities based on a single discipline in the preschool period, integrated activities that combine different types of activities can be implemented. Instead of applying science activities alone, teachers can integrate science with different types of activities such as art, music, and literacy.
- Studies show that the use of scientific process skills supports scientific creativity (Aktamis & Ergin, 2008; Gupta & Sharma, 2018) and that there is a relationship between preschool children's creative thinking skills and scientific process skills (Yildiz & Guler Yildiz, 2021). Therefore, in order to support scientific creativity in early childhood, children should be provided with learning opportunities to use their basic scientific process skills (observing, classifying, predicting, measuring, inferring and scientific communication).
- If scientific knowledge increases, scientific creativity may increase as well (Yang et al., 2016). In the early childhood period, children's scientific knowledge and scientific creativity can be developed with exploratory science activities that are appropriate for children's age and developmental levels.
- Finally, in the study conducted by Kozhevnikov et al. (2021), it was revealed that visual and spatial skills can be a predictor of scientific creativity. In the early childhood period, children's visual and spatial skills can be improved with matching and attention activities and activities using three-dimensional materials such as blocks and manipulative toys, thus contributing to the development of their scientific creativity.

REFERENCES

- Aktamis, H., & Ergin, O. (2007). Investigating the relationship between science process skills and scientific creativity. *Hacettepe University Journal of Education*, 33, 11-23.
- Aktamis, H., & Ergin, O. (2008). The effect of scientific process skills education on students' scientific creativity, science attitudes and academic achievements. *Asia-Pacific Forum On Science Learning and Teaching*, 9(1), 1-21.
- Alsrouf, N. H., & Al-Ali, S. (2014). An investigation of the differences in creativity of preschool children according to gender, age and kindergarten type in Jordan. *Gifted and Talented International*, 29(1-2), 33-38. <https://doi.org/10.1080/15332276.2014.11678427>
- Artut, K. (2013). *Sanat eğitimi kuramları ve yöntemleri*. Anı Publishing.
- Ateşgoz, N. N., & Sak, U. (2021). Test of scientific creativity animations for children: Development and validity study. *Thinking Skills and Creativity*, 40, 100818. <https://doi.org/10.1016/j.tsc.2021.100818>
- Ayas, M. B., & Sak, U. (2014). Objective measure of scientific creativity: Psychometric validity of the Creative Scientific Ability Test. *Thinking Skills and Creativity*, 13, 195-205. <https://doi.org/10.1016/j.tsc.2014.06.001>
- Ayverdi, L., Asker, E., Aydın, S. Ö., & Sarıtaş, T. (2012). Determination of the relationship between elementary students' scientific creativity and academic achievement in science and technology courses. *Elementary Education Online*, 11(3), 646-659.
- Baer, J., & Kaufman, J. C. (2008). Gender differences in creativity. *The Journal of Creative Behavior*, 42(2), 75-105. <https://doi.org/10.1002/j.2162-6057.2008.tb01289.x>
- Barbot, B., Lubart, T. I., & Besançon, M. (2016). "Peaks, slumps, and bumps": Individual differences in the development of creativity in children and adolescents. *New Directions for Child and Adolescent Development*, 2016(151), 33-45. <https://doi.org/10.1002/cad.20152>
- Baysal, Z., Baysal, Z. N., Kaya, N., & Üçüncü, G. (2013). Examination of scientific creativity level of fourth grade students in terms of several variables. *Marmara Üniversitesi Atatürk Eğitim Fakültesi Eğitim Bilimleri Dergisi*, 38(38), 55-64. <https://doi.org/10.15285/EBD.2013385566>
- Bi, H., Mi, S., Lu, S., & Hu, X. (2020). Meta-analysis of interventions and their effectiveness in students' scientific creativity. *Thinking Skills and Creativity*, 38, 100750. <https://doi.org/10.1016/j.tsc.2020.100750>
- Cheung, R. H. P. (2010). Designing movement activities to develop children's creativity in early childhood education. *Early Child Development and Care*, 180(3), 377-385. <https://doi.org/10.1080/03004430801931196>
- Chin, M. K., & Siew, N. M. (2015). The development and validation of a figural scientific creativity test for preschool pupils. *Creative Education*, 6, 1391-1402. <https://doi.org/10.4236/ce.2015.612139>

- Can Yasar, M., & Aral, N. (2010). The effects of early childhood education on creative thinking skills, *Journal of Theoretical Educational Science*, 3(2), 201-209.
- Dere, Z. (2019). Investigating the creativity of children in early childhood education institutions. *Universal Journal of Educational Research*, 7(3), 652-658.
<https://doi.org/10.13189/ujer.2019.070302>
- de Vries, H. B., & Lubart, T. I. (2019). Scientific creativity: divergent and convergent thinking and the impact of culture. *The Journal of Creative Behavior*, 53(2), 145-155.
<https://doi.org/10.1002/jocb.184>
- Dhir, T. (2014). Problem solving ability and science process skills as the influential factors of scientific creativity. *International Journal of Research Pedagogy and Technology in Education and Movement Sciences*, 2(4), 11-17.
- Dikici, A., Ozdemir, G., & Clark, D. B. (2020). The relationship between demographic variables and scientific creativity: mediating and moderating roles of scientific process skills. *Research in Science Education*, 50(5), 2055-2079.
<https://doi.org/10.1007/s11165-018-9763-2>
- Dikici Sigirtmac, A. (2016). An investigation on the effectiveness of chess training on creativity and theory of mind development at early childhood. *Educational Research and Reviews*, 11(11), 1056-1063. <https://doi.org/10.5897/ERR2016.2676>
- Dogan, A., & Kahraman, E. (2021). The effect of STEM activities on the scientific creativity of middle school students. *International Journal of Curriculum and Instruction*, 13(2), 1241-1266.
- Ece Genek, S., & Doganca Kucuk, Z. (2020). Investigation of scientific creativity levels of elementary school students who enrolled in a STEM program. *Elementary Education Online*, 19(3), 1715-1728. <https://doi.org/10.17051/ilkonline.2020.734849>
- Fox, J. E., & Schirrmacher, R. (2014). *Çocuklarda sanat ve yaratıcılığın gelişimi* (Trans. Ed. N. Aral, & G. Duman). Nobel Publishing.
- Garaigordobil, M., & Berruero, L. (2011). Effects of a play program on creative thinking of preschool children. *The Spanish Journal of Psychology*, 14(2), 608-618.
https://doi.org/10.5209/rev_SJOP.2011.v14.n2.9
- Gupta, P., & Sharma, Y. (2019). Nurturing scientific creativity in science classroom. *Resonance*, 24(5), 561-574. <https://doi.org/10.1007/s12045-019-0810-8>
- Hadzigeorgiou, Y., Fokialis, P., & Kabouropoulou, M. (2012). Thinking about creativity in science education. *Creative Education*, 3(5), 603-611.
<http://dx.doi.org/10.4236/ce.2012.350>
- Hou, Y. L. (2013). The generalizability of preschool children's science creativity performance assessment. *南台人文社會學報*, 10, 109-135. <https://doi.org/10.29841/STUTJHSS>
- Hu, W., & Adey, P. (2002). A scientific creativity test for secondary school students. *International Journal of Science Education*, 24(4), 389-403.
<https://doi.org/10.1080/09500690110098912>

- Hu, W., Wu, B., Jia, X., Yi, X., Duan, C., Meyer, W., & Kaufman, J. C. (2013). Increasing students' scientific creativity: The "Learn to Think" intervention program. *The Journal of Creative Behavior*, 47(1), 3-21. <https://doi.org/10.1002/jocb.20>
- Huang, C. F., & Wang, K. C. (2019). Comparative analysis of different creativity tests for the prediction of students' scientific creativity. *Creativity Research Journal*, 31(4), 443-447. <https://doi.org/10.1080/10400419.2019.1684116>
- Huang, X., Lee, J. C. K., & Yang, X. (2019). What really counts? Investigating the effects of creative role identity and self-efficacy on teachers' attitudes towards the implementation of teaching for creativity. *Teaching and Teacher Education*, 84, 57-65. <https://doi.org/10.1016/j.tate.2019.04.017>
- Hui, A. N., He, M. W., & Ye, S. S. (2015). Arts education and creativity enhancement in young children in Hong Kong. *Educational Psychology*, 35(3), 315-327. <https://doi.org/10.1080/01443410.2013.875518>
- Karlıdag, I., & Gonen, M. (2019). The influence of early childhood environment quality on children's creativity. *Cumhuriyet International Journal of Education*, 8(4), 928-960. <http://dx.doi.org/10.30703/cije.542785>
- Kozhevnikov, M., Ho, S., & Koh, E. (2021). The role of visual abilities and cognitive style in artistic and scientific creativity of Singaporean secondary school students. *The Journal of Creative Behavior*, 1-18. <https://doi.org/10.1002/jocb.522>
- Lee, I., & Park, J. (2021). Student, parent and teacher perceptions on the behavioral characteristics of scientific creativity and the implications to enhance students' scientific creativity. *Journal of Baltic Science Education*, 20(1), 67-79. <https://doi.org/10.33225/jbse/21.20.67>
- Leggett, N. (2017). Early childhood creativity: challenging educators in their role to intentionally develop creative thinking in children. *Early Childhood Education Journal*, 45(6), 845-853. <https://doi.org/10.1007/s10643-016-0836-4>
- Lin, C., Hu, W., Adey, P., & Shen, J. (2003). The influence of CASE on scientific creativity. *Research in Science Education*, 33(2), 143-162. <https://doi.org/10.1023/A:1025078600616>
- Liu, S. C., & Lin, H. S. (2014). Primary teachers' beliefs about scientific creativity in the classroom context. *International Journal of Science Education*, 36(10), 1551-1567. <https://doi.org/10.1080/09500693.2013.868619>
- Majid, A., El Deeb, R., & Taha, A. M. (2020). Developing science fiction among kindergarten children. *International Journal of Instructional Technology and Educational Studies*, 1(2), 33-36. <https://doi.org/10.21608/ihites.2021.69933.1039>
- Mohamed, A. (2006). *Investigating the scientific creativity of fifth-grade students* [Doctoral dissertation] Arizona University.

- Ozdemir, G., & Dikici, A. (2017). Relationships between scientific process skills and scientific creativity: Mediating role of nature of science knowledge. *Journal of Education in Science Environment and Health*, 3(1), 52-68. <https://doi.org/10.21891/jeseh.275696>
- Park, J. (2004). A suggestion of cognitive model of scientific creativity (CMSC). *Journal of Korean Association of Science Education*, 24(2), 375-386
- Park, J., & Jee, K. (2015). Investigating students, teachers, and parents' recognition of contrary views on scientific creativity. *Journal of the Korean Association for Science Education*, 35(3), 395-402. <https://doi.org/10.14697/jkase.2015.35.3.0395>
- Philip, R. (2008). *A study of the relationship between intelligence, scientific creativity, achievement motivation, home environment and achievement in science of higher secondary school pupils of Kerala* [Doctoral dissertation]. Mahatma Gandhi University.
- Raj, H., & Saxena, D. R. (2016). Scientific creativity: A review of researches. *European Academic Research*, 4(2), 1122-1138.
- Sak, U., & Ayas, M. B. (2013). Creative Scientific Ability Test (C-SAT): A new measure of scientific creativity. *Psychological Test and Assessment Modeling*, 55(3), 316-329.
- San, İ. (1985). Sanat ve yaratıcılık eğitimi olarak tiyatro. *Ankara University Journal of Educational Sciences*, 18, 99-112.
- Siew, N. M., & Ambo, N. (2020). The scientific creativity of fifth graders in a STEM project-based cooperative learning approach. *Problems of Education in the 21st Century*, 78(4), 627-643. <https://doi.org/10.33225/pec/20.78.627>
- Siew, N. M., & Chin, M. K. (2018). Design, development and evaluation of a problem-based with cooperative module on scientific creativity of pre-schoolers. *Journal of Baltic Science Education*, 17(2), 215-228. <https://doi.org/10.33225/jbse/18.17.215>
- Siew, N. M., Chin, M. K., & Sombuling, A. (2017). The effects of problem based learning with cooperative learning on preschoolers' scientific creativity. *Journal of Baltic Science Education*, 16(1), 100-112. <https://doi.org/10.33225/jbse/17.16.100>
- Siew, N. M., Chong, C. L., & Chin, K. O. (2014). Developing a scientific creativity test for fifth graders. *Problems of Education in the 21st Century*, 62, 109-123. <https://doi.org/10.33225/pec/14.62.109>
- Siew, N. M., Chong, C. L., & Lee, B. N. (2015). Fostering fifth graders' scientific creativity through problem-based learning. *Journal of Baltic Science Education*, 14(5), 655-669. <https://doi.org/10.33225/jbse/15.14.655>
- Smyrniou, Z., Georgakopoulou, E., & Sotiriou, S. (2020). Promoting a mixed-design model of scientific creativity through digital storytelling—the CCQ model for creativity. *International Journal of STEM Education*, 7(1), 1-22. <https://doi.org/10.1186/s40594-020-00223-6>
- Sternberg, R.J. (2010). Limits on science: A comment on where does creativity fit into a productivist industrial model of knowledge production? *Gifted and Talented International*, 25(1), 21-22. <https://doi.org/10.1080/15332276.2010.11673541>

- Tok, E. (2021). Early childhood teachers' roles in fostering creativity through free play. *International Journal of Early Years Education*, 1-13.
<https://doi.org/10.1080/09669760.2021.1933919>
- Torrance, E. P. (1962). *Guiding creative talent*. Prentice Hall.
- Torrance, E. P. (1969). *What research says to the teacher*. National Education Association.
- Trundle, K. C. (2010). Teaching science during the early childhood years. In *Best practices and research base*. National Geographic.
http://ngl.cengage.com/assets/downloads/ngsci_pro0000000028/am_trundle_teach_sci_early_child_scl22-0429a.pdf
- Usta, E., & Akkanat, Ç. (2015). Investigating scientific creativity level of seventh grade students. *Procedia-Social and Behavioral Sciences*, 191, 1408-1415.
<https://doi.org/10.1016/j.sbspro.2015.04.643>
- Wiyanto, Saptono, S., & Hidayah, I. (2020). Scientific creativity: a literature review. *Journal of Physics: Conference Series*, 1567(2), 1-8. <https://doi.org/10.1088/1742-6596/1567/2/022044>
- Yang, K. K., Lin, S. F., Hong, Z. R., & Lin, H. S. (2016). Exploring the assessment of and relationship between elementary students' scientific creativity and science inquiry. *Creativity Research Journal*, 28(1), 16-23.
<https://doi.org/10.1080/10400419.2016.1125270>
- Yildiz, C., & Guler Yildiz, T. (2021). Exploring the relationship between creative thinking and scientific process skills of preschool children. *Thinking Skills and Creativity*, 39, 100795.
<https://doi.org/10.1016/j.tsc.2021.100795>
- Yolcu, E. (2009). *Sanat eğitimi kuramları ve yöntemleri*. Nobel Publishing.