DEBATES ON CREATIVITY AND ITS REFLECTIONS IN MATHEMATICS EDUCATION

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1. Introduction

Creativity is an ability that we have encountered and are still encountering in many different fields of life since ancient times. Creativity, which was thought to be a divine power in ancient times, was considered a reflection of God in man (Glaveanu & Kaufman, 2019). Man's creative actions were regarded as the manifestation of God. This divine perception has turned towards the individual over time. It is known that the Renaissance period affected the emergence of the idea that creativity is an individual phenomenon. Numerous valuable works in the Renaissance period have developed the idea that individuals produce creative products by performing creative actions. This ability, which has been reduced from divinity to the individual, has begun to come to the fore in different fields and to be given greater importance (Runco, 2004). Creativity has served as the foundation for many theories (see The Investment Theory in Creativity) and has emerged as a crucial factor in the selection of qualified personnel, particularly in entrepreneurship. However, it gained popularity in social sciences and psychology with a more specific event, when Guilford underlined the need to focus on creativity in his presidential speech at the American Psychological Association (APA) congress in 1950 (Kaufman, 2009). Before Guilford's speech, creativity was a phenomenon attributed to art and thought to manifest itself in visual works, while in much older history, a mystical perspective on creativity had existed. Over time, how creativity is perceived has moved away from mysticism and evolved towards being specific to the individual (Sternberg et al., 2008), and it has paved the way for a scientific approach to creativity.

There are various definitions of creativity in the literature. For this reason, although it is difficult to talk about a single basic definition of creativity, as a result of the review of more than 90 studies in the literature by Plucker et al. (2004), it was found that the majority of these definitions intersect at two common points, novelty, and usefulness (Plucker & Beghetto, 2004; Plucker et al., 2004). According to many researchers, being new and useful are essential components of creativity (Cropley, 1999; Csikszentmihalyi, 1996; Sternberg & Lubart, 1995). Based on these intersecting components in the definitions, creativity is a new and useful product/idea creation process (Plucker & Beghetto 2004; Plucker et al., 2004; Sak, 2014). Definitions such as generating ideas and strategies as an individual or as a community, being able to reason critically between them and producing reasonable explanations and strategies consistent with the available evidence (Stylianidou et al., 2018), being able to establish relationships between previously unestablished relationships, being able to come up with a new experience or product within the framework of a newly formed idea and creating an innovation suitable for the culture or the individual (Ataman, 2018).

There are many misconceptions in society about creativity. Among these well-known misconceptions, which are called myths, the following can be listed: everyone is creative, creativity is unknown, creativity cannot be learned, developed and is unconscious, creative people are crazy, creativity can develop with a group and listening to classical music like Mozart compositions (Chabris, 1999; Sak, 2014; Treffinger et al., 2006). These unrealistic beliefs stem from the lack of knowledge about creativity, and as studies on creativity increase, these ideas are proving to be urban legends.

When the creativity literature is reviewed, different opinions on many issues can be revealed. These opinions are supported by studies, but the discussions continue without clarification as there are different findings. In this section, different answers to the ongoing questions about creativity with the research in the literature and their reflections on mathematics education are compiled.

2. Is it Necessary to be Intelligent to be Creative?

The view that there is a relationship between creativity and intelligence extends from the past to the present. There have been studies indicating that creativity is part of intelligence or intelligence is part of creativity or that there is no relationship between the two (Sak, 2014). Sternberg and O'Hara (2009) discussed the views on the relationships between intelligence and creativity under five headings. These are;

- Intelligence includes creativity.
- Creativity includes intelligence.
- Creativity and intelligence are identical sets; they are the same.
- Creativity and intelligence are equivalent sets; they overlap.
- There is no relationship between creativity and intelligence.

The most comprehensive of the studies that can be considered under these headings is Terman's classic work in the literature. In Terman's longitudinal study on 1500 participants with high IQ scores, known as Termites, individuals who were not included in the study because they were below the IQ limit determined by Terman were later awarded the Nobel Prize for their original and creative contributions to the fields of science in their adulthood. Similarly, the threshold theory is a study that reveals a relationship between intelligence and creativity. The threshold theory argues that an individual must have at least an average level of intelligence to exhibit creative performance. According to the theory, the intelligence level of individuals does not increase in parallel with their creativity. More specifically, a significant relationship between creativity and intelligence up to 120 IQ scores was observed, but no statistically significant relationship above 120 IQ scores was found (see Sternberg, et al., 2011; Sternberg & O'Hara, 1999; Kim et al., 2010; Torrance, 1968).

Şahin (2014) found that the intelligence scores of average-mildly students (87-114 IQ) and moderately gifted (115-129 IQ) students had a significantly low-level positive correlation with creativity in a study he conducted with the participants classified according to their intelligence scores. It was also observed that the creative potential of individuals does not rise parallel to their intelligence, that there is a low correlation between the intelligence and creativity potential of individuals with an IQ in the range of 87-129 and that there is no significant correlation between the two for individuals with a 130 IQ and above. As a result of this study, Şahin (2014) reached findings to support the threshold theory. While there are studies that support the threshold theory, there are also studies that do not support it (Ogurlu, 2014; Yılmaz et al., 2020). Yılmaz et al. (2020) compared the correlation values of the lower and upper groups classified according to the threshold value of 120 IQ and reached findings that do not support the threshold hypothesis in the younger age groups. In addition, a piecewise regression analysis was performed to test whether there was a threshold value at other levels, and an inverse threshold effect at about 120 IQ was observed between creativity indices and general intelligence level. As a result, in the study, contrary to the threshold hypothesis, it was interpreted that the intelligence components possessed in young age groups bring an advantage to the creative imagination process as the IQ exceeds 120. Thus, even though the literature presents strong evidence for threshold theory, some of the studies still find it argumentative.

3. Can Creativity Be Scored?

Another controversial issue about creativity is whether creativity can be measured or not. While the evaluation of creativity was an application that first started with the needs of the entrepreneurship sector, over time it also started to be considered in education. When the literature is examined, different approaches and measurement tools to evaluate creativity can be found. Until recently, the most common way of evaluating creativity in psychology and educational sciences has been the divergent thinking approach and tests (Said-Metwaly et al., 2021). For example, the Structure of Intelligence Divergent Thinking Test (Guilford, 1967), the Torrance Creative Thinking Test (Torrance, 1974), and the Divergent Thinking Test (Kogan, 1965) are among the measurement tools put forward to score the divergent thinking within the framework of the Structure of Intelligence theory proposed by Guilford. In these measurement tools, participants' responses are generally scored based on the following dimensions; fluency (number of correct answers), flexibility (number of answer categories), originality (newness of answers), and elaboration (richness of details in answers). Over time, with the strengthening of the idea that it is not correct to evaluate creativity only from the perspective of divergent thinking (Runco & Acar 2012), different approaches and measurement tools have started to come to the fore. One of these measurement tools is the Remote Associates Test (RAT), which was created based on Mednick's (1962) theory of associations. In this test, the associations formed by the words given as triples are examined. One of the assessment approaches, which has been put forward on a basis different from that of divergent thinking is the Consensual-Based Assessment Technique (CAT), which was formed based on Amabile's (1982) componential theory. In this approach, it is emphasized that it is not correct to assess creativity objectively and that a team of experts should assess each output subjectively. However, although both divergent thinking tests and assessments based on expert opinion are used in scientific studies, the insufficient number of studies on creativity measurement in terms of predictive, discriminative, and construct validity is still a subject of criticism in the literature (Plucker et al., 2019).

4. Can Creativity Be Developed?

One of the controversial issues about creativity is whether creativity can be developed or not. Treffinger et al. (2006) stated that the idea that creativity cannot be improved is a mistake. Studies in the literature have also revealed that creativity can be developed.

Another debate in the literature can be included in the scope of this subject. This debate is about whether there is a fourth-grade slump in creativity. Studies have revealed that creativity is high in children, continues to increase until a certain age, but decreases after the middle age of childhood and forms a U-shaped graph (Beghetto & Kaufman, 2007; Gardner & Winner, 1982). Torrance (1968) defined the situation that changes the direction in this U chart as a fourth-grade slump. The fourth-grade slump is a term that describes when students enter fourth grade, there occur obvious declines in their creativity with certain environmental influences. It is stated that this decline may be caused by students' developing conformist behavior, getting used to thinking more realistically, acquiring a social environment, and the curriculum's becoming harder (Torrance, 1968; Sak, 2014). In the literature, some studies support this view (Besançon & Lubart, 2008; Long & Henderson, 1965), as well as studies that do not. Camp (1994) and Charles and Runco (2001) found that there is no increase or decrease in creativity in the fourth grade, while Hong and Milgram (2010), Lopez et al. (1993), and Sak and Maker (2006) found that there is an increase in divergent thinking in creativity. In addition to these findings, there have also been studies that have reached findings on the decline of divergent thinking in creativity in different periods. Kim et al. (2006) and Kim (2011) reported that divergent thinking in creativity falls in the sixth grade, Jastrzębska and Limont (2017), Lau and Cheung (2010), Said-Metwaly et al. (2021) and Sherwood and Strahan (1985), on the other hand, concluded that divergent thinking in creativity falls in the seventh grade.

Although creativity increases and decreases in different ages and situations, creativity should continue to be developed and supported throughout all ages and grade levels. Different models and strategies have been proposed for the development of creativity. The most prominent ones among them are having experiences in different fields (Cropley & Urban, 2000), using divergent thinking strategies in creative problem solving, using metaphors and analogies, brainstorming, using the SCAMPER technique, and morphological synthesis (Starko, 2017).

As a result of the conviction that creativity is found in all individuals as a potential, it is emphasized that creativity can be improved with such techniques and various pieces of training. The importance of education for the development of creativity is accepted by the majority. It should be mentioned that it is important to transfer creativity to the field so that teaching it in class can be more meaningful (Kanlı, 2019). Although general creativity skills are taught, this teaching will gain meaning by transferring it to the field in context. For this reason, it is important to carry out practices and activities that support creativity in the context of each lesson.

5. Can a Person Creative in Art Be Creative in Mathematics?

In creativity, as in intelligence, the question of "whether it is general or domain-specific?" is discussed. Simon (1976), one of the researchers who defend the view that creativity is general, claims that a person who shows creative potential in one area has creative potential in other areas with the influence of Guilford's Theory of Structure of Intellect (Guilford, 1967). The researchers who support this view place divergent thinking like Guilford to the essence of creative thinking (Kogan, 1994). The group, which is against the view that creativity is a general skill, criticizes Guilford's theory for lack of empirical evidence and support (Runco & Nemiro, 1994), stating that divergent thinking alone cannot represent creativity (Csikszentmihalyi, 1990) and support the view that creativity can emerge in a field. Kanlı (2019) contributed to this discussion with an example that although Chekhov is a medical doctor, he is known for his contributions to literature, emphasizing that knowledge and expertise are important determinants in this discussion. Weisberg (2006) stated that it is not possible to be creative in every field and emphasized that the reason for this is the ten-year rule advocating that ten thousand hours must be spent to specialize in a field and that creativity can only develop with the development of knowledge and skills. According to Plucker and Beghetto (2004), creativity that starts with general skills necessarily progresses toward domain specificity with the progression of life. This progress is shown in Figure 1.

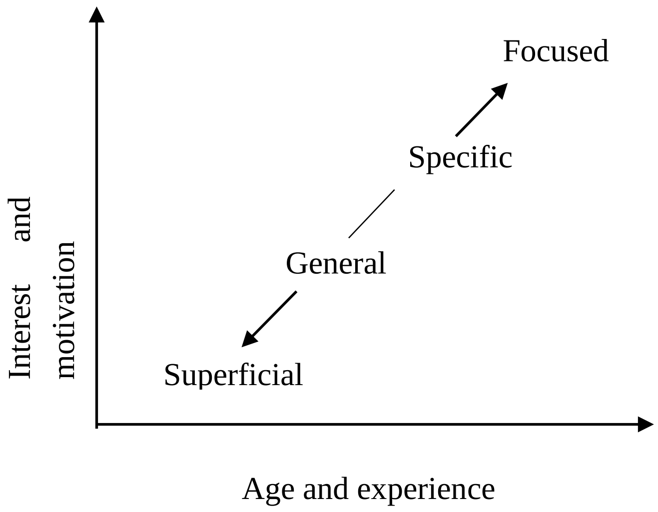

Figure 1. Conceptualization of general and domain-specific creativity (Plucker & Beghetto, 2004)

As seen in the model, Plucker and Beghetto (2004) stated that the focus points will become more domain-specific as the person gets older and gains experience in a particular domain or a particular task, and also as the individual's interest and motivation for a particular subject or problem increases. They explain this situation as follows; "as people become more interested in a subject or task, they will devote less time to working in other areas". From this perspective, creativity may seem domain-specific, but this is partly because people make choices in life that force them toward being domain-specific. It is emphasized that the optimal condition for creative production is a flexible position somewhere between general and domain-specific creativity (Plucker & Beghetto, 2004).

Mathematical creativity, which is a field of creativity that comes to mind about creativity specific to the field, should also be mentioned. In this section, mathematical creativity and reflections on creativity on mathematics education will be discussed.

Ervynck (1991) stated that mathematical creativity is one of the features of higher-order mathematical thinking, that the individual needs a context for creativity to take an important step forward with his/her prior experiences, that this kind of preparation takes place through previous activities and creates a suitable environment for creative development. Sriraman (2005) defined mathematical creativity at the Professional level as

"-the ability to produce original work that significantly extends the body of knowledge, and/or - the ability to open avenues of new questions for other mathematicians." (p.23)

Despite the confusion caused by the fact that many existing definitions of mathematical creativity are vague or incomprehensible (Sriraman, 2004), most of the efforts of educational researchers are generally directed at proposing frameworks for evaluating creativity, particularly demonstrating creativity through problem-posing and problem solving (Singer, Voica, & Pelczer, 2017). There is a dominant view that problem-posing in mathematics is related to creativity (Singer & Voica, 2015, Singer et al., 2017, Bicer et al., 2020, Leiken 2009).

Torrence defined creative thinking "*as the process of sensing difficulties, problems, gaps in information, missing elements, something askew; making guesses and formulating hypotheses about these deficiencies; evaluating and testing these guesses and hypotheses; possibly revising and retesting them; and finally communicating the results"* (Torrance, 1988, p. 47). From this point of view, problem posing is among the creative strategies that should be used to facilitate teaching in mathematics education, improve problem-solving skills (Rosli et al., 2014), support conceptual learning and as a teaching approach and an assessment tool (English, 1997; Silver, 2013) and as a process of supporting students' creativity.

Luria et al. (2017) suggested using creative strategies such as presenting open-ended problems, modeling activities, encouraging risk-taking, discussing mathematical concepts, concept-based learning, different thinking strategies and incorporating cultural elements into problem-solving activities to support mathematical creativity in the classroom.

Ataman (2018) defined a creative person as a person who gets rid of memorized and stereotyped thinking patterns, thinks multi-dimensionally in an interdisciplinary manner, and can produce new products. Based on this definition of the creative person, it becomes clear that problem-posing activities are among the classroom activities that can be used to support mathematical creativity. The use of problem-posing activities allows both the generation of new problems and the reformulation of given problems and the formation of mathematical problems from a situation (Silver, 1993; Silver, 1994). Problem posing is a very important mental activity for scientific discoveries (Silver & Cai, 2005). In addition, it improves the student's creativity and accessibility to mathematical concepts (Ayllon & Gómez, 2014). Problem posing requires posing a personal and creative problem using acquired mathematical knowledge and related concepts. Problem-posing activities recommended to be used in the development of mathematical creativity are also used in the evaluation of mathematical creativity. Two examples of problem-posing activities taken from the activities in the book written by Yığ and Ay (2021) are presented below.

Example 1:

A dance show will be held as part of the school's end-of-year events. The zone where they will dance considered a coordinate system. Each unit of spacing on the horizontal and vertical axes is equivalent to 1 meter. Students Ayşe, Bilge, Can, and Deniz are located at points A(-2,4), B(2,4), C(2,-4), and D(-2,-4) respectively.

a) What are the regions where students are located?

b) For demonstration purposes, students at positions A, B, C, and D must hold a colored stripe in their hands to form a perimeter of a rectangle. How many meters of tape are required?

c) Express what is given and requested in the problem in your own words.

d) Based on the above problem, pose a problem such that Ayşe, Bilge, Can and Deniz settle on the zone differently, but they hold the length of the colored stripe in their hands does not change.

Example 2:

Pose a solvable problem containing the coordinate system and rational numbers.

Take care that the problems are not like other problems you solve in the classroom.

Although there is no consensus on the definition of mathematical creativity, many studies emphasize that creativity in mathematics education can be supported by problem solving and problem posing activities (like the examples above). It is recommended to use model eliciting activities in addition to problem solving and problem posing activities in mathematics lessons (Silver, 1994; Şengil-Akar, 2017; Yığ & Ay, 2021). In this section, the mathematics education dimension of domain-specific creativity, which is one of the controversial issues in the literature, is discussed.

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