

Quantitative Research Vortex?

-- A Systematic Review of Scientific Creativity in K-12 Stages (2018-2022)

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Abstract

This research used a systematic review method to sort out the research frontiers of scientific creativity in the past five years, and describes the frontier research overview of scientific creativity from the publication trend, research design, research results, trends and challenges. The results show that the research of scientific creativity has entered the vortex of quantitative analysis, and the quantity of qualitative research and mixed research is insufficient. Currently, researchers have mainly discussed scientific creativity in the context of science learning, with many studies focusing on gender differences. However, the discussion on the elements and connotation of scientific creativity is not theoretical enough.

Keywords

Scientific Creativity; Systematic Literature; Five Past Years.

1. Introduction

Development relies on innovation, innovation relies on talents, and the future world competition is essentially a competition for innovative talents. The Organization for Economic Co-operation and Development (OECD) advocates that the future of education should focus on the cultivation of students' creativity (OECD, 2012), and has explicitly added tests related to creative thinking in the 2022 Programme for International Student Assessment (PISA) (OECD, 2021).

The development of creativity has gradually moved from the arts to other disciplines, and research is gaining momentum, especially in the sciences. Students' creativity in Chinese classrooms is poorly represented (Yang et al., 2015). The study of creativity originated in art and music classes (Sawyer, 2012), and the rise of STEM and STEAM education has led to the spread of creativity research to science learning, mathematics learning, and engineering practice (Madden et al., 2013; Perignat & Katz-Buonincontro, 2019).

Scientific creativity is a specific expression of general creativity in scientific disciplines and is the culmination of general creativity and scientific learning. Among the existing review articles related to scientific creativity as the core, the number of reviews is far from adequate. In the last five years, among the published review studies, only two are representative and academic, but there are still many limitations. Bi et al. reviewed research on scientific creativity from 1992 to 2017, systematically reviewing four interventions for student scientific creativity from preschool to higher education, but did not discuss other aspects of scientific creativity (Bi et al., 2020). Wang and Tan reviewed the relevance of using bibliometrics to evaluate scientists' scientific creativity, which does not have much value for the development of students' scientific creativity (Wang & Tan, 2017).

In summary, a review of high-quality empirical research articles from the last five years is necessary in the context of the current progressive focus on scientific creativity in the science

education community. Therefore, this study intends to answer the following research questions through a literature review:

Q1: What are the publication trends in scientific creativity in the last five years? Q2: What are the characteristics of empirical studies of scientific creativity in terms of research design? Q3: What are the key findings? Q4: What are the trends and challenges?

2. Study Design

2.1. Methodology

This study was conducted using the currently emerging systematic literature review method. The systematic literature review method requires a clear research question, followed by a systematic literature search strategy, and content analysis methods to draw systematic research conclusions (Siddaway et al. , 2019) . Based on the above research questions, this study conducted a literature screening and specified screening criteria for content analysis and data statistics. By establishing connections between the literature, an attempt was made to obtain new findings about scientific creativity in order to provide valuable insights for researchers in science education.

2.2. Sample Selection

The literature selected for this study was obtained mainly through journal screening and literature screening.

2.2.1. Journal Selection

There are two reasons for choosing a journal: First, the quality of articles in an industry-recognized journal is guaranteed. Secondly, scientific creativity is a composite term, and it is necessary to screen key journals in related fields. The following six journals were selected:

Science Education Field: Journal of Research in Science Teaching (JRST, IF:3. 918) Science & Education (SE, IF:2. 921) , International Journal of Science Education (IJSE, IF:2. 518) , Research in Science Education (RSE, IF:2. 469). Psychology Field: Thinking Skills and Creativity (TSC, IF:3. 644), Creativity and Innovation Management (CIM, IF:3. 652).

2.2.2. Literature Screening

This study searches the literature on scientific creativity from 2018-2022. The search was conducted in the web of science database with the string " (TS= (scien*)) AND (TS= (creativity)) " in "Subjects". In addition, English was chosen as the language, and the six journals mentioned above were limited to "publications", and the period was set from 2018-1-1 to 2022-12-31. 110 papers were obtained.

According to the purpose of the study, the preliminary selected literature was read article by article for a second round of screening according to the following criteria: (1) Non-empirical research papers; (2) non-journal papers; (3) The full text is not available; (4) the length is less than three pages; (5) the paper does not have clear research questions, research methods and research conclusions; (6) the research theme does not focus on scientific creativity; (7) Papers in non-K-12 fields.

The titles and abstracts were read according to the above filtering criteria, and a total of 28 articles were eligible. The full text of the 28 articles was read through according to the screening criteria, and 17 articles were identified as finally eligible. The literature screening flowchart is shown in Figure 1.

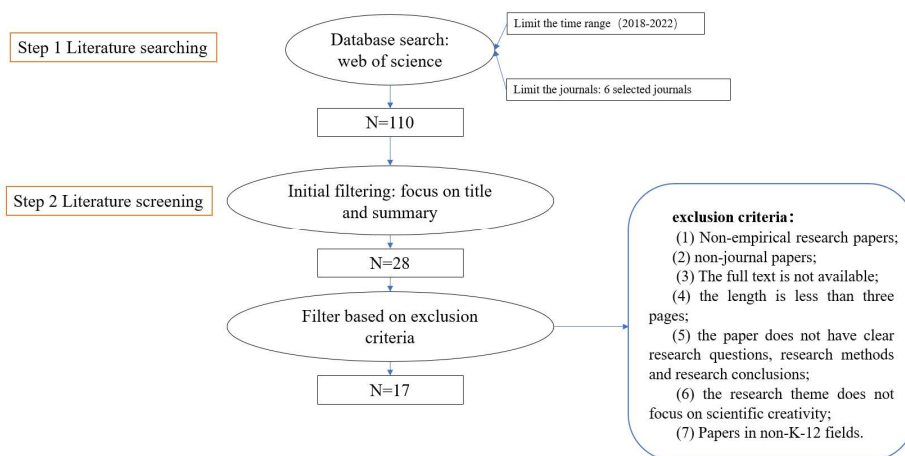


Figure 1. Literature screening flowchart

3. Results and Discussion

In order to answer the research questions more clearly, this study will present the results in four aspects: publication trends, research design, important findings, and trends and challenges.

3.1. Publication Trends

The overall publication trends of scientific creativity-related research can be grasped from the annual trend of article publication, journal distribution, regional distribution and research section.

The resulting 17 papers indicate that international research on scientific creativity is still at a basic stage and that the attention and number of papers published on this topic are still far from adequate. In terms of distribution of year, 2020 has the highest number of publications, followed by 2022, with an overall increasing trend, indicating that the research fervor for scientific creativity is on the rise.

In terms of distribution of journal, it shows a certain degree of periodical concentration, indicating that scientific creativity is gradually expanding from the field of psychology to the field of science education. In terms of distribution of authors' regions, the data presents a stepped stratification. In terms of the distribution of school segments, it is mainly concentrated in the primary and secondary school stage, and there is a lack of attention to preschool children.

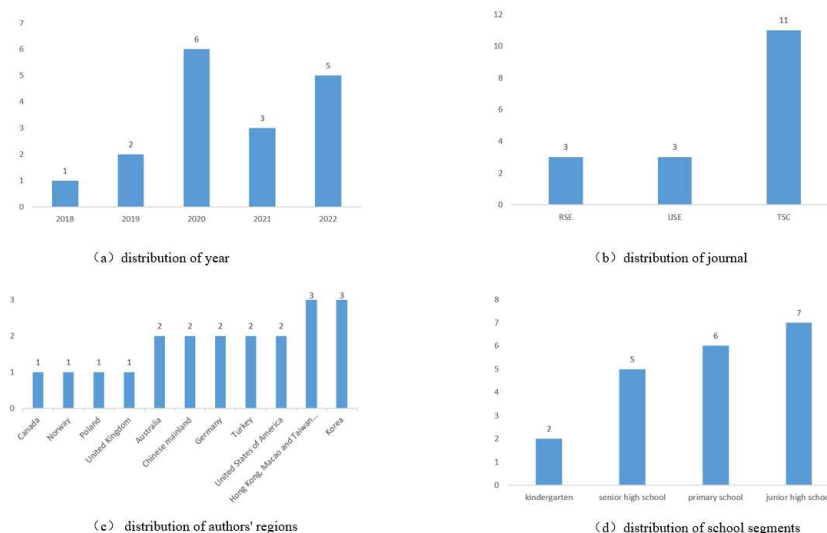


Figure 2. Publication of articles in four perspectives

3.2. Research Design

In this section, this study will address four aspects of the selected articles: research paradigm, theoretical framework, sample selection, and data collection and analysis.

3.2.1. Research Paradigm

This study summarizes 3 research paradigms and 7 research designs. As shown in Table 1, 13 studies used quantitative research methods and 4 studies used qualitative research methods. However, no studies have used a true mixed research paradigm.

Table 1. Research paradigms and concrete types of 17 empirical articles

Research Paradigm	type	quantity	summation
Quantitative Research	education assessment	7	13
	quasi-experimental design	5	
	scale development	1	
Qualitative Research	critical incident technique	1	4
	case study	1	
	discourse analysis	1	
	grounded theory approach	1	
Mixed research		0	

In the last five years of empirical research, quantitative research on scientific creativity has mainly dominated, especially focusing on the measurement of scientific creativity. This reflects the current tendency of researchers to conduct research through quantitative approaches. The predominance of quantitative measurement studies indicates on the one hand that a certain foundation has been accumulated in the development of tools for scientific creativity, and on the other hand, it exposes the lack of qualitative excavation of the deeper content behind the numbers and phenomena in related studies.

The use of mixed research methods will be one of the future trends in educational research; however, in the literature selected for this study, the mixed research paradigm is missing, and research reflecting scientific creativity cannot avoid having to use both quantitative and qualitative analysis for a more comprehensive study in the future.

3.2.2. Theoretical Framework

In the last five years of empirical studies, more than half of the studies did not report the theoretical framework of the study. This indicates, on the one hand, that research on scientific creativity is still at a basic stage and, on the other hand, that the majority of researchers should pay attention to the theoretical construction and development of scientific creativity.

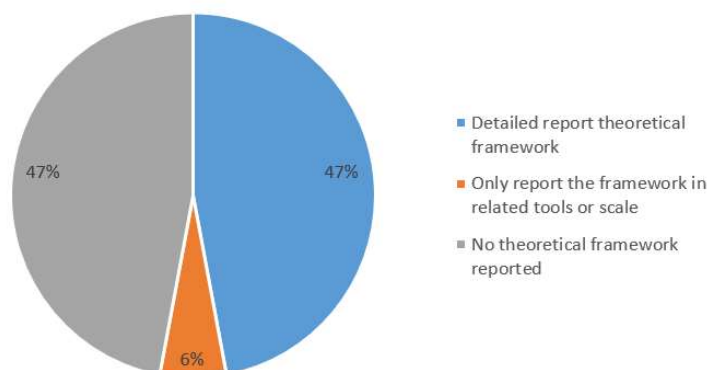


Figure 3. Proportion of 17 articles reporting theoretical framework

In studies where the theoretical basis is reported, there are two main categories. The first reported in detail a particular theory on which the study was based and its significance in guiding the study, and the second, in the case of studies in the measurement category, primarily used the framework of the original measurement instrument chosen or modified for the study as the theoretical framework for the study.

In the first category, common theories include:

- ① Four C Mode of Creativity (James C. Kaufman. & Ronald A. Beghetto. , 2009) , which includes: Big-C, related to outstanding achievement; Pro-c, related expertise; Lite-c, related to everyday innovation; and Mini-c, related to transformative learning.
- ② The 4Ps framework (Dorniak-Wall, 2016) , in which creativity is described using the terms "Person, Process, Press and Product".
- ③ The five dimensions of scientific creativity (Zhang et al. , 2018) : (1) creative problem identification, (2) creative product design, (3) creative product improvement, (4) creative problem solving and (5) creative imagination.

In the second category, the most referenced or selected scale, developed by Hu and Adey in 2002, is the Scientific Creativity Test Scale (Hu & Adey, 2002).

3.2.3. Sample Selection

Sample sizes were reported in all 7 articles, and their distribution is shown in Figure 4 (a). As shown earlier, the research on scientific creativity in the past five years is mainly based on quantitative research, which further shows that the current research on robot education is mainly for large sample data, while the depth tracking and mining of small sample data are missing.

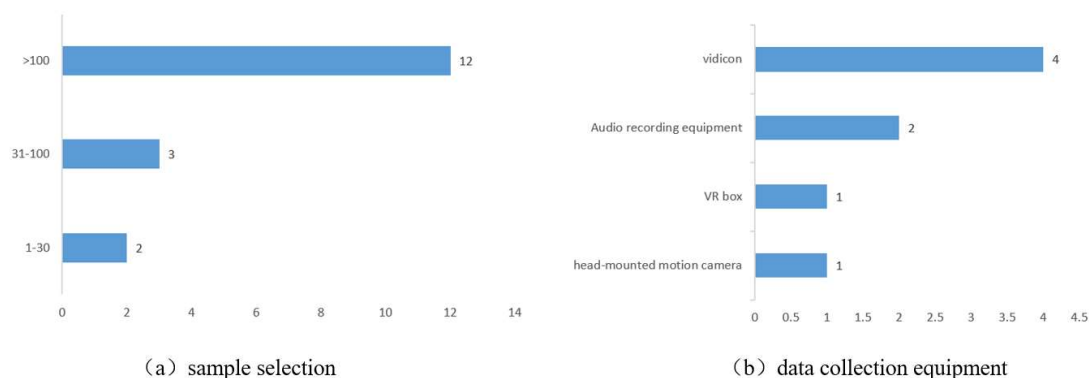


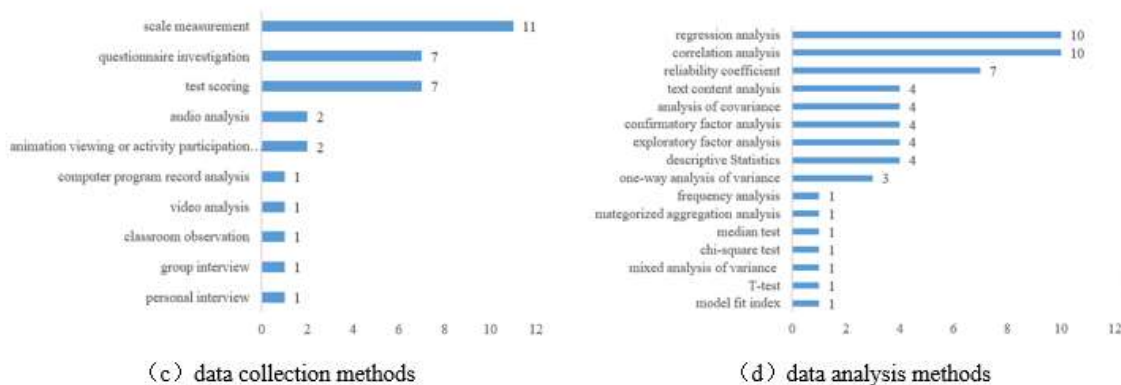
Figure 4. Sample selection and data collection equipment usage of 17 articles

3.2.4. Data Collection and Analysis

The distribution of receipt collection patterns is shown in figure 4 (b). In addition to traditional paper-and-pencil tests, a third of studies typically use other devices, such as cameras, for data collection. Head-mounted motion cameras can record interactions between groups in detail (Skjelstad Fredagsvik, 2022) . VR data acquisition box is a form of combining scientific creative research with new technologies in education (H. Lin et al. , 2020) . When new means of educational technology are introduced, the equipment and methods used for data collection will be updated as well.

The sum of data collection methods (n=34) will be greater than the number of literature (n=17) because different empirical studies have more than one data collection method. As shown in Figure 5 (c), scale measurement is the most commonly used method of data collection. Questionnaires and test questions are the more common methods used in research. The

questionnaires were used to measure other variables in the study, such as psychology and personality traits. Some studies employ emerging testing methods, such as animation testing. The data analysis methods are shown in Figure 5 (d), and it is worth clarifying that only the data analysis methods explicitly mentioned in the study are reported here. In the quantitative study, regression analysis and correlation analysis were the most used analysis methods; while in the qualitative study, the main analysis method chosen was text content analysis. Text content analysis is generally used to analyze interview data, open-ended question data, log data, etc.



Note: Only methods that are explicitly reported in the article are counted

Figure 5. Data collection and analysis methodology used in 17 articles

3.3. Important Findings

3.3.1. Measurement of Scientific Creativity

In order to achieve the purpose of measuring scientific creativity, it is necessary to determine the constituent elements of scientific creativity. Not all studies directly measure scientific creativity, including both direct and indirect measurements.

Among the types that directly measure scientific creativity are two empirical studies. Atesgoz believes that students' scientific creativity includes two important aspects: hypothesis generation and experiment design, and examines four aspects: fluency, flexibility, originality and creativity (Atesgoz & Sak, 2021). Roth divided scientific creativity into act and flow aspects, using a declarative statement for each item that subjects rated. In this assessment tool, act refers to the individual's creative behavior, and flow is the psychological experience during the creative process, describing a creative mental state of full immersion (Roth et al., 2022).

Among the types of indirect measures of creativity, there are four studies that analyze and generalize the elements of scientific creativity.

Ferguson identified nine characteristics of creative reasoning in students participating in a multi-agent computational model (natural selection): noticing anomalies, checking trends, looking at controls, physically and virtually pointing, verbal hypothesising, textual and pictorial hypothesising, asking questions, giving instructions, and interacting with others (Ferguson, 2022). Yoon et al. chose the Creative Problem Solving Profile Inventory (CPSPI) developed by Lee et al. in 2014, and believed that students' group creative problem solving ability was reflected in four dimensions with time series, namely, problem identification and analysis, generation of ideas, execution planning, execution, and persuasion and communication (Yoon et al., 2020). Lin et al. developed the engineering design creativity scale and conducted the evaluation. They believed that it included two main parts: creative design process and creative design output, in which included five stages, namely empathize, define, ideate, prototype, and test.

In addition, a qualitative study on exploring students' creative behavior deserves attention, because it deeply explains the specific process of students' creative behavior, which is very helpful for us to understand how students' scientific creative process occurs. Skjelstad Fredagsvik summarized the creative process of students through the grounded theory, including six ways. That is, (1) Adaptation, means adapting ideas and knowledge in the field of science and using them to create something new.. (2) Transfer, means to the use of life experience to stimulate creative ideas. (3) Synthesis, means the combination of two or more ideas from different fields. (4) Originality, means students' self-generated innovative thinking and ideas. (5) Practicality, means that students build new ideas based on actual use and methods. (6) Need, means the construction of creative ideas or solutions according to needs. (Skjelstad Fredagsvik, 2022).

A prominent feature of the above studies on the relevant elements of scientific creativity is that they do not discuss the proposed elements in detail, including the specific meaning of the elements, behavior, the process of occurrence and the relationship between the elements. However, these aspects happen to be key parts of understanding and measuring scientific creativity.

3.3.2. Gender Differences in Scientific Creativity

In science, it is a fact that men dominate, and female roles are often overlooked. Studies have shown that women do not underperform men in science, technology, engineering and mathematics, and encouraging women to participate in STEM-related career development and engineering learning has become a key policy in many developed countries (Office of Science and Technology Policy, 2018).

Among the 17 empirical studies, 7 of them focused on or deeply discussed the phenomenon of gender differences in the research results. A considerable number of researchers believe that scientific creativity shows differences in gender that are worthy of further study. For example, Lin et al. found that the application of VR in teaching has a greater impact on the engineering design thinking process of girls than boys (Lin et al., 2020). Yildiz et al. found that female students were significantly better than male students in creative fluency and expressiveness (Yildiz & Guler Yildiz, 2021).

What's more, the conflicting findings are of greater concern. For example, Dikici's research found that scientific process skills regulate the relationship between students' age and scientific creativity, and improving scientific process skills will enhance students' scientific creativity, while gender effect has a great impact on scientific creativity, which is in favor of female students, and the score of female students' scientific process skills is higher than that of male students (Dikici et al., 2020). However, this contradicts the findings of Yildiz's research, which found no gender differences in students' science process skills (Yildiz & Guler Yildiz, 2021).

The essence of gender difference is not in absolute ability, but in intrinsic interest. When we have a more in-depth exploration of the gender differences in scientific creativity, science education classrooms adapted to both male and female teenagers will gradually appear, which will be of great help to the training of innovative talents in various countries.

3.4. Trends and Challenges

Based on the analysis of 17 studies, it can be found that the research on scientific creativity in the future will have the following trends, and these trends are accompanied by corresponding challenges:

(1) Combined with emerging educational technologies, such as AR and VR, a team of researchers with cross-professional backgrounds will be conducive to research. (2) From quantitative or qualitative single research paradigm to mixed research. In addition, the emergence of action research will add more evidence to the current research. (3) Attach

importance to the scientific creativity research of preschool children. (4) Explore the key elements, specific connotation and behavior of scientific creativity, and build a more scientific theoretical framework. (5) Paying attention to gender differences.

4. Conclusion

Based on 17 empirical studies on scientific creativity in the past five years, this study systematically reviewed the literature from four aspects: publication trend, research design, research results, advantages and challenges. At present, the research on scientific creativity mainly adopts quantitative evaluation method. However, at present, the theoretical construction of scientific creativity is very lacking, which not only directly restricts the development of the evaluation scale, but also delays the development of the research related to scientific creativity to a more scientific and mature field. It is necessary and essential to use qualitative analysis method to conduct in-depth research, which can not only uncover the mystery of the process of students' scientific creativity, but also describe what scientific creativity is through a large number of in-depth evidence-based analysis. The focus on gender in education also radiates into the study of scientific creativity, and there is a need to promote similar support for the development of scientific creativity in girls and boys, as education always strives for achievable and sustainable equity.

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