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Science teachers' perspectives on scientific creativity in an examination-oriented educational system

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ABSTRACT

In many countries, examination-oriented education systems constrain scientific creativity in classrooms. This study investigates science teachers' perspectives on scientific creativity within such a context. Semi-structured interviews were undertaken with 16 science teachers from a Chinese upper secondary school. The interviews were audio-taped and subsequently transcribed for analysis. Findings revealed that teachers characterised creative students by their thinking styles, learning abilities, subject interests, personalities, and knowledge, with the perception that high-achieving students tend to be more creative. While inquiry-based teaching and science experiments were seen as creative processes, teachers argued that these activities involved greater teacher involvement and less student participation. Teachers identified four manifestations of students' creative ideas: knowledge divergence, transfer or integration; independent student-generated questions; science experiments, modelling or specimen production; and applying theory to real-life problem solving. They also emphasised the importance of providing feedback to support students in developing creative ideas. Teachers mentioned various factors for creating a creative environment, with teaching approaches raised most frequently; inquiry-based teaching was a contributing factor, while the approach of merely transmitting facts was noted as a major inhibitor. This study therefore provides practical guidance and insights for teachers and policymakers to promote scientific creativity in China and similar educational contexts.

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Scientific creativity; science pedagogy; teacher perspectives

Introduction

Fostering creativity has gained increasing global recognition in science education (Hetherington et al., 2020), as it supports students' learning, helps them discover their creative potential, and prepares them to adapt to a rapidly changing world (OECD,

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2022). According to Sternberg (1999), creativity is the ability to produce work that is both novel and appropriate. In the context of science education, Xu et al. (2024a) expands this understanding by defining scientific creativity as not only the manifestation of inspiration and imagination, but also the process of transforming creative ideas into scientific knowledge by logical reasoning.

In science classrooms, the support of science teachers and the nature of the classroom environment are critical dimensions in enabling students' scientific creativity (O. Hong & Song, 2020). However, a number of studies have shown that many science teachers are reluctant to teach for creativity due to a lack of creativity-centred teaching training, insufficient time allocation, and the perception that creativity is less important than test scores (Al-Abdali & Al-Balushi, 2016; M. Hong & Kang, 2010). According to Nursiwan and Hanri (2023), prospective chemistry teachers achieved high scores in scientific attitudes, demonstrating objectivity and a critical attitude to science; however, their scientific creativity lagged behind, particularly in the dimensions of fluency and flexibility. Therefore, understanding science teachers' perspectives on scientific creativity is needed if students' scientific creativity is to be promoted in science classrooms.

Perspectives on creativity differ across different cultural contexts (Al-Abdali & Al-Balushi, 2016; M. Hong & Kang, 2010). Zhou et al. (2013) argue that Chinese teachers tend to associate creativity in students with cognitive and executive ability, while German teachers focus on problem-solving and decision-making skills, and Japanese teachers highlight the persistence of students' own opinions. Furthermore, Chinese teachers often evaluate students' creativity based on their academic performance and their daily behaviours (Guo et al., 2021). This cultural variation in the conceptualisation and evaluation of creativity underscores the significance of context in educational practices.

In East Asian societies, where high-stakes testing prevails, developing creativity is a particularly challenging task (Cheng, 2010; Niu & Sternberg, 2003). As Niu and Sternberg (2003) found, compared to the USA, the national performance assessments (e.g. the National College Entrance Examinations) in China can decisively determine a student's educational destiny, consequently leading Chinese teachers and students to be predominantly concerned with performing well on standardised tests, leaving less time and attention for non-standardised activities, such as those to do with the facilitation of creativity. Such an educational environment could further hamper students' spirit of intellectual adventure and questioning, as well as teachers' and students' tolerance for uncertainty in responses (Ke & Liang, 2023), both of which seem likely to facilitate creativity in students.

An increasing number of studies in various countries have used interviews to capture teachers' nuanced views on creativity. Notable examples include studies from Australia (McLure et al., 2024), Poland (Gralewski, 2019), South Korea (So & Hu, 2019), and Turkey (Kirişçi, 2023). However, according to two systematic literature reviews (Bereczki & Kárpáti, 2018; Mullet et al., 2016), research on Chinese teachers' perspectives remains relatively limited. Furthermore, recent research on Chinese teachers' perspectives on creativity has largely been quantitative, focusing on specific variables rather than providing a comprehensive exploration of teachers' perceptions (e.g. Liu & Zaman, 2025; Wang, 2025). This scarcity of qualitative research, particularly among upper secondary school science teachers in China, represents a significant gap in the literature. As highlighted by Yazhuan et al. (2010), Chinese science teachers in upper secondary schools face significant examination pressures and an extremely demanding teaching workload.

Therefore, a more comprehensive qualitative investigation into their perspectives on scientific creativity is needed. Such research can also provide valuable insights for developing creativity in other examination-oriented educational systems. Additionally, the views of upper secondary school science teachers can offer constructive suggestions for balancing examination pressures with creativity development in science education.

This study therefore aims to investigate science teachers' perspectives on scientific creativity, with a particular focus on China. To address these issues, this study begins with a review of several frameworks for scientific creativity and selects one with adaptations for this research. After reviewing the existing literature, this study employs a qualitative research design to collect data and analyse it using thematic analysis. The results are then described and discussed, with their possible implications considered, before the study concludes with a summary and acknowledgement of its limitations.

Literature review

Many researchers have developed various frameworks to understand creativity in general (see, for example, Kupers et al., 2019) and scientific creativity in particular (see, for example, O. Hong & Song, 2020). One widely used framework is Rhodes's (1961) four Ps of creativity, namely person, process, product, and press. Rhodes explained the framework as follows: first, the term 'person' covers information about personality and other traits; secondly, the term 'processes' focuses on motivation, perception, learning, thinking, and communication; thirdly, the term 'product' is the outcome of creativity, and creative products embody original and valuable ideas; lastly, the term 'press' refers to the relationship between human beings and their environment. This framework provides general guidelines for structurally analysing creativity across various contexts, but does not make reference to specific disciplines or setting orientations.

To investigate creativity in science education, O. Hong and Song (2020) proposed the 'Science Classroom Creativity' (SCC) model, mainly based on the four Ps framework. The SCC offered a broad perspective on creativity within science classrooms, involving students' characteristics (cognitive and affective), engagement (internal and external), creative behaviours (individual and collective), science teacher support (cognitive and emotional), and the science classroom environment (physical and socio-cultural). While empirically validated in Korean science classrooms for its suitability in analysing creativity, the SCC model has been critiqued for its overlapping components and unclear delineations (Xu et al., 2024b). However, given the similar Asian context, Hong and Song's model is likely to be applicable to Chinese scientific creativity education, albeit with necessary refinements.

Xu et al. (2024b) proposed an analytical model for science classroom creativity in China, drawing on the SCC model (O. Hong & Song, 2020), the 'Dynamic Componential Model of Creativity' (Amabile & Pratt, 2016), and 'Cultural Pyramid Model of Creativity' (Yi, 2008), tailored to the Chinese context. Xu et al.'s (2024b) model includes 'creative students', who possess or are developing inherent creative characteristics; 'the creative process', which describes scientific inquiry activities; 'teachers' attitudes to creativity', including teachers' perceptions of creative students and their feedback on creative ideas; and 'a creative environment' comprising the physical and socio-cultural environments. However, further analysis also reveals overlaps, such as teachers' perceptions of creative students with 'creative students', and the absence of a 'product' dimension, which would help identify the outcomes of students' creativity in science classrooms. Therefore, the following literature review draws on three key dimensions from the model – creative students, the creative process, and a creative environment – while also introducing 'creative ideas', to address the missing 'product' dimension and offer a more comprehensive understanding of scientific creativity in science classrooms.

Creative students

According to Sternberg's (2018) investment theory of creativity, creative individuals are characterised by a combination of intelligence, knowledge, thinking styles, personality, motivation, and environmental factors, which together form an overarching structure. Andiliou and Murphy (2010) had previously developed a conceptual framework of teachers' beliefs about creative individuals, identifying two key components: knowledge base and personality. The knowledge base includes domain-specific and task-related knowledge, whereas personality encompasses attitudinal traits (e.g. independence, emotional resilience), intellectual characteristics (e.g. inventiveness, originality), and motivational traits. This framework provides a valuable conceptual foundation for further research into teachers' perceptions of creative individuals.

Empirical studies have further developed these theoretical perspectives. In a study with a sample of US teachers, Aljughaiman and Mowrer-Reynolds (2005) reported that teachers identified thinking differently and being imaginative as two of the most important traits of creative students, particularly in relation to their thinking styles. Gralewski (2019), based on interviews with 14 Polish teachers, found that creative students were typically described in terms of personality, cognitive predispositions, and motivation. Furthermore, Xu et al. (2024a) argued that scientific creativity differs from creativity in other fields due to its greater requirement for rationality and logic. According to their review of previous studies on scientific creativity, creative students in science not only demonstrate traits such as divergent thinking but also manifest convergent thinking, scientific knowledge, and motivation for scientific creativity; these components were also found to be applicable to Chinese secondary school students (Xu et al., 2024a).

In addition, compared to Western perspectives, Chinese individuals often include intelligence and behavioural components in their descriptions of creative people (Niu & Sternberg, 2002). For example, Guo et al. (2021) found that Chinese teachers tend to overestimate well-behaved high achievers' creativity, even when these students were in the low creativity group, while they underestimated the originality of misbehaving low achievers, despite these students being highly original. Therefore, more research is needed not only to investigate how science teachers describe creative students' characteristics, but also how science teachers in China perceive the relationship between academic performance and scientific creativity.

The creative process

The creative process can be defined as 'the sequence of thoughts and actions that lead to a novel, adaptive production' (Lubart, 2001, p. 295). In this sense, 'thoughts' involve cognitive processes such as divergent thinking, which entails associating or combining different ideas, while 'actions' reflect the flexible sequencing of activities – for instance, exploring information before identifying problems, rather than beginning with well-defined problem. These features thus distinguish the creative process from routine processes (Lubart, 2001). In science, this process is further shaped by the scientific process. As Simonton (2003) explains, scientific creativity operates as a 'constrained stochastic behaviour' (p.475): scientists generate numerous ideas and combinations, yet these are bounded by existing scientific knowledge, problem-solving methods, and the specific rules of a discipline. Thus, the creative process in science can be understood as the interplay between open-ended idea generation and the structured scientific process, where constraints guide but do not eliminate creativity.

Translating this interplay into classroom practice, inquiry-based teaching has been widely recognised as a pathway to foster students' creative thinking (for a review, see Muhamad Dah et al., 2024). Blanchard et al. (2010) defined inquiry-based teaching as comprising three activities, including asking questions, collecting data, and interpreting data. However, they found that students often did not perform all of the stages of inquiry, with some of them being given or even conducted by teachers, so they classified the inquiry process into four levels of inquiry, with lower levels indicating more teacher guidance and less student autonomy. This pattern is exemplified in Pei and Liu's (2018) study, which examined the inquiry-based teaching practices of nine Chinese lower secondary science teachers. They found that although the lessons incorporated various inquiry activities, the process remained largely teacher-directed, with students playing a passive role in learning.

Some science activities conducted in laboratories can also promote creativity. As Muhamad Dah et al. (2024) highlighted, certain laboratory teachers provide students with opportunities to engage in open-ended, inquiry-based, hands-on experiments. Such activities can offer students a sense of freedom similar to that experienced by scientists (Muhamad Dah et al., 2024). However, in practice, many school activities take the form of 'cookbook' experiments, where students follow step-by-step procedures from textbooks to reproduce pre-determined outcomes rather than constructing their own ideas through hands-on exploration (Muhamad Dah et al., 2024). For example, Zhao and Thomas (2016) found in their empirical study with 96 students in two Chinese secondary schools that students reported a lack of opportunities to undertake inquiry-based experiments. Instead, they were usually required simply to remember the procedures and conclusions of the experiments to pass their examinations. As noted by D. Newton and Newton (2009), when students saw 'inquiry' as a way of undertaking their studies by following their teachers' instructions, science classrooms were transformed into a place of re-production rather than creativity, a perspective that applies to so-called science experiments as well.

In addition to inquiry-based teaching and hands-on science experiments, other activities in science education, such as independent research projects, problem-based learning, and project-based learning, are recognised for their role in nurturing students' creativity (Bennett et al., 2018). Another noteworthy creative activity in Chinese science education is the Olympiad programme, which has been active since 1985 and is widely implemented in schools to identify and cultivate STEM talent through demanding learning content aimed at preparing for Olympiad competitions (Campbell et al., 2017). In Ren et al.'s (2012) empirical study, participation in Olympiad courses positively influenced Chinese students' creativity. These various creative activities offer Chinese students alternative pathways to experience the creative process in science education.

Creative ideas

Creative ideas emerge from students through the creative process and can manifest as creative products in the field of science (Hu & Adey, 2002). L. Newton and Newton (2010) argued that students exhibit creative ideas when they construct understandings, produce action plans, generate alternative interpretations, understand events, solve problems, or even devise lies to avoid trouble, as these ideas are novel to the individual students. To capture such manifestations, various self-report instruments have been designed to assess creativity in science learning. For example, Carson et al.'s (2005) 'Creative Achievement Questionnaire' reflects students' creative accomplishments through indicators such as science prizes, scholarships, publications, or creative problem-solving. Similarly, the 'Kaufman Domains of Creativity Scale' asks participants to report if they have performed creativity in certain science activities, such as 'taking apart machines and figuring out how they work' (Kaufman, 2012, p. 308).

Notably, Andiliou and Murphy (2010) highlighted in their review that many teachers associate creative ideas with the liberal arts (e.g. music, dance, and architecture) or hands-on activities such as drawing and painting, rather than recognising creativity in science education contexts. In Chinese schools, Mullen (2017) similarly primarily identified creative expression with activities such as artworks and traditional cultural representations, with less emphasis on creative ideas in science. Thus, there is a need for further clarification on how creative ideas manifest in science education, aiding educators and researchers in effectively identifying and nurturing creativity in this domain.

Teachers' feedback plays a crucial role in nurturing creative ideas, as it significantly impacts whether these creative ideas thrive or diminish over time (Andiliou & Murphy, 2010). In O. Hong and Song's (2020) SCC model, cognitive and emotional support from science teachers were two key components in facilitating students' creative ideas or behaviours. O. Hong and Song (2020) highlighted that teachers should actively support students' inquiry processes, pose appropriate questions, and provide positive feedback in response to their ideas. Therefore, Davies et al. (2014) concluded that teachers' formative feedback provided during the creative process was more beneficial for developing students' creativity than merely judging the final creative product.

A creative environment

Creative environments in education, as identified by Davies et al. (2013) in their systematic review, include the physical environment, resource availability, outdoor settings, pedagogical approaches, use of external environments, play-based learning, effective and flexible time use, and teacher-learner relationships. In creative science classrooms, O. Hong and Song (2020) discussed them in terms of the physical and socio-cultural environments, with the former valuing the available resources, sufficient time, and comfortable space and the latter emphasising a communication-oriented and cooperation-oriented climate. Both studies underscore the significant influence of social dynamics on creativity, particularly in classrooms with larger student numbers and typically a single teacher. In addition, Meyer and Lederman (2013) examined teachers' pedagogical characteristics that shape students' creativity in science classrooms. They emphasised the importance of balancing open-endedness with teacher expectations, fostering constructive teacher–student and peer interactions, encouraging questioning, providing clear behavioural norms, and maintaining openness to alternative ideas, thereby contributing to a creative pedagogical environment.

Further analysing Chinese science classrooms, Xu et al. (2024b) criticised the situation where laboratories were inadequate or not well served for science learning. They also pointed out the limited time allocated for students in science classrooms because of teachers' instructions, classmates' learning pace, and the curriculum's schedule. Additionally, Cheng (2011) highlighted that the pressure of examination-oriented educational systems has led to the predominance of a narrow teaching approach in many Asian classrooms, ultimately leaving no room for uncertainty and thereby hindering creativity.

Methods

Research questions

The central research question of this study is: 'What are the perspectives of science teachers on scientific creativity?'. Based on the four dimensions identified in the literature – creative students, the creative process, creative ideas, and a creative environment – this study further investigates the following four sub-questions:

RQ1: What are science teachers' perceptions of creative students?

RQ2: What are science teachers' perceptions of the creative process?

RQ3: What types of ideas do science teachers consider to be creative?

RQ4: How do environmental factors in the science classroom influence the development of scientific creativity?

Research setting and participants

This study was conducted at a public upper secondary school in China, which follows the national curriculum for grades 10–12, representative of typical upper secondary education practices in the country. The participants consisted of 16 science teachers who taught grades 10–12, including five biology teachers, seven chemistry teachers, and four physics teachers. The profiles of the interview participants are provided in Table 1. Recruitment continued until data saturation was reached, so that no new themes emerged in the interviews, and all participants consistently discussed similar themes.

Data collection

Semi-structured interviews were used to investigate science teachers' perspectives on scientific creativity. Based on the literature review, the interview mainly focused on four dimensions: creative students; the creative process; creative ideas; and a creative environment. The four dimensions were aligned sequentially with the four research

Table 1. The profiles of the interview participants.

Participant code	Gender	Age	Teaching experience	Degree	Subject	Grade
T1	Female	45	18 years	Master	Biology	10
T2	Female	28	7 years	Master	Biology	10
T3	Female	27	5 years	Master	Biology	11
T4	Male	47	26 years	Master	Biology	12
T5	Female	31	5 years	Master	Biology	12
T6	Female	39	17 years	Bachelor	Chemistry	10
T7	Female	22	1 month	Bachelor	Chemistry	10
T8	Female	23	1 year	Bachelor	Chemistry	11
T9	Male	45	23 years	Master	Chemistry	11
T10	Female	50	29 years	Master	Chemistry	11
T11	Male	27	6 years	Master	Chemistry	12
T12	Female	44	18 years	Master	Chemistry	12
T13	Female	34	12 years	Master	Physics	11
T14	Male	55	32 years	Master	Physics	11
T15	Female	24	3 years	Bachelor	Physics	12
T16	Male	30	8 years	Master	Physics	12

Note: ‘T’ indicates ‘Teacher’. ‘T1’ (etc) refers to Teacher 1 (etc) to ensure anonymity.

questions: RQ1 concerned creative students, RQ2 the creative process, RQ3 creative ideas, and RQ4 the creative environment. Each section of the interview schedule contained questions corresponding to these four research questions. A detailed mapping of interview questions to research questions is provided in the Supplementary Material. The initial interview schedules were developed by the three authors and piloted with two Chinese science teachers to ensure intelligibility. These two teachers also taught in the participating school. The final interview questions were very similar to those in the initial version. It is important to note that while the interview questions were informed by the literature review and initially structured around these four dimensions, we ensured the openness of the interviews to allow for the emergence of new themes that might not have been anticipated by the literature.

The study received ethics approval from University College London. Before each interview, a consent form was distributed to each potential interviewee. After obtaining consent, all interviews were conducted face-to-face at the school. Data were collected via audio recording. The duration of the interviews ranged from 15 to 44 min, with a mean duration of 29 min. The transcriptions underwent a thorough cleaning process. Any unclear or inaudible sections were revisited and clarified with the interviewees to ensure accuracy. Once the transcripts were finalised, the data were prepared for coding.

Data analysis

The interviews were analysed using reflexive thematic analysis (Braun & Clarke, 2022). This approach acknowledges that thematic analysis is a values-driven and situated practice, influenced by the subjective perspectives of researchers who engage with the process both practically and theoretically. The analysis was conducted through the following steps:

Initially, the first author manually transcribed all interviews to ensure familiarity with the data. Subsequently, initial codes were generated and applied to the data set. These codes were then grouped into themes based on their content. The main themes were reviewed and refined, followed by the identification and refinement of sub-themes.

The final themes were coded inductively, resulting in the identification of four themes – creative students, the creative process, creative ideas, and a creative environment – which, while initially informed by the literature, were ultimately grounded in the data and reflected the participants' perspectives. Sub-themes and codes were also coded inductively. Further details are provided in Table 2, where the four themes and their sub-themes are presented. The four themes were aligned sequentially with the four research questions: Theme 1 'Creative students' addressed RQ1; Theme 2 'The creative process' addressed RQ2; Theme 3 'Creative ideas' addressed RQ3; and Theme 4 'A creative environment' addressed RQ4. Together, these themes capture teachers' overall perspectives on scientific creativity.

To ensure the reliability and validity of the coding process, triangulation was employed. After the initial coding by the first author in Mandarin, the initial themes, sub-themes, codes, and coding examples were translated into English and sent to the other two authors for their review. Throughout this process, frequent comparisons and discussions in English were held to identify and resolve any discrepancies, ultimately resulting in a consensus among the three authors to ensure the reliability of the coding results. Additionally, the first author's fieldwork experiences – living in the school and closely observing and interacting with the science teachers – further validated the relevance and robustness of the identified themes, sub-themes, and codes in addressing the research questions.

Saturation was deemed to have been achieved when no new themes emerged from the data after iterative coding rounds. Theoretical saturation was reached as the refined themes consistently reflected the underlying theoretical concepts related to scientific creativity, as outlined in the literature.

MAXQDA 2020, a qualitative data analysis software, was used to organise, code, and conduct a thematic analysis of the interview data (Rädiker & Kuckartz, 2020). To clarify the terms used in the following results: 'most' means ≥12 teachers, 'many' means 8–11 teachers, 'some' means 6–7 teachers, 'several' means 4–5 teachers, and 'a few' means 3 teachers.

Results

The analysis of interview data revealed that science teachers' perspectives on scientific creativity are organised around four central themes: creative students, the creative process, creative ideas, and a creative environment. Within each of these themes,

Table 2. The themes and sub-themes for the teachers' perspectives on scientific creativity.

Theme	Sub-theme
Creative students	The features of creative students
	The relationship between academic performance and scientific creativity
The creative process	Inquiry-based teaching process in science classrooms
	Science teachers' perspectives on inquiry-based teaching
	Challenges in implementing inquiry-based teaching
	Different approaches to conducting science experiments
	The creative process at the three levels of the curriculum
Creative ideas	The perspectives on creative ideas
	Teachers' feedback approaches to creative ideas
	Challenges in dealing with creative ideas
A creative environment	Contributing factors
	Inhibiting factors

several sub-themes emerged to offer new insights into how teachers perceive and foster scientific creativity in science education.

Creative students

This section addresses RQ1: What are science teachers' perceptions of creative students? The teachers initially shared their views on the features of creative students, with Table 3 showing the number of science teachers who mentioned the corresponding components. Illustrative quotations are provided in the Supplementary Material.

The relationship between academic performance and scientific creativity was also discussed with teachers. Many agreed that students with good academic performance were more likely to exhibit high levels of scientific creativity. As T3 explained:

> Students with higher academic performance are exposed to a wide range of information, have broad reading, and engage more with scientific content, so they may exhibit more creativity.

However, several teachers questioned this relationship between academic performance and scientific creativity, noting differing influencing factors. T4 believed that:

> Creativity is primarily about the ability to delve deeply into topics, curiosity, and interest. However, academic performance is influenced by factors, such as whether the student is obedient and whether they follow through with their studies, and it largely depends on study habits.

Furthermore, two teachers discussed how students' performance in scientific creativity and academic achievement might vary based on task situations. T14 noted:

> Academic performance involves closed-ended and well-structured questions. However, addressing real-world issues often requires divergent thinking, especially for ill-structured problems that contain uncertainties and are not fixed in structure.

The creative process

This section addresses RQ2: What are science teachers' perceptions of the creative process? Many teachers agreed that inquiry-based teaching and science experiments

Table 3. The number of science teachers reporting on components of creative students.

	Component	Science teachers ($N = 16$)
Thinking styles	Divergent thinking	6
	Logical reasoning	6
	Independent thinking	5
	Active thinking	4
Learning abilities	Hands-on practical ability	6
	Communication ability	4
	Inquiry ability	2
	Teamwork ability	1
Subject interest	Subject interest	4
Personality	Curiosity	3
	Being energetic	2
	Being outgoing	2
Knowledge	Fundamental subject knowledge	3
	Broad knowledge	2

were key components of the creative process. They described the inquiry process as consisting of five different stages: establishing contexts; generating questions; formulating hypotheses; conducting investigation; and drawing conclusions. However, in practice, these stages were often implemented under strong teacher guidance with limited opportunities for student autonomy, thereby reducing support for the creative process. For example, T13 regarded her physics classes as inquiry-based, but her account reveals a teacher-directed sequence that guided students step by step towards predetermined outcomes, reflecting a limited understanding of effective inquiry-based pedagogy. As she explained:

> First, I will present an example from a life phenomenon and guide them to find out the problem. Once they have identified it, I will let them make guesses about what the outcome might be. Then, guide them to explore further, either through theory or experiments, to see if their guesses match the results. In the end, this method leads them to a conclusion.

Similarly, many teachers adopted fragmented approaches to the inquiry process, with particular stages being simplified or omitted. Specifically, they directly provided questions, typically sourced from textbooks or generated by the teachers themselves, and skipped the hypothesis formulation stage, proceeding straight to the investigation. The investigation stage often involved either theoretical deduction, characterised by 'teachers posing questions for students to answer' (T14), or experimental deduction, involving 'conducting experiments in classrooms or laboratories with pre-determined steps' (T3). The final conclusions were derived from the previous results, incorporating activities where 'students present and discuss their findings' (T15) and 'receive feedback or evaluation from others' (T11).

Furthermore, several teachers equated inquiry-based teaching merely with question-based teaching, where 'the teacher incorporates more question-based segments during the lesson' (T13). Others described it as 'fake inquiry', where 'students simply repeat the inquiry process provided in the textbooks' (T4).

Two primary challenges were also highlighted in implementing inquiry-based teaching. First, tight teaching schedules left little time for student-led inquiry, as 'all new content should be completed in the first two years' (T10). Secondly, some teachers worried it might hinder students' academic performance, since 'inquiry-based teaching does not directly impart knowledge to students or teach them how to answer questions' (T12).

Science experiments were also identified by science teachers as a key context in which the creative process could be demonstrated, both in classrooms and science laboratories, with teachers distinguishing between two different types: demonstration experiments and hands-on experiments. Demonstration experiments, conducted in regular classrooms through 'teacher demonstrations or video demonstrations' (T6), dominated science experiments, as 'they can save time and explain every knowledge point involved in these experiments' (T8). Hands-on experiments were explicitly stated in the textbook to be completed by students in the laboratory, and often the teachers would 'first have a theory class and then go to the laboratory for a hands-on class' (T15). As T5 noted, 'These experiments are verification experiments and rarely inquiry-based'. Thus, both demonstration and verification experiments, which were highly procedural, tended to limit students' opportunities to engage in the creative process.

Inquiry-based teaching and science experiments were conducted in the basic level courses, which were available to all students every weekday. Many teachers also highlighted other science activities in the school, such as elective courses, project-based learning, and Olympiad subject competition courses, which allowed for student creativity outside regular science learning. These activities were categorised by the school into three levels: basic, expanded, and excellent. While basic courses were constrained by time and examination pressure, the expanded and excellent levels offered greater potential for fostering creativity.

At the expanded level, elective courses were offered weekly (90 min per session), allowing students to choose subjects based on interest. For example, 48 grade 10 students selected a biology elective, which included activities like 'identifying plants in a local park or exploring human body using the adult human skeleton' (T1). Project-based learning also occurred at this level, primarily during winter and summer breaks. For instance, chemistry projects included 'exploring iron content in food and creating batteries' (T11), while physics projects involved a 'water rocket project' (T16).

At the excellent level, Olympiad subject competition courses were provided to those exceptionally performing students with a strong interest in science. T2, responsible for the biology Olympiad in the school, mentioned that 'the curriculum content can be equivalent to four years of university-level coursework for a biology major'. These courses were also personalised for students, with 'the majority of the content requiring self-study' (T16).

Creative ideas

This section addresses RQ3: What types of ideas do science teachers consider to be creative? Science teachers outlined various expressions of what they perceived as creative ideas within the science classroom. These creative ideas can be categorised into four different forms. First, most teachers believed that creative ideas involved knowledge divergence, transfer or integration. T16 recounted an instance where a student created a comprehensive question that integrated material from the entire course, incorporating over ten key concepts: 'It demonstrates a successful transformation of knowledge into personal understanding' (T16). Secondly, some teachers viewed those independent student-generated questions as creative ideas, as 'these questions can reflect creative thinking' (T4). A third manifestation included science experiments, modelling or specimen production. For instance, T6 cited experiments on fluorescent reactions conducted by her students, while T7 highlighted the creative use of small magic tricks in chemistry experiments. The final form of creative ideas involved bridging theory with practical application to solve real-life problems. As T3, a biology teacher, stressed: 'Biology knowledge would be useful when applied in real-life scenarios' (T3).

In response to these creative ideas, the teachers also shared their approaches to providing feedback. A common approach mentioned by most teachers was supporting students in advancing and testing creative ideas. For example, T16 described using professional software to visualise a student's hand-drawn creative question and sharing it with the whole class for discussion. Some teachers also praised students' creative ideas or encouraged students to show and share their creative ideas in public.

Faced with these creative ideas, teachers encountered two challenges in the science classroom. First, evaluating creative ideas required a strong subject knowledge base;

without it, 'teachers might not be able to discern whether an idea is nonsensical or creative' (T3). Secondly, some creative ideas that were not promptly addressed during class might be overlooked thereafter, as 'students did not revisit these ideas after class' (T8).

A creative environment

This section addresses RQ4: How do environmental factors in the science classroom influence the development of scientific creativity? A creative environment needs to foster contributing factors that enhance students' scientific creativity and consider inhibiting factors that may limit it. In response to the fourth sub-question on environmental influences, Table 4 shows these factors and the number of science teachers who mentioned them.

The most frequent contributing factor mentioned by the teachers was inquiry-based teaching, while the most significant inhibiting factor was '灌输' ('*guànshū*'), defined as a teaching approach of mere transmission of facts:

> The teaching approach, whether it is *guànshū* or inquiry-based teaching, results in different outcomes. Inquiry-based teaching may be relatively more open and have a positive impact on students' creativity. The *guànshū* approach might be more efficient and grade-oriented but does not focus on ability development, which may hinder creativity. (T4)

The second most frequently mentioned contributing factor was a supportive classroom environment, characterised by communicative discussion, cooperation, openness, democracy, and teachers' encouraging attitudes. In such an atmosphere, as T3 shared, 'Students feel more comfortable voicing their doubts in class'. However, many teachers acknowledged that their science classrooms were burdened by heavy study loads and examination pressure. Students were required to complete five textbooks each for biology and chemistry, and six for physics within the first two years, leaving the third year for review. Given this pressure, T15 remarked that creative activities were often viewed as inefficient: 'With six major subjects, the workload is enormous. Students are either unwilling or objectively unable to spend time on creative tasks'.

Discussion

The findings of this study are discussed in relation to the central research question – 'What are the perspectives of science teachers on scientific creativity?' – and its four

Table 4. Scientific creativity: teacher reported contributing and inhibiting factors.

		Science teachers (*N* = 16)
Contributing factors	Inquiry-based teaching	12
	Supportive classroom atmosphere	11
	Hands-on experiments	7
	A diverse choice of courses and activities	6
	Family support	3
	Using social resources	3
	Well-equipped laboratories	2
Inhibiting factors	Teaching approach of mere transmission of facts	10
	Study burden and examination pressure	10
	Students' limited rest time	4
	Insufficient laboratory equipment and personnel	4
	Families' economic hardship	1
	Quiet classroom atmosphere	1

sub-questions. Specifically, the discussion is organised around teachers' perceptions of creative students, the creative process, creative ideas, and a creative environment, offering a framework of teachers' understanding of scientific creativity at upper secondary school level. Each theme corresponds directly to one sub-question, and each sub-question is analysed and answered through teachers' teaching experiences, perspectives, and the challenges they encountered in fostering scientific creativity.

Creative students

In relation to the first sub-question, this study revealed that science teachers perceived creative Chinese secondary science students as possessing specific thinking styles, learning abilities, subject interests, personalities, and knowledge. These findings, while broadly aligned with Sternberg's (2018) investment theory of creativity and Andiliou and Murphy's (2010) framework of teachers' beliefs, extend this literature by providing new insights into how teachers conceptualise creative students in Chinese science classrooms. For example, logical reasoning as a thinking style highlights the role of rationality in scientific creativity (Xu et al., 2024a). The identification of hands-on practical ability further underscores the value of experimental competence in science learning (Muhamad Dah et al., 2024). High energy helps students persist with creative tasks despite academic pressure (Wu et al., 2022), while an outgoing personality enables them to express ideas confidently in typically quiet, overcrowded classrooms (Ha & Li, 2014). Furthermore, both fundamental and broad subject knowledge – emphasised by examination-oriented education – remain essential for supporting scientific creativity (Hu & Adey, 2002). These findings further suggest that nurturing creative students requires multifaceted support. Science teachers should provide rich subject knowledge, cultivate diverse thinking styles, foster students' learning abilities and creative character traits, and motivate students' subject interests in science learning.

This study also found that many science teachers perceive high-achieving students as more scientifically creative. This view aligns with previous research on teachers' implicit theories of creativity, where creativity is often linked to high intelligence or strong academic performance (Aljughaiman & Mowrer-Reynolds, 2005; Guo et al., 2021). However, this study also revealed alternative perspectives, highlighting that academic performance and scientific creativity are seen as distinct and influenced by a variety of factors. These findings encourage teachers to critically reflect on whether they equate high academic achievement with creativity. A more holistic understanding of creativity – as discussed earlier, creative students demonstrate strengths in multiple areas – can help teachers better identify and support creative potential across a wider range of students.

The creative process

With regard to perceptions of the creative process, the participating teachers believed that creativity was enhanced by practices such as inquiry-based teaching, science experiments, elective courses, project-based learning, and participation in Olympiad subject competition courses.

This study found that science teachers conceptualised inquiry-based teaching as a form of creative process, recognising its value in fostering students' creativity in science classrooms. They described inquiry-based teaching as involving five stages: establishing contexts; generating questions; formulating hypotheses; conducting investigations; and drawing conclusions. Although this sequence reflects common activities associated with inquiry, it was largely teacher-directed and resembled 'structured inquiry' (Blanchard et al., 2010), where both the question and method are provided to students, limiting their autonomy to pose their own questions or design investigative procedures. Additionally, several interviewed teachers equated inquiry-based teaching with question-based teaching and recognised the issue of 'fake inquiry'. The former view reveals a misunderstanding that inquiry is primarily about asking questions. The latter reduces students' roles to merely replicating a prescribed process – an issue also identified in Pei and Liu's (2018) study, where Chinese students were given the question, method, and even the final answer in so-called inquiry-based science classrooms. Therefore, this study reveals that teachers' 'inquiry' practices in science classrooms did not adequately capture the features of a genuinely creative inquiry process, which is characterised by divergent thinking and flexible, non-linear pathways (Cirkony, 2023; Lubart, 2001).

Addressing this gap highlights the need for professional development that helps teachers move beyond simplified or overly procedural views of inquiry to design inquiry-based teaching that empowers students to take the lead, engage autonomously, and demonstrate their scientific creativity throughout the inquiry process. Furthermore, this study identifies two key challenges related to inquiry-based teaching, namely time constraints and concerns about its impact on academic performance, which aligns with previous research (Al-Abdali & Al-Balushi, 2016; Li, 2019). These factors may help explain why teachers tend to favour more structured, teacher-directed, and less time-intensive approaches over open-ended inquiry, but also underscore the need to develop inquiry-based teaching strategies that are both efficient and effective in overcoming these challenges.

Although science practical work is ideally designed to be hands-on and inquiry-based, reflecting the creative process (Muhamad Dah et al., 2024), the participating teachers reported that their classroom practices were typically dominated by demonstration experiments, with hands-on tasks mainly used for verification purposes. These features were also observed in Zhao and Thomas's (2016) study of science experiments in Chinese science education, which highlighted the procedural, manipulative, and rigid nature of such practices. Thus, science teachers should consider how to better guide students in conducting science experiments, enabling them to engage in the creative process as 'scientists' and experience a sense of autonomy and freedom (Muhamad Dah et al., 2024).

The inquiry-based teaching and science experiments identified in this study were classified as basic-level activities, while elective courses and project-based learning represented expanded-level examples of the creative process. Olympiad subject competition courses were regarded as excellent-level demonstrations of creativity. These expanded-level and excellent-level activities typically provide students with personalised learning experiences, broaden their scientific knowledge, and offer hands-on opportunities (Cavallo & Laubach, 2001; J.-C. Hong et al., 2013; Ren et al., 2012), thereby enhancing their motivation in the creative process. Moreover, these activities constitute a 'three-level curriculum' (comprising basic-level, expanded-level, and excellent-level activities), in which students engage with scientific content of varying difficulty and receive differing levels of teacher support. By balancing examination pressure, tight schedules, and the need for creativity, this curriculum offers a systematic yet flexible model for promoting the creative process in other similar schools.

Creative ideas

Addressing the third sub-question on creative ideas, the findings showed that science teachers recognised four manifestations of creative ideas in science learning: knowledge divergence, transfer or integration; independent student-generated questions; science experiments, modelling or specimen production; and the application of theory to practical real-life problem solving. L. Newton and Newton (2010) argued that creative ideas are closely linked to the process of knowledge construction or problem solving. Our study extends this understanding by illustrating concrete ways in which students' creative ideas manifest in science classrooms. These four forms offer a useful lens for teachers to notice and value students' creative expressions in science learning.

Teachers in this study also provided various feedback approaches to these creative ideas. The most frequently used approach was supporting students in advancing and testing creative ideas, followed by praising students' creative ideas. These approaches align with O. Hong and Song's (2020) suggestions that science teachers should provide cognitive support (e.g. refining ideas) and emotional support (e.g. encouragement) to nurture creative ideas. However, teachers raised concerns about limited subject knowledge and time constraints, which hindered their ability to recognise and respond to students' creative ideas during lessons. This further underscores the demands that creativity education places on teacher education, requiring both deeper and broader subject knowledge as well as targeted teaching strategies.

A creative environment

In response to the fourth sub-question on environmental influences, the findings indicated that teachers considered a range of factors to be critical in either fostering or inhibiting students' scientific creativity. Contributing factors include inquiry-based teaching, a supportive classroom environment, more hands-on experiments, a diverse choice of courses and activities, family support, use of social resources, and good laboratory equipment. Conversely, inhibiting factors encompassed the teaching approach of mere transmission of facts, heavy study loads and examination pressure, limited rest time for students, and insufficient laboratory equipment and personnel. The teachers' perspectives on a creative environment are partly consistent with existing science classroom models (O. Hong & Song, 2020; Xu et al., 2024b) but further highlight context-specific factors by considering both the local examination-oriented educational culture and the broader socio-cultural context.

Specifically, most teachers in this study recommended inquiry-based teaching as the most significant contributing factor, while the mere transmission of facts emerged as the most significant inhibiting factor. The key distinction between these two approaches lies in the nature of the teaching environment they create. Inquiry-based teaching offers an open and exploratory space where students are encouraged to question, investigate, and share diverse ideas, thereby respecting and nurturing their autonomy and creativity (Muhamad Dah et al., 2024). In contrast, the mere transmission of facts tends to emphasise the delivery of predetermined knowledge, enabling students to access standard answers more efficiently but positioning them as passive recipients of information (Qian & Li, 2024). These contrasting views thus also reflect teachers' recognition of the central role of pedagogy in shaping a creative environment and suggest that adopting pedagogical strategies that promote openness, student autonomy, and creative exploration is essential for developing students' creativity.

The second most frequently mentioned contributing factor was a supportive classroom environment, characterised by communicative discussion, cooperation, openness, democracy, and teachers' encouraging attitudes – elements aligned with O. Hong and Song's (2020) SCC model. These findings thus encourage educators to intentionally cultivate supportive interpersonal atmospheres in their science classrooms. In contrast, teachers criticised environments dominated by heavy workloads, examination pressure, and insufficient rest, which limit students' opportunities for creative engagement. These constraints stem largely from China's examination-oriented educational system (Niu & Sternberg, 2003) and are similarly observed in other East Asian societies, such as South Korea (M. Hong & Kang, 2010). Insights from these science teachers, who directly experience the pressures of a heavily examination-oriented system, highlight the urgent need for policymakers to address systemic issues. Efforts should be made to gradually reform the examination-oriented culture, alleviate students' academic pressure, and thereby enable teachers to create more creative science classrooms.

Conclusion and limitations

This study investigated the perspectives of science teachers on scientific creativity in an examination-oriented educational system, focusing on four dimensions: creative students, the creative process, creative ideas, and a creative environment. The findings from these dimensions provide valuable insights and practical guidance for researchers, teachers, and policymakers aiming to foster scientific creativity in China and similar educational contexts.

However, this study involved only sixteen participants from a single urban public upper secondary school in China, which limits the generalisability of the findings. Previous studies have shown that school location in China (e.g. urban vs. rural) can influence creative teaching practices (Huang et al., 2019), and that school type (e.g. public vs. private) may affect teacher autonomy (Poole, 2024). Therefore, future research should include larger and more diverse samples from multiple schools and regions to enhance representativeness and potentially reveal new insights. Additionally, as this study did not include student perspectives, incorporating students in future research would provide a more comprehensive understanding of scientific creativity in science classrooms.

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Ethics statement

The present study was approved by the Research Ethics Committee of the University College London, Institute of Education. The UCL Data Protection Registration Number is Z6364106/2023/08/23 for social research.

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References

Al-Abdali, N. S., & Al-Balushi, S. M. (2016). Teaching for creativity by science teachers in grades 5–10. *International Journal of Science and Mathematics Education*, *14*(S2), 251–268. https://doi.org/10.1007/s10763-014-9612-3

Aljughaiman, A., & Mowrer-Reynolds, E. (2005). Teachers' conceptions of creativity and creative students. *The Journal of Creative Behavior*, *39*(1), 17–34. https://doi.org/10.1002/j.2162-6057.2005.tb01247.x

Amabile, T. M., & Pratt, M. G. (2016). The dynamic componential model of creativity and innovation in organizations: Making progress, making meaning. *Research in Organizational Behavior*, *36*, 157–183. https://doi.org/10.1016/j.riob.2016.10.001

Andiliou, A., & Murphy, P. K. (2010). Examining variations among researchers' and teachers' conceptualizations of creativity: A review and synthesis of contemporary research. *Educational Research Review*, *5*(3), 201–219. https://doi.org/10.1016/j.edurev.2010.07.003

Bennett, J., Dunlop, L., Knox, K. J., Reiss, M. J., & Torrance Jenkins, R. (2018). Practical independent research projects in science: A synthesis and evaluation of the evidence of impact on high school students. *International Journal of Science Education*, *40*(14), 1755–1773. https://doi.org/10.1080/09500693.2018.1511936

Bereczki, E. O., & Kárpáti, A. (2018). Teachers' beliefs about creativity and its nurture: A systematic review of the recent research literature. *Educational Research Review*, *23*, 25–56. https://doi.org/10.1016/j.edurev.2017.10.003

Blanchard, M. R., Southerland, S. A., Osborne, J. W., Sampson, V. D., Annetta, L. A., & Granger, E. M. (2010). Is inquiry possible in light of accountability?: A quantitative comparison of the relative effectiveness of guided inquiry and verification laboratory instruction: Guided inquiry and verification laboratory instruction. *Science Education*, *94*(4), 577–616. https://doi.org/10.1002/sce.20390

Braun, V., & Clarke, V. (2022). *Thematic analysis: A practical guide*. SAGE.

Campbell, J., Cho, S., & Tirri, K. (2017). Mathematics and science Olympiad studies: The outcomes of Olympiads and contributing factors to talent development of Olympians. *International Journal for Talent Development and Creativity*, *5*, 49–60. https://eric.ed.gov/?id=EJ1301497

Carson, S. H., Peterson, J. B., & Higgins, D. M. (2005). Reliability, validity, and factor structure of the creative achievement questionnaire. *Creativity Research Journal*, *17*(1), 37–50. https://doi.org/10.1207/s15326934crj1701_4

Cavallo, A. M. L., & Laubach, T. A. (2001). Students' science perceptions and enrollment decisions in differing learning cycle classrooms. *Journal of Research in Science Teaching*, *38*(9), 1029–1062. https://doi.org/10.1002/tea.1046

Cheng, V. M. Y. (2010). Tensions and dilemmas of teachers in creativity reform in a Chinese context. *Thinking Skills and Creativity*, *5*(3), 120–137. https://doi.org/10.1016/j.tsc.2010.09.005

Cheng, V. M. Y. (2011). Infusing creativity into Eastern classrooms: Evaluations from student perspectives. *Thinking Skills and Creativity*, *6*(1), 67–87. https://doi.org/10.1016/j.tsc.2010.05.001

Cirkony, C. (2023). Flexible, creative, constructive, and collaborative: The makings of an authentic science inquiry task. *International Journal of Science Education*, *45*(17), 1440–1462. https://doi.org/10.1080/09500693.2023.2213384

Davies, D., Jindal-Snape, D., Collier, C., Digby, R., Hay, P., & Howe, A. (2013). Creative learning environments in education – A systematic literature review. *Thinking Skills and Creativity*, *8*, 80–91. https://doi.org/10.1016/j.tsc.2012.07.004

Davies, D., Jindal-Snape, D., Digby, R., Howe, A., Collier, C., & Hay, P. (2014). The roles and development needs of teachers to promote creativity: A systematic review of literature. *Teaching and Teacher Education*, *41*, 34–41. https://doi.org/10.1016/j.tate.2014.03.003

Gralewski, J. (2019). Teachers' beliefs about creative students' characteristics: A qualitative study. *Thinking Skills and Creativity*, *31*, 138–155. https://doi.org/10.1016/j.tsc.2018.11.008

Guo, J., Tong, Y., & Pang, W. (2021). Teachers' perceptions of students' creativity in China's classrooms: The role of students' academic achievement and misbehaviors. *The Journal of Creative Behavior*, *55*(1), 228–240. https://doi.org/10.1002/jocb.448

Ha, P. L., & Li, B. (2014). Silence as right, choice, resistance and strategy among Chinese 'Me Generation' students: Implications for pedagogy. *Discourse: Studies in the Cultural Politics of Education*, *35*(2), 233–248. https://doi.org/10.1080/01596306.2012.745733

Hetherington, L., Chappell, K., Ruck Keene, H., Wren, H., Cukurova, M., Hathaway, C., Sotiriou, S., & Bogner, F. (2020). International educators' perspectives on the purpose of science education and the relationship between school science and creativity. *Research in Science & Technological Education*, *38*(1), 19–41. https://doi.org/10.1080/02635143.2019.1575803

Hong, J.-C., Chen, M.-Y., & Hwang, M.-Y. (2013). Vitalizing creative learning in science and technology through an extracurricular club: A perspective based on activity theory. *Thinking Skills and Creativity*, *8*, 45–55. https://doi.org/10.1016/j.tsc.2012.06.001

Hong, M., & Kang, N.-H. (2010). South Korean and the US secondary school science teachers' conceptions of creativity and teaching for creativity. *International Journal of Science and Mathematics Education*, *8*(5), 821–843. https://doi.org/10.1007/s10763-009-9188-5

Hong, O., & Song, J. (2020). A componential model of Science Classroom Creativity (SCC) for understanding collective creativity in the science classroom. *Thinking Skills and Creativity*, *37*, 100698. https://doi.org/10.1016/j.tsc.2020.100698

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

Huang, X., Chi-Kin Lee, J., & Dong, X. (2019). Mapping the factors influencing creative teaching in mainland China: An exploratory study. *Thinking Skills and Creativity*, *31*, 79–90. https://doi.org/10.1016/j.tsc.2018.11.002

Kaufman, J. C. (2012). Counting the muses: Development of the Kaufman Domains of Creativity Scale (K-DOCS). *Psychology of Aesthetics, Creativity, and the Arts*, *6*(4), 298–308. https://doi.org/10.1037/a0029751

Ke, Z., & Liang, C. (2023). Research on the relationship between exam-oriented education and students' creativity. *Journal of East China Normal University (Education Science)*, *4*, 72–82. https://doi.org/10.16382/j.cnki.1000-5560.2023.04.006

Kirişçi, N. (2023). Teacher beliefs about creativity and creative student characteristics: Teachers' perspectives on Turkish gifted students. *Education 3-13*, *53*, 1–14. https://doi.org/10.1080/03004279.2023.2272721

Kupers, E., Lehmann-Wermser, A., McPherson, G., & van Geert, P. (2019). Children's creativity: A theoretical framework and systematic review. *Review of Educational Research*, *89*(1), 93–124. https://doi.org/10.3102/0034654318815707

Li, G. (2019). *An empirical study on the influence of inquiry-based teaching on students' science achievement and attitudes towards science learning – Evidence from PISA2015 Beijing-Shanghai-Jiangsu-Guangzhou (China) data analysis* (in Chinese) [Unpublished postdoctoral research]. Beijing Normal University.
Liu, L., & Zaman, U. (2025). From leadership to innovation: Psychological mechanisms behind teacher creativity in physical education. *Acta Psychologica*, *255*, 104965. https://doi.org/10.1016/j.actpsy.2025.104965
Lubart, T. I. (2001). Models of the creative process: Past, present and future. *Creativity Research Journal*, *13*(3-4), 295–308. https://doi.org/10.1207/S15326934CRJ1334_07
McLure, F., Won, M., & Treagust, D. F. (2024). Science teachers' understanding of creative thinking and how to foster it as mandated by the Australian curriculum. *Journal of Science Teacher Education*, *35*(5), 524–543. https://doi.org/10.1080/1046560X.2024.2313882
Meyer, A. A., & Lederman, N. G. (2013). Inventing creativity: An exploration of the pedagogy of ingenuity in science classrooms. *School Science and Mathematics*, *113*(8), 400–409. https://doi.org/10.1111/ssm.12039
Muhamad Dah, N., Mat Noor, M. S. A., Kamarudin, M. Z., & Syed Abdul Azziz, S. S. (2024). The impacts of open inquiry on students' learning in science: A systematic literature review. *Educational Research Review*, *43*, 100601. https://doi.org/10.1016/j.edurev.2024.100601
Mullen, C. A. (2017). Creativity in Chinese schools: Perspectival frames of paradox and possibility. *International Journal of Chinese Education*, *6*(1), 27–56. https://doi.org/10.1163/22125868-12340073
Mullet, D. R., Willerson, A., N. Lamb, K., & Kettler, T. (2016). Examining teacher perceptions of creativity: A systematic review of the literature. *Thinking Skills and Creativity*, *21*, 9–30. https://doi.org/10.1016/j.tsc.2016.05.001
Newton, D., & Newton, L. (2009). Some student teachers' conceptions of creativity in school science. *Research in Science & Technological Education*, *27*(1), 45–60. https://doi.org/10.1080/02635140802658842
Newton, L., & Newton, D. (2010). Creative thinking and teaching for creativity in elementary school science. *Gifted and Talented International*, *25*(2), 111–124. https://doi.org/10.1080/15332276.2010.11673575
Niu, W., & Sternberg, R. J. (2002). Contemporary studies on the concept of creativity: The East and the West. *The Journal of Creative Behavior*, *36*(4), 269–288. https://doi.org/10.1002/j.2162-6057.2002.tb01069.x
Niu, W., & Sternberg, R. J. (2003). Societal and school influences on student creativity: The case of China. *Psychology in the Schools*, *40*(1), 103–114. https://doi.org/10.1002/pits.10072
Nursiwan, W. A., & Hanri, C. (2023). Relationship between level of scientific creativity and scientific attitudes among prospective chemistry teachers. *International Journal of Evaluation and Research in Education*, *12*(1), 174–179. https://doi.org/10.11591/ijere.v12i1.22852
OECD. (2022). *Thinking outside the box: The PISA 2022 creative thinking assessment*. Retrieved July 3, 2024, from https://www.oecd.org/en/topics/sub-issues/creative-thinking/pisa-2022-creative-thinking.html
Pei, X., & Liu, X. (2018). What happens in scientific inquiry in middle school classroom: An empirical study based on multiple cases. *Journal of East China Normal University (Education Science)*, *36*(4), 107–122, 165–166 (in Chinese).
Poole, A. (2024). The teacher as designer, scientist and technician: Positioning private school teachers in China as post-performative teachers. *Educational Review*, *76*(7), 1898–1916. https://doi.org/10.1080/00131911.2024.2302414
Qian, J., & Li, Q. (2024). How 'examination-oriented teaching affects the development of students' creativity: An empirical analysis based on SSES data. *Journal of Schooling Studies*, *21*(4), 59–74 (in Chinese).
Rädiker, S., & Kuckartz, U. (2020). *Focused analysis of qualitative interviews with MAXQDA*. MaxQDA Press. https://doi.org/10.36192/978-3-948768072
Ren, F., Li, X., Zhang, H., & Wang, L. (2012). Progression of Chinese students' creative imagination from elementary through high school. *International Journal of Science Education*, *34*(13), 2043–2059. https://doi.org/10.1080/09500693.2012.709334

Rhodes, M. (1961). An analysis of creativity. *The Phi Delta Kappan*, *42*(7), 305–310. JSTOR.
Simonton, D. K. (2003). Scientific creativity as constrained stochastic behavior: The integration of product, person, and process perspectives. *Psychological Bulletin*, *129*(4), 475–494. https://doi.org/10.1037/0033-2909.129.4.475
So, K., & Hu, Y. (2019). Understanding creativity in an Asian school context: Korean teachers' perspectives. *Thinking Skills and Creativity*, *33*, 100573. https://doi.org/10.1016/j.tsc.2019.100573
Sternberg, R. J. (1999). *Handbook of creativity*. Cambridge University Press.
Sternberg, R. J. (2018). A triangular theory of creativity. *Psychology of Aesthetics, Creativity, and the Arts*, *12*(1), 50–67. https://doi.org/10.1037/aca0000095
Wang, Y. (2025). Overworked and under-creative: Teacher workload, time allocation, and creative pedagogy in Chinese secondary schools-evidence from PISA 2022. *Teaching and Teacher Education*, *160*, 105039. https://doi.org/10.1016/j.tate.2025.105039
Wu, X., Ma, X., & Luo, X. (2022). Can less be more? Effects of study load on science achievement among Chinese eighth-grade students. *Studies in Educational Evaluation*, *75*, 101219. https://doi.org/10.1016/j.stueduc.2022.101219
Xu, S., Reiss, M. J., & Lodge, W. (2024a). Comprehensive scientific creativity assessment (C-SCA): A new approach for measuring scientific creativity in secondary school students. *International Journal of Science and Mathematics Education*, *23*, 1–27. https://doi.org/10.1007/s10763-024-10469-z
Xu, S., Reiss, M. J., & Lodge, W. (2024b). The development of an analytical model for science classroom creativity in China. *Research in Science & Technological Education*, *43*, 1–26. https://doi.org/10.1080/02635143.2024.2377265
Yazhuan, L., Qing, Z., & Yugui, Z. (2010). An investigation into sources of stress among high school chemistry teachers in China. *Procedia – Social and Behavioral Sciences*, *9*, 1658–1665. https://doi.org/10.1016/j.sbspro.2010.12.382
Yi, X. (2008). *Creativity, efficacy and their organizational, cultural influences* [Doctoral dissertation]. Freie University Berlin. https://refubium.fu-berlin.de/handle/fub188/11001
Zhao, Z., & Thomas, G. P. (2016). Mainland Chinese students conceptions of learning science: A phenomenographic study in Hebei and Shandong Provinces. *International Journal of Educational Research*, *75*, 76–87. https://doi.org/10.1016/j.ijer.2015.11.008
Zhou, J., Shen, J., Wang, X., Neber, H., & Johji, I. (2013). A cross-cultural comparison: Teachers' conceptualizations of creativity. *Creativity Research Journal*, *25*(3), 239–247. https://doi.org/10.1080/10400419.2012.730006