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Pedagogical Approaches to Inculcate Scientific Creativity among Secondary Students

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Abstract

This research was conducted to explore the teaching and learning approaches that facilitate the development of students' scientific creativity traits. This in-depth research was conducted due to the dissatisfaction in creativity levels among the school students. This research adopted a qualitative approach with a case study design. It involved 4 science teachers in a secondary school as informants. The data was collected by interview method. Data showed teaching and learning approaches that facilitate the development of students' scientific creativity comprised of; teaching thinking skills, technology-aid teaching and learning approach, experiment and practical based learning, inquiry-discovery based learning, cooperative based learning, and project-based learning. The findings also showed that the process of scientific creativity inculcation in schools is influenced by three factors namely teachers, students, and education setting. These factors can be categorized as facilitating and challenging factors. The teachers believed that the teaching and learning approaches will enhance students' scientific creativity through science learning. However, the implementation of the approaches must be followed by the effective roles of teachers and students. At the same time, the influenced factors need to be considered to inculcate scientific creativity in teaching and learning. These factors will facilitate the effective inculcation of scientific creativity.

Keywords

Scientific Creativity, Science Education, Creativity in Science, Creativity Nurturing

1. Introduction

Creativity, being an important aspect in teaching and learning influences teacher

trainings and practices globally, and helps the 21st century students. In science, creative thinking process is known as scientific creativity. Scientific creativity can be defined as the ability to come up with new ideas and products that are scientifically useful and vital in relevance to science context (Ayas & Sak, 2014). Studies on science subject's KBKK (Critical and Creative Thinking Skills) show that students' command in creative skills are at moderate level as well as low and lacking (Yahaya & Lajium, 2017). This shows that students' creative thinking skills in science subject are still inadequate and it is a major challenge for the nation to produce future highly skilled individuls.

Teachers' decisions and instructional strategies have an impact on creating a learning environment that supports scientific innovation in the classroom. Many studies in the literature suggest that teacher-practiced instruction is one of the most important factors in boosting students' scientific creative talents in schools. To spur student's scientific creative thinking, the learning atmosphere and environment should encourage students to think creatively and teachers are found to be able to positively support students' scientific creativity capability (Siew, Chong, & Chin, 2014).

Therefore, it is important to have an in depth study as a continuation to get clearer view and perspective from the teachers on teaching and learning towards nurturing students' scientific creativity. These teaching and learning practices are established and set from the teachers' understandings and perceptions. Therefore, teachers' understanding and perceptions on scientific creativity can influence their teaching practices to inculcate scientific creativity in deciding, selecting approaches and, overall teaching methods and conducts. Additionally, these understandings and perceptions are also important for teachers to recognise the students' scientific creativity chacateristics as well as plan a multitude of pedagogical methods to help students to excel (Andiliou & Murphy, 2010; Newton & Newton, 2009; Demir, 2015).

Thus, a more in-depth study needs to be conducted as an extension to get a clearer perspective and phenomenon on the extent of teaching and learning practices in schools towards fostering students' scientific creativity. In general, this study aims to explore the perspectives of teachers based on their practice in school on teaching and learning approaches that are capable of fostering students' scientific creativity. Therefore, the objectives of this study are:

1) To explore teachers' "perceptions on the approaches that can foster students" scientific creativity.

2) To explore teachers' perceptions on the environmental factors that influence the inculcation of scientific creativity in teaching and learning.

2. Literature Review

2.1. Scientific Creativity in Education

Scientific Creativity in education is divided into three categories: creative teaching, teaching for creativity, and creative learning. These three types of creative

instruction are susceptible to teaching and learning practise. Teachers can make their lessons more creative by using creative teaching techniques. These types of instructions are frequently used to improve the efficiency of teaching and learning. Teaching for creativity refers to instructors' efforts to recognise, foster, and develop students' creativity's skills, abilities, and potential (Cremin, 2015). These two concepts are inextricably linked, i.e., teaching for creativity entails creative teaching (NACCE, 1999).

Lin (2011) offered a pedagogy of creativity instruction as in **Figure 1**, which depicts the interaction between the three concepts and how they affect one another. For example, if teachers want to encourage pupils to be creative, they should develop new teaching approaches that students have never encountered before (Jeffrey & Craft, 2004). Simultaneously, the interplay and combination of these two styles of teaching will respond and provide creative learning. Furthermore, teachers who employ a creative, dynamic, and original approach in teaching will foster students' imagination and development of new ideas, ultimately leading to teaching for creativity. In other cases, using creative teaching methods will boost student involvement, curiosity, and motivation to learn creatively.

2.2. Teacher's Role to Inculcate Scientific Creativity

Teachers are crucial agents in the development of creativity. Chambers (1973) identified a number of teaching actions that promote creativity. Ensure that lessons are handled in a casual manner, that materials are prepared prior to teaching and learning, that students are encouraged to participate, and that students' original and innovative ideas are valued. In addition to the character of the teacher and the atmosphere in the classroom, instructional strategies or activities determined by the teacher during the teaching and learning process is also a determinant of teaching and learning practices that foster creativity. Studies have found that more active methods can significantly increase students' level of creative thinking.

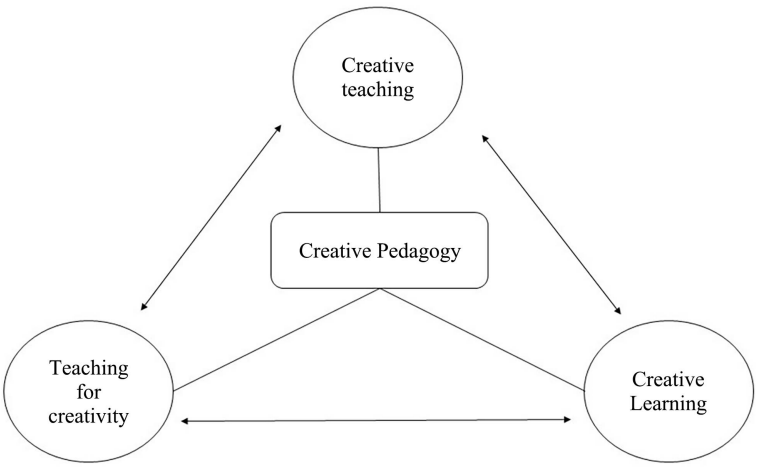

Figure 1. Elements in creative pedagogy.

The instructional aspects of teachers that promote active learning should emphasize on the aspects of analysis, synthesis, critical reasoning as well as high-level cognitive skills that can foster creative thinking (DeHaan, 2011). Teachers can help students improve their creativity by using the practise or behaviour of promoting creativity in their interactions with students during the teaching and learning process. The decisions made by teachers during teaching, as well as their behaviour, determine the learning environment that incorporates and develops creativity. Aside from providing a suitable classroom environment, teachers should also serve as role models for creativity and select relevant activities to promote creativity in the classroom (Cropley, 1995).

3. Methodology

This study is devised on qualitative case study (Yin, 2009). Four core scientific or pure science teachers with more than five years of experience teaching the subject took part in the study. These science teachers, Arni, Razali, Sharifah, and Mustafa, will be reported using pseudonyms to protect their identities. These science teachers will be reported using pseudonyms to maintain confidentiality, namely Arni, Razali, Sharifah and Mustafa. Their details are presented as below (**Table 1**).

This study used interviews as a method of data collection. Prior to entering the field, the researcher has prepared interview protocols and observation protocols that will guide the researcher while carrying out the data collection procedure. These protocols were reviewed by three experts in research in the field of science education as well as the field of creativity. Each participant went through two interview sessions. The interview session lasted for 30 to 40 minutes. Interview data were transcribed in verbatim form (word for word) for the data analysis process. Data are then thematically analysed and further elaborated.

4. Findings and Discussion

4.1. Teachers' Perception on Teaching and Learning Approaches That Foster Scientific Creativity

This study has explored how these science teachers gave their inputs on direct and indirect teaching methods that help in facilitating students' scientific creativity. Findings indicated a multitude of approaches and pedagogical methods

Table 1. Table type styles (table caption is indispensable).

Research participant	Age	Academic achivement	Teaching option	Teaching experience (years)
Arni	33	Bachelor's Degree	Bioligy	9
Razali	52	Bachelor's Degree	Science	28
Sharifah	49	Master's Degree	Science	25
Mustafa	9	Bachelor's Degree	Chemistry	12

given by these science teachers during interviews conducted. Results from findings defined the theme. The themes showed the eight pedagogical themes which are capable to nurture student's scientific creativity: 1) thinking skills approach, 2) technology-assisted teaching and learning approach, 3) experiment and hands-on based learning approach, 4) discovery inquiries based learning approach, 5) cooperative learning approach, and 6) project-based learning approach, as shown in Figure 2.

According to the teachers, the teaching and learning methodologies they employ have their own role and requirements for cultivating and developing students' scientific creativity. The first teaching and learning approach is the teaching of thinking skills. This approach can be used in two ways: question and answer activities and through problem-based learning. Both techniques can pique students' interest and inspire them to think more thoroughly. Questioning based on scientific principles with open-ended and high-level queries might foster the production of more diverse thoughts. Cikgu Arni, for example, expressed the following:

Through these questions we can see the answers of creative students or not. For example, in the topic of pressure and surface area. We teach the basic concepts. But the questions posed are divergent and open. So when he answers we can know if his answer is creative or not (*Arni, Interview* 1)

Students can benefit from questioning since it allows them to think more deeply and expand their curiosity (Considine, 2014; Kaufman & Sternberg, 2006). Effective questioning has been proven to beone of the most essential approaches for encouraging student creativity (Cropley, 1995; Dikici & Soh, 2015; Hu et al., 2013). Students will also get the opportunity to work in groups and follow procedures through problem-based learning. Students will begin by identifying the issue and determining its primary cause. Then they' will try to use their imaginations to come up with different solutions to the difficulties they have discovered. By using a problem-based learning strategy, students will be able to hone one of the most crucial thinking skills, synthesizing skills, where students

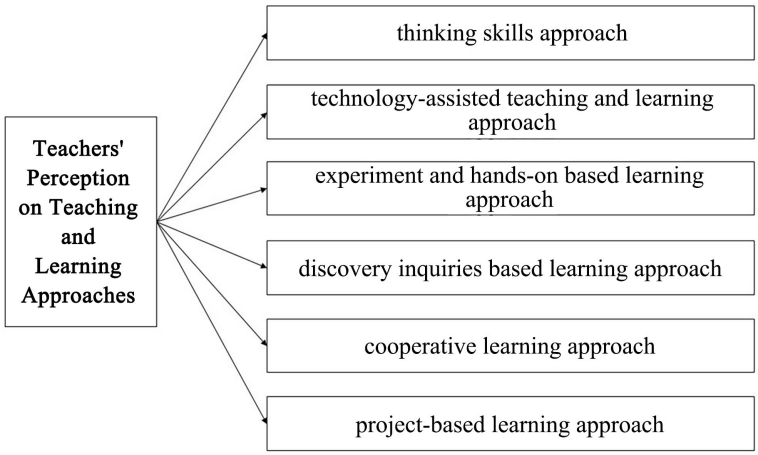

Figure 2. Teachers' Perception on teaching and learning approaches that foster scientific creativity.

must arrange their knowledge and then enable numerous appropriate solutions (Jia et al., 2017; Siew, Chin, & Sombuling, 2017).

Teachers believe that pupils are more driven to learn and express their creativity due to technology, particularly in the subject of science. Technology also aids cross-border communication by giving limitless information and serving as a method of communication between teachers and students outside of school hours. The following is what Mustafa has stated:

We can increase students' creativity in various ways using teaching aids, technology or whatever. I asked students to form groups and each group was given a tablet and an internet connection. They can use the technology to find information about the topic, increase their knowledge, expand their ideas and be more creative (*Mustafa*, *Interview* 2)

Based on the findings from these teachers, it is depicted that technology has benefited teaching and learning as a tool for teacher teaching, a tool for student-centered learning, and as a learning management system or a means of communication between teachers and students outside of class time. Students' interest in technology has aided teachers in encouraging student engagement, making teaching more engaging and interactive. As a result, students can build something unique and valuable using a variety of technology instruments, enhancing the quality of teacher instruction as well as overcoming manpower and resource constraints (Wicaksono, Wasis, & Madlazim, 2017).

Furthermore, these teachers believed that hands-on activities, laboratory experiments, and inquiry-discovery methodologies contribute to the development and nurturing of students' scientific creativity. This is due to the fact that these three strategies can arouse students' interest and involvement in learning, resulting in more meaningful and effective learning. These strategies will be able to boost students' critical thinking and scientific abilities such as science process skills, manipulative skills, and inquiry skills. Furthermore, by using these methods, students will be able to connect their scientific understanding to real-world applications. Fostering creativity can be accomplished through laboratory and practical experimental activities that entail hands-on participation by student-centered pupils, filling in with meaningful contexts, requiring critical thinking, and directly linked to student motivation (Ahmed, 2006; Haigh, 2007; Kind & Kind, 2007; Trnova, 2015).

The perspectives of cooperative learning among teachers can be separated into two categories: group work as well as dialogue and presenting activities. Both strategies can stimulate student participation in the teaching and learning process and reduce teacher-centered instruction. Students have more space and possibilities to interact with one another when they participate in group activities. Students will feel less embarrass to express a variety of thoughts and offer space to the invention of creative science ideas when they are surrounded by peers. Furthermore, this strategy can help pupils to develop abilities such as communication, leadership, and decision-making, as mentioned by Sharifah below:

Working in this group is also very useful and helps to develop one's creativity.

This groupwork can improve their communication. When working in this group, they learn how to lead, want to share ideas and also make decisions together (*Sharifah*, *Interview* 2)

In the meantime, dialog and presentation activities allow students to convey their innovative science ideas. Students have the freedom and space to communicate their thoughts, enhance their communication skills, and boost their self-esteem. Students will be exposed to real-world science challenges through a co-operative approach in which they actively engage with classmates to uncover a variety of unique answers from a variety of angles (Siew et al., 2017).

Finally, project-based learning is demonstrated to be a successful way to fully engage students in the learning process. Teachers believed that this strategy promotes creativity since students can apply their creative ideas and scientific knowledge to create a variety of science products or models. The following is what Cikgu Arni has stated:

my students did a project about the life cycle of mosquitoes and its breeding places. From there, we produced a report to state that this school has the potential for mosquitoes to breed including how and where. These students are actively involved. When they are active, we can see their creativity
(*Arni*, *Interview* 1)

Project-based learning is synonymous with science learning and leads to creativity because it can develop students' cognitive skills to a higher level (Iyengar, Meier, & Hamelers, 2017; Karademir, 2016). The testing part of project-based learning can also help pupils to generate something useful and usable, which is an important aspect of creativity. Students will work together to create novel and helpful scientific products or models that may be used to solve problems in everyday life using this strategy.

In conclusion, the skills acquired by students from these approaches are included in convergent thinking and are able to encourage students towards divergent thinking which is fundamental in the ability of scientific creativity. The ability to produce something original, whether in terms of ideas or physical products, is one of the skills of divergent thinking that is fundamental to the ability of scientific creativity. Furthermore, meaningful learning is critical for students to develop their grasp of science subjects. Scientific creativity is built on scientific ideas thus information, and concepts, mastery of scientific notions is essential. According to Lin (2011), motivation, on the other hand, is one of the most significant aspects of scientific creativity, according to Lin (2011). Learning that improves students' understanding of science while also increase their willingness to be creative hence will lead to development of students' scientific creativity.

4.2. Factors Influencing the Inculcation Process

Teachers provided various factors either impeding or facilitating the process of inculcating scientific creativity in the teaching and learning of science. **Figure 3** displayed the factors perceived by teachers influencing the process of inculcation of scientific creativity.

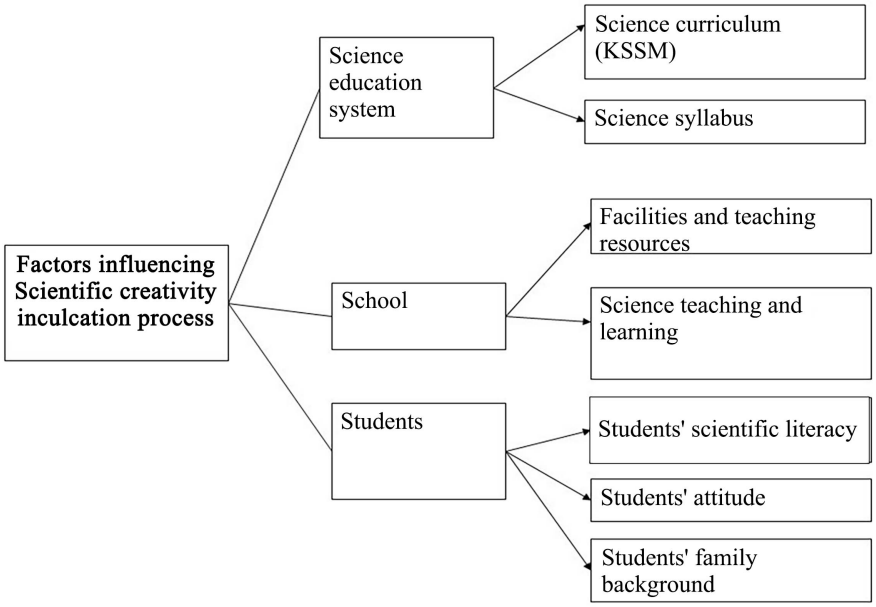

Figure 3. Factors affecting the inculcation of scientific creativity as perceived by teachers.

Three main factors were identified which are 1) education system, 2) teacher, and 3) students. The science curriculum has evolved in terms of its philosophy and content. The depth and breadth of the science curriculum to some extent led the teachers to try and complete the syllabus thus has impeded the teachers to teach science for scientific creativity (Akkanat & Gökdere, 2018; Meyer & Lederman, 2013; Müller, Prenzel, Seidel, Schiepe-tiska, & Kjærnsli, 2017).

In addition, the assessment of science subjects did not lend to examine students' scientific creativity and teachers found there is a lack of resources in the teaching of science for scientific creativity. The overall school's environment has to be conducive in enabling students to share creative ideas of science (Akkanat & Gökdere, 2018; Andiliou & Murphy, 2010; Wilson, 2009). Nevertheless, science teachers perceived that the science curriculum that has undergone review has led to portraying science as a creative subject, and this notion is in line with previous studies (Hetherington et al., 2019; Ozdemir & Dikici, 2017; Schmidt, 2011; Serdar Köksal & Tunç Şahin, 2014).

The second factor identified by teachers that facilitates the inculcation of science creativity is related to the teachers' own content competencies. Teachers need to have a sound conceptual understanding so that they can encourage students to be creative scientifically. In addition, teachers need to have a repertoire of teaching skills that allow students to acquire scientific creativity and its components (e.g. able to provide original ideas, be able to have flexible thinking in providing ideas). Thus, teachers need to attend professional development courses so that their professional knowledge will drive them to choose the relevant and effective teaching approaches that enable students to acquire scientific creativity (Kelly & Cutting, 2013; Liu & Lin, 2014; Yates & Twigg, 2016).

Teachers also perceived that readiness of students also influences the success-

ful inculcation of scientific creativity. Factors such as students' science conceptual understanding, attitude and motivation to learn and their family background will drive students to acquire the scientific creativity skills. One's cognitive ability has been shown to have a positive association with students' scientific creativity skills (Cevher, Ertekin, & Koksal, 2014; Ruiz, Bermejo, Ferrando, Almeida, & Sa'inz, 2014; Şahin, 2016). Students' personality has also been shown to have an effect on the acquisition of scientific creativity skills (Qian & Yu, 2012; Şahin, 2016).

5. Conclusion

These science teachers' perceptions on fostering scientific ability through pedagogical approaches are in line with creativity research in the field of science teaching. Generally, the approaches are able to generate positive impacts on the divergent thinking in terms of originality, inclination/flexibility and fluency. However, more advanced pedagogical approaches to expand students' scientific creativity were less identified by the teachers. Hence, science teachers need to acquire skills in conducting those pedagogical approaches such as conducting brainstorming activities, providing students the opportunity to provide arguments and alternative ideas, developing analogy or creating creative metaphors that encourage students to exercise divergent thinking. This study suggests investigating explicitly teachers' pedagogical approaches and their effectiveness in nurturing students' scientific creativity.

In addition, science education, school learning environment, teachers' competencies and students' readiness are contextual factors that can affect the drive to conduct lessons which inculcate domains of scientific creativity. Science education policy and curriculum implications include ensuring that science education in Malaysia satisfies the demands of instructors in nurturing and developing students' scientific inventiveness. One of them is the necessity of involving teachers in policy and curriculum development decision-making. According to the findings of this study, some teachers believe they are only carrying out the needs of rules and curricula that have been developed. As a result, instructors' opinions and perspectives must also be heard and considered.

Besides, a specific curriculum on the use of scientific creativity in the classroom should be taught to aspiring science teachers in educational institutions, as well as continuing education courses to serve teachers, to improve teacher competencies. Hence, further studies can be carried out to further explore these phenomena by administrating a survey with a larger sample of science teachers. Such baseline data will provide future researchers to examine the role of each factor in promoting scientific creativity among the students.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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