The Effects of General Creativity, Conceptual Physics Knowledge and Inventive Thinking on Scientific Creativity Among Physics Teachers

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Abstract. The purpose of the study is to identify (i) the level of scientific creativity, general creativity, physics conceptual knowledge and inventive thinking, and (ii) the influence of general creativity, conceptual physics knowledge and inventive thinking towards scientific creativity among physics teachers. The aspects of scientific creativity studied were fluency, flexibility, originality and productivity. This study used a survey design using questionnaires and tests as the research instrument. A total of 52 physics teachers were involved in this study. The findings were analysed using descriptive analysis (frequency, percentage, mean score, and standard deviation) and inferential analysis (multiple regression). The study results showed that the level of scientific creativity was moderately low, and general creativity and inventive thinking were moderately high. Meanwhile, the level of conceptual physics knowledge was at a high level. The multiple regression analysis showed that 16.7% of the data variance is explained by general creativity, conceptual physics knowledge and inventive thinking. In addition, conceptual physics knowledge has a significant influence (32.0 %) on the level of scientific creativity among physics teachers. The implications of the study suggest that good understanding of physics concepts is important for ensuring teachers have a high level of scientific creativity.

Keywords: Scientific Creativity, Conceptual Physics Knowledge, Inventive Thinking, General Creativity

INTRODUCTION

Creativity is part of a higher level of thinking skills related to one's cognitive ability and intellectual property (Astutik et al., 2017). In the context of science education, studies on the status or development of scientific creativity have always focussed on students' scientific creativity traits such as fluency, flexibility and originality (eg: Lin et al. 2003; Usta and Akkanat 2015; Astutik et al. 2017; Mo & Cheng 2001; Dehaan 2009, Mohtar, 2019). Scientific creativity is different from creativity in general. This is because scientific creativity involve conceptual knowledge and scientific skills. This kind of knowledge and skills making creative ideas more valuable in contributing to something innovative in the specific field of knowledge. Research by Lilia (2019) found that scientific creativity including divergent thinking in physics (fluency, flexibility, originality) and producing creative physics product can influence students' physics achievement.

Therefore, it is recommended that teachers apply this scientific creativity to physics students as a method of learning physics as it can affect physics achievement.

Nevertheless, teachers' knowledge and skills of scientific creativity are questionable whether teachers are skilled and able to conduct activities that promote scientific creativity or vice versa. The weakness of teachers' thinking and creativity can lead to the failure to apply scientific creativity to students (Sadeghi Boroujerdi & Hasani 2013). Suppose the teacher's level of scientific creativity is low. In that case, teachers are likely less confident in incorporating elements of creativity such as different thinking and helping students come up with original ideas (Robinson 2006). Thus, fostering student creativity is part of the teaching and learning process where the role of a teacher is to teach the science content and incorporate elements of scientific creativity into the subject. Therefore, teachers' knowledge and scientific creativity skills are critical to fostering students' scientific creativity.

However, previous studies found that science teachers (especially pre-service teachers) still lack scientific creativity mastery and require greater attention to creativity skills during training (Kacan 2015). In the context of Malaysia, despite various reforms and approaches introduced by the Ministry of Education Malaysia (MOE), teachers still fail to inculcate and enhance student creativity (Mohamad Mohsin & Mohamad Nasruddin 2008). The weakness of teachers' thinking and creativity can lead to the failure to apply scientific creativity to students (Sadeghi Boroujerdi & Hasani 2013). Suppose the teacher has a low creativity level. In that case, the teacher is likely less confident in incorporating elements of creativity such as divergent thinking and helping students develop original ideas (Robinson 2006). Therefore, a study needs to be conducted to identify the level of scientific creativity among physics teachers and the influence of general creativity, conceptual physics knowledge and inventive thinking on scientific creativity to ensure that the integration of the scientific creativity element with the student reaches the optimum level.

RESEARCH OBJECTIVES

This study aimed to assess the level of inventive thinking, general creativity, physics conceptual concept, and scientific creativity among physics teachers. This study will also assess the influence of general creativity, physics conceptual knowledge and inventive thinking on scientific creativity. The following research questions (RQ) guided this study:

RQ1. What is the level of inventive thinking, general creativity, physics conceptual concept and scientific creativity among physics teachers?

RQ2. What effect does general creativity, knowledge of physics concepts and inventive thinking have on scientific creativity among physics teachers?

RESEARCH METHODOLOGY

Research Design

The survey research design was used in this study. The researchers distributed questionnaires to the teachers. The findings were analysed using descriptive analysis (frequency, percentage, mean score, and standard deviation) to answer RQ1 and inferential analysis (multiple regression) to answer RQ2.

Population and Sample

The population of this study was 60 physics teachers from 37 secondary schools under the Ministry of Education Malaysia (MOE) in Seremban district, Negeri Sembilan, Malaysia. According to Krejcie and Morgan's (1970) sample size table, a population of 60 can be represented by a sample of 52 people. Thus, 52 physics teachers were chosen for this study using a simple random sampling method.

Research Instrument

This study uses questionnaires and tests as research instruments. The 5-point Likert scale questionnaire was used to measure self-assessment of general creativity and inventive thinking, while tests were used to measure knowledge of physics concepts and scientific creativity of physics teachers. The research instruments used in this study are summarised in Table 1.

Data analysis

In addition to the descriptive and inferential analyses used to answer research questions 1 and 2 respectively, analysis for measuring characteristics of scientific creativity ie. fluency, flexibility and originality are shown in Appendix 1. The appendix provides the analytical rubric for each characteristic of scientific creativity, including the scoring of technical product suggested in the answer by the teachers. Appendix 1 also shows the formulae for calculating physics teachers' level of scientific creativity.

TABLE 1. Instruments of the Study

Type of Instrument	**Construct/ Test Form**
Questionnaire 5 points *Likert scale*.	General Creativity • Ideas • Work Style • Different thoughts
Questionnaire 5 points *Likert scale*.	Inventive Thinking: • Adjustment power • Self-regulation • Curiosity • Risk-taking • Higher-order thinking
Physics Test	Multiple answer questions with 3 or 4 answer options (Physics concepts taught at form 4 and form 5)
Scientific creativity test	Open-ended questions (e.g. Write as many possible scientific usages for a piece of glass. e.g. test tube). • Measures characteristics of fluency, flexibility, originality and technical products

FINDINGS

Level of Scientific Creativity

The level of scientific creativity of a physics teacher is assessed based on four main characteristics: fluency, flexibility, originality, and product. Table 2 shows the mean scores, standard deviations, and interpretations of each feature of scientific creativity.

TABLE 2. Scientific Creativity of Physics Teacher

Characteristics of Scientific Creativity	Mean	Standard Deviation	Interpretation
Fluency	2.03	0.972	Moderately Low
Flexibility	2.37	0.919	Moderately Low
Originality	1.63	0.970	Low
Technical Product	2.38	1.714	Moderately Low
Overall (Scientific Creativity)	2.12	0.917	Moderately Low

The results show that fluency, flexibility and product productivity are at a moderately low level while originality is low. The mean score for the technical product was the highest (M=2.38, s.d=1.714), while the mean score for originality was the lowest (M=1.63, s.p=0.970). Overall the results of the study show that the level of scientific creativity among the physics teachers is at a moderately low level.

Level of General Creativity

Table 3 shows the level of general creativity according to different conceptual constructs, styles and thoughts. Results show that the mean for work style constructs were the highest (M=3.91, s.p=0.287), followed by ideas (M=3.87, s.p=0.4) and different thought (M=3.69, s.p=0.379). Overall, general creativity is at a moderately high level.

TABLE 3. General Creativity of Physics Teachers

Construct	Mean	Standard Deviation	Interpretation
Idea	3.87	0.400	Moderately high
Work style	3.91	0.287	Moderately high
Different thoughts	3.69	0.379	Moderately high
Overall (General Creativity)	3.82	0.356	Moderately high

Level of conceptual physics knowledge

The level of physics conceptual knowledge of physics teachers is evaluated based on the percentage of scores in the physics concept knowledge test. The scores are then categorized into four stages. Table 4 further shows the mean scores obtained by the physics teacher based on the test of physics concept knowledge. The overall mean score for the conceptual physics knowledge test was 80.38, with a standard deviation of 9.694. The overall mean score indicates that the level of knowledge of physics concepts is at a high level.

TABLE 4. Physics Conceptual Knowledge of Physics Teachers

	Min	Max	Mean	Standard Deviation	Interpretation
A test score of conceptual physics knowledge	55.00	100.00	80.38	9.694	High

Level of inventive thinking

Table 5 shows the interpretation of the level of inventive thinking among physics teachers. The self-regulation construct has the highest mean value (M=4.10, s.p=0.330), while risk-taking has the lowest mean value (M=3.75, s.p=0.484). Overall, the level of inventive thinking of physics teachers was moderately high (M= 3.90, s.p = 0.409).

TABLE 5. Inventive Thinking of Physics Teachers

Construct	Mean	Standard Deviation	Interpretation
Adjustment power	3.81	0.453	Moderately High
Self-regulation	4.10	0.330	Moderately High
Curiosity	4.07	0.361	Moderately High
Risk-taking	3.75	0.484	Moderately High
Higher-order thinking	3.77	0.420	Moderately High
Overall (Inventive thinking)	**3.90**	**0.409**	**Moderately High**

Influence of General Creativity, Physical Conceptual Knowledge and Inventive Thinking on Scientific Creativity among Physics Teachers

Multiple regression analysis was conducted between the mean scores of scientific creativity (dependent variables) and general creativity, knowledge of physics concepts and inventive thinking (independent variables). Table 6 shows the correlation values between the independent and dependent variables involved in the regression analysis of this study. Based on Table 6, all the independent variables were found to be correlated with the dependent variables. Therefore, the prerequisites for performing multiple regression analysis have been complied with, and the analysis can be continued.

TABLE 6. Correlation values between Independent Variable (Scientific Creativity)

	Scientific Creativity	General Creativity	Physics Conceptual Knowledge	Inventive Thinking
Scientific Creativity	1.00	0.212	0.249	0.271
General Creativity	0.212	1.00	0.081	0.679
Conceptual Physics Knowledge	0.249	0.081	1.00	-0.175
Inventive Thinking	0.271	0.679	-0.175	1.00

Tables 7 and 8 show the results of the multiple analyzes involving three variables: general creativity, knowledge of physics concepts, and inventive thinking in science teachers' scientific creativity. Overall, all three predictor variables (variance) accounted for 16.7 percent ($R^2 = 0.167$) of the physics teacher's level of scientific creativity change. The variance value of F is 3.197 (DK 3, 48) with a significance level of p= 0.032.

TABLE 7. Regression models of general creativity, knowledge of physics concepts and inventive thinking of physics teachers on scientific creativity

R	R^2	Standard R^2	Std. error of estimate
0.408[a]	0.167	0.114	0.8630

TABLE 8. Multiple regression analysis of predictor variables on physics teachers' scientific creativity

Variation	Total squared	Degree of Freedom	Mean squared	F	Sig.
Regression	7.143	3	2.381	3.197	0.032[b]
Residual	35.747	48	0.745		
Total	42.890	51			

a. Criterion variable: Physics teachers' scientific creativity
b. Predictor: (constant), Inventive thinking, Physics conceptual knowledge, General creativity

From these findings, the regression equation can be written as follows:

$$Y = (-3.527) + (0.030)X_1 + (0.030)X_2 + (-0.008)X_3 + 0.863$$

where;

Y	= Scientific creativity
X_1	= Inventive thinking
X_2	= Physic conceptual knowledge
X_3	= General creativity
Constant	= -3.527
Error	= 0.863

The beta value showed a contribution of 0.372 (37.2%) of inventive thinking and -0.066 (6.6 %) of general creativity, however, the contribution is non-significant. Meanwhile, 0.320 (32.0%) of the conceptual physics knowledge significantly influenced teachers' scientific creativity after controlling other variables' contribution in the model. Total contribution of all the dependent variables on the independent variables (scientific creativity) was a total R^2 =0.167.

DISCUSSION

Overall, the results of this study revealed that our participants' level of scientific creativity is moderate and unsatisfactory. This finding explains why teachers present similar or routine answers or ideas to their students. Teachers' inability to come up with ideas when producing a product (which is a drawing tool for picking fruits) is most likely due to a lack of ideas, which can be explained by the lack of product drawings produced by teachers in this study. This finding is consistent with the findings of Kaçan (2015) and Ndeke et al. (2015), who both show that teachers have an inadequate level of scientific creativity. Teachers have been observed to provide answers or ideas that are similar or routine to them. Thus, this level of scientific creativity must be improved because if teachers do not master it well, students will lack the resources to be highly creative (Usta & Akkanat, 2015; Cevher et al., 2014). Moreover, teachers may not encourage students to provide or accept non-routine ideas, which may limit students' opportunities to demonstrate scientific creativity in the process of physics learning and, eventually, in assessments that encourage scientific creativity answers, which is the current trend in Malaysian public examinations.

The findings, however, show that the mean score for general creativity is higher than that for scientific creativity. The level of general creativity and all three sub-constructs, which are ideas, work styles, and thinking differ, are moderately high. In terms of a work style that includes people from various backgrounds, this study demonstrates that teachers can be tolerant of their colleagues when it comes to sharing ideas. Furthermore, teachers are perceived as agreeing to positively resolve problems while carrying out their assignments. Regarding the various aspects of thinking, it can be concluded that teachers in this study value the originality of the assignment and can share ideas with other teachers because a task will be more meaningful if it involves multiple or convergent ideas.

This finding is consistent with the researcher's expectations and the findings of previous studies by Mohtar (2012) that teachers are capable of imagining and providing solutions to problems as well as making judgments from a variety of perspectives. The ability to imagine (imagination) and problem solving is critical because if the teacher does not own these characteristics, it will stifle activities such as innovation in their teaching. This is due to the fact that when such activities are carried out, teachers must act completely to generate ideas and must constantly think about how to carry out a task and constantly think about making decisions in various areas for the problem to be solved.

This study's findings also revealed that physics teachers have a relatively high level of inventive thinking (moderately high). This finding demonstrates that teachers can change their ideas in response to changing circumstances, remain positive, plan for information, and solve problems using a variety of methods. Furthermore, teachers are open to new ideas from colleagues and have a natural curiosity about phenomena that leads to suspicion and a desire to ask questions and test hypotheses. This study also discovered that after completing difficult assignments, teachers agreed to defend their ideas by critically evaluating and improving them. This study supports the findings of Mohtar (2012), who discovered that physics teachers have divergent thinking, problem solving, and imagination skills.

One interesting finding from this study is that physics teachers' scientific creativity is influenced by their self-assessment of general creativity, knowledge of physics concepts, and inventive thinking. All three predictors (variants) contributed 16.7 percent to changes in the level of scientific creativity. However, only one variable (physics conceptual knowledge) has a significant influence on the level of scientific creativity, accounting for 32.0 percent. This finding explains how scientific creativity can be enhanced when physics teachers have a high level of knowledge of physics concepts. This study's findings on the level of knowledge of physics concepts show that teachers have a high level of knowledge of physics concepts. This finding suggests that the teachers in this study have adequate physical content knowledge to teach. As a result, this implies that the opportunity to foster creativity exists because the teacher in this study demonstrates a high level of acquisition in physics concepts (physics introduction, power and motion, force and pressure, heat, electricity, electromagnet, electronics, wave, and radioactivity). This also suggests that, in terms of conceptual mastery, teachers have a high potential for understanding and problem solving among students (Ahmad, 2016). According to McConnell et al. (2013), knowledge is the foundation for teaching because teachers must understand the fundamental concepts in order to implement science, particularly physics, instruction. As a result, teachers must master physics concepts in order to incorporate scientific creativity into the teaching and learning process. The positive relationship between creativity and knowledge discovered in this study also indicates that as a person's level of knowledge increases, so does his or her level of creativity. Thus, it can be concluded that creativity plays a role in enhancing knowledge, and in order to be creative in science, knowledge of science is required (Bermejo et al. 2016).

CONCLUSION AND IMPLICATIONS

Previous research on scientific creativity has focused on students rather than teachers. This study's findings provided an empirical overview of I general creativity, (ii) knowledge of physical concepts, (iii) inventive thinking, (iv) scientific creativity, and (iv) the influence of general creativity, knowledge of physics concepts, and inventive thinking on scientific creativity among physics teachers. Overall, the findings of this study revealed a high level of knowledge of physics concepts. However, scientific creativity and inventive thinking were moderately low among physics teachers, while general creativity was moderate. Multiple regression analyses revealed that physics teachers' scientific creativity is influenced by their general creativity, knowledge of physics concepts, and inventive thinking. However, only 16.7 percent of teachers contributed to their level of scientific creativity.

One possible explanation is that, for example, teachers' inventive thinking was measured in terms of perception. Thus, future research should examine inventive thinking in a test form and also explore other variables such as teachers' divergent thinking. Divergent thinking might have been percusor to teachers' ability to provide flexible or original ideas. This study suggests that in order to foster creativity among physics teachers, they should become more familiar with elements of scientific creativity on a regular basis, such as triggering unexpected or challenging situations and attempting to get students interested in physics without being bound by textbooks or reference books. Furthermore, professional development programmes should focus on teaching and learning approaches that can develop teachers' ability to be scientifically creative, involving student-centered activities that have been shown in many studies to stimulate creativity among them.

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APPENDIX 1

Analytical rubric for open ended questions adapated from Hu dan Adey (2002)

Traits of Scientific Creativity	Explanation	Score
Fluency	i. Accept all relevant answers	1 mark for each answer
Flexibility	ii. Accept repsonses of similar categories/ functions. E.g. Beaker is similar to concial flask	1 mark for similar category/ function
Originality	i. Categorize similar ideas provided by respondents in the same group ii. For exampe, responden A has similar idea with respondents B, C or D iii. Calculation: say total respondets is 30	2 mark - < 5% 1 mark - 5% - 10% 0 mark- > 10%

Beaker	Convex Lens	Glass slides
Responden A Responden B	Responden B Responden C	Responden A Responden B Responden C
2/30 x 100 = 6.7%	2/30 x 100 = 6.7%	3/30 x 100 = 10%

Experiment (Flexbility)	i. Method : • Instrument • Principle • Procedure	9 marks (maximum) Instrument: 3 marks Principles: 3 marks Procedure: 3 marks
Experiment (Originality)	i. Categorize similar ideas provided by respondents in the same category ii. For exampe, responden A has similar idea with respondents B, C or D iii. Calculation: say total respondets is 30	4 marks- < 5% 2 marks- 5% - 10% 0 mark- > 10%

Stress test	Surface area of napkin	Weight
Resondent A Responde nt B	Respondent B Respondent C	Respondent A Respondent B Respondent C
2/30 x 100 = 6.7%	2/30 x 100 = 6.7%	3/30 x 100 = 10%

Sketch and function (Technical product)	i. Function: • Reach out to fruits • Find the fruits • Choose the fruits • Raise the fruits from ground	8 marks (maximum) Sketch: 1 mark Function: 1 mark

$$\text{Scientific creativity score} = \frac{\text{Total of each element of scientific creativity}}{4}$$

$$= \frac{\text{Fluency} + \text{Flexibility} + \text{Originality} + \text{Technical Product}}{4}$$