Creative Problem-Solving in K to 12 Physics Classroom on STEM Strand

Albert Andry E. Panergayo
albertandry.panergayo@lspu.edu.ph
Laguna State Polytechnic University – San Pablo

Alfons Jayson O. Pelgone
Philippine Normal University

Abstract Creativity is an important skill to be developed in STEM education and is also needed for economic development. Hence, this study identified and described the instructional practices of Physics teachers that foster creativity in problem-solving in Physics classrooms and their students creativity as influenced by these practices. Using a descriptive case study, classroom observation, semi-structured interviews, and document analysis were initiated from the purposive sample of six cases of Physics teachers. Thematic analysis revealed that the teacher participants foster creativity in problem-solving through constructivist-oriented and student-directed learning activities. The descriptive statistics further revealed that Creative Problem-Solving v6.1™ stages were moderately observed. Assessment of the students' learning outputs uncovered that *relevance, effectiveness, problematization*, and *elegance* were the criteria that were highlighted in all cases. In conclusion, the instructional practices and their extent of alignment to CPS v6.1™ can influence the level of creativity in problem-solving. Implications and recommendations were also discussed.

Keywords: creativity, creative problem-solving, problem solving, science curriculum

Panergayo, A.A.E., & Pelgone, A.J.O. (2023). *Creative problem-solving in K to 12 physics classroom on STEM strand*. *The Normal Lights*, *17*(2), 29–56
Corresponding Author: albertandry.panergayo@lspu.edu.ph

Introduction

The unabated and accelerating adoption of technology coupled with the emergence of a global pandemic in 2020 has restructured the way tasks, jobs, and skills are done in daily life, in school, and in the workplace. This also shifted the educational paradigm from conventional learning to a flexible learning system (Andal et al., 2020). Moreover, the current educational reforms highlighted the need to integrate complex skills such as analytical, critical, and creative thinking into the school curriculum to respond to the global demand and rising standards of education (Daud et al., 2012; Schwab & Saman, 2016).

Creativity is a valuable skill immune to technological automation. It is acknowledged as one of the foundations of social and economic success in every nation (Blessinger et al., 2018). It drives economic productivity and fosters global competitiveness. Furthermore, the constant inclusion of creativity among the top abilities in past and present reports highlighted this talent's critical role in an information- and technology-based society (Schwab, 2018). As a result, educators and policymakers are prompted to support changes to meet the global demand for these skills.

In the Philippine setting, the Department of Education started offering the K-12 Enhanced Basic Education Act of 2013 (R. A. 10533) as a response to the growing demand for industries and rising standards for education. Specifically, the K-12 conceptual model for science education is directed towards acquiring skills essential in the workplace and a knowledge-based society. These skills include responsible stewardship of nature, effective communication, informed decision-making, innovative thinking, and creative and critical problem-solving (K to 12 Curriculum Guide in Science, 2016). Creativity and problem-solving received common concern from international and local educators, emphasizing their crucial role in success in an evolving society.

Various pedagogical frameworks were proposed locally and internationally to address this demand. The Creative Problem Solving (CPS) model is one of the most widely used models for fostering creativity and problem-solving (Scrhoth, 2016; Sumners, 2016). This method integrates critical and creative thinking skills to generate imaginative and innovative solutions to complex problems (Treffinger et al., 2006, 2008, 2013). The CPS model, as a teaching method, incorporates active learning strategies to engage students in working with complex situations. It further allows students to go beyond conventional thinking and develop creative and novel solutions (Reali, 2017).

The CPS model is a viable response to the need for practical and creative science teachers and learning materials. Thus, the role of teachers is crucial in promoting creativity and problem-solving (Davies et al., 2014). The effectiveness of science instruction in terms of creativity development lies in the instructional practices employed by the teachers. Teachers' beliefs about creativity or students' abilities may affect the development of students' creativity (Beghetto & Kaufman, 2014). It is important to establish an empirical basis for the effectiveness of a creative learning environment and approaches to the student's development of creativity and problem-solving skills (Davies et al., 2014). Moreover, there is a dearth of research on Filipino learners' creativity and problem-solving levels. Yet, creativity and problem-solving are among the skills needed in the future society. Thus, this study was undertaken to describe the creativity and problem-solving of Filipino learners in a Physics classroom and the teaching method through the lens of the CPS model.

Scientific Creativity

The product viewpoint of scientific creativity as its focal point outcomes are those that result from the creative process. In defining creativity from the perspective of a product, Sternberg, Kaufman & Pretz (2002) maintain that creativity is the ability to produce outcomes that are both novel (i.e., original and unexpected) and appropriate (i.e., useful, adaptive concerning task constraints). Cropley et al. (2017) defined creativity as depicting novel products that serve some useful social purpose, known as functional creativity. This is similar to the standard definition proposed by Runco and Leckelt (2012) and Amabile and Pillemer (2012). Cropley et al. (2005; 2019) proposed an enriched hierarchical four-criterion model of functional creativity and, later transformed by Cropley et al. (2011) and Cropley & Kaufmann (2012) to the five-criterion model, which includes relevance & effectiveness, problematization, propulsion, elegance, and genesis as dimensions.

In the study of scientific creativity at the senior high school level, Panergayo (2023) revealed that Grade 12 STEM Filipino learners have average scientific creativity. This suggests that scientific creativity is fairly evident in senior high schools in the STEM field. Similar findings were uncovered by Gupta and Kumar (2020), stating that half of the senior high schools registered an average level of scientific creativity. These results can be attributed to the teachers' perceptions and practices in enhancing scientific creativity. Siew et al. (2014) contended that teachers' decisions and instructional strategies are crucial in designing a learning environment that supports scientific innovation. Sidek et al. (2022) argued that teacher and learning activities significantly influence scientific creativity in science learning. The systematic review conducted by Sidek et al. (2020) further revealed that the role of the teacher is central to the cultivation of scientific creativity. As a result, it is further recommended to explore the teachers' beliefs and practices and their effect in real settings in science learning.

Creative Problem-Solving

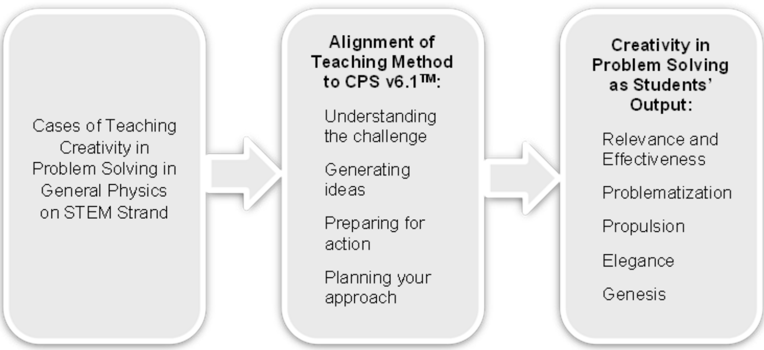
CPS as a skill is an ability that students must have to succeed in future society (Hu et al., 2017). This skill pertains to the ability of the students to solve problems through the generation of function and creative ideas (Saeidah & Nooren, 2013). In simple terms, it refers to problem-solving with creativity. It is the relation between creativity and problem-solving (Osborn, 1963). CPS can be viewed as a creative and critical thinking process of developing something new, requiring creative efforts through its process. It helps people redefine the problems and opportunities they encounter, generate innovative solutions, and take action (Isaksen, 2023; Treffinger et al., 2008). The CPS model is a proven method for approaching a problem or a challenge imaginatively and innovatively. It has been used for over 60 years by various organizations worldwide and has been supported by numerous research studies, with hundreds of published studies on its effectiveness and impact (Isaksen, 2023; Treffinger & Isaksen, 2013). According to Birgili (2015), critical and creative thinking skills should be integrated critically into instructional design to produce learners who might be possible young scientists of the future. Moreover, CPS is also influenced by the pedagogical practices of the teachers. David et al. (2013) revealed that instructional materials and resources used by teachers can be utilized to stimulate the learners' creative thinking.

Teachers' instructional practices can affect the development of the scientific creativity. The delivery of science education can impact students' ability to think creatively and critically. Science educators can encourage students to think creatively and solve problems innovatively by providing creative teaching strategies and a supportive learning environment. Given these, it is imperative to explore the various instructions that promote creativity in science. Investigating how teachers can tailor their strategies to promote creative thinking and problem-solving is essential. The results from this study can provide inputs in designing creativity-fostering instructional materials and learning environments.

Framework of the Study

Figure 1 shows the conceptual framework of the study. It features the salient steps of the CPS model used to map the Physics teachers' instructional practices and the components of creativity in problem-solving used to assess students' scientific creativity.

Figure 1



Grounded on CPS v6.1™, the study aimed to document the instructional practices of the six cases of physics teachers and assess the alignment of the model to evaluate the effectiveness of the teacher's instructional practices in enhancing scientific creativity in STEM classes. Scientific creativity can be shaped by the Physics teachers' beliefs, decisions, and actions in the science teaching and learning process (Gupta & Kumar, 2020; Sidek et al., 2020; Sidek et al., 2022). The CPS model emphasizes problem-solving skills through systematically and logically arranged stages using different thinking patterns (Hu et al., 2017). CPS v6.1™ is a proven, portable, powerful, practical, and positive problem-solving model. It has been used for more than 60 years by organizations worldwide (Fahrisa & Parmin, 2022). It is portable because it links a person's natural creativity and problem-solving approaches. It can substantially improve the creativity and problem-solving performance of the students. It was also proven to foster engagement and motivation, improve metacognition (Effendi, 2017) and boost the mathematical problem-solving ability of the students.

The framework further shows the four crucial steps of CPS v6.1™ to solve problems and manage change creatively: (1) *understanding the challenge* - involves investigating a broad goal, opportunity, or challenge, and clarifying, formulating, or focusing your thinking on setting the principal direction for your work; (2) *generating ideas* – involves coming up with new possibilities and many varied, unusual ideas for a clearly stated problem, and identify the promising possibilities; (3) *preparing for action* – involves exploring ways to make promising options into workable solutions and preparing for successful implementation; and 4) *planning your approach* – involves keeping track of your thinking while it is happening, to ensure that you are moving in the direction you want to go. It also guides you in customizing your approach to applying CPS.

Figure 1 also shows that the alignment of the instructional practices and the CPS model significantly shapes the students' scientific creativity as manifested in their learning output. The framework further posits that alignment can create a conducive learning environment where teachers employ pedagogical strategies that reflect the principles of the CPS model. In this study, the five-criterion model of functional creativity, as shown in Table 1, was used to evaluate the students' scientific creativity in their learning outputs.

Table 1

The Hierarchical Five-Criterion Model for Functional Creativity

Product Creativity				
Relevance & Effectiveness	**Problematization**	**Propulsion**	**Elegance**	**Genesis**
Performance	Prescription	Redefinition	Pleasingness	Vision
Appropriateness	Prognosis	Reinitiation	Completeness	Transferability
Correctness	Diagnosis	Generation	Sustainability	Seminality
Operability		Redirection	Gracefulness	Pathfinding
Durability		Reconstruction	Convincingness	Germinality
Safety			Harmoniousness	Foundationality
			Recognition	

Creativity and problem-solving can be taught in children of any age in any subject. The teaching method is critical in developing learners' creativity and problem-solving skills (Davies et al., 2014; Ramankulov et al., 2016). There are various of methods for teaching creativity and problem-solving available in the literature (Treffinger et al., 2006). Hence, this study presupposes that creativity in problem-solving of the students in a physics classroom can be attributed to the methods used by the teachers. The teaching methods play a vital role in developing creativity in students' problem-solving. Likewise, mapping the alignment of these methods with the CPS v6.1™ would help teachers effectively promote creativity and problem-solving in their respective Physics classrooms.

Research Questions

This study aimed to describe the method of teaching creativity in problem-solving in General Physics 1 on the STEM strand. Specifically, it sought to answer the following questions:

1. How do teachers develop Physics students' creativity in problem-solving?
2. How does teaching creativity in problem-solving align with the CPS v6.1™ in terms of
   2.1. understanding the challenge;
   2.2. generating ideas;
   2.3. preparing for action; and
   2.4. planning your approach?
3. How evident is creativity in problem-solving of STEM students in physics classrooms as manifested in their learning outputs in terms of:
   3.1. relevance and effectiveness;
   3.2. problematization;
   3.3. propulsion;
   3.4. elegance; and
   3.5. genesis?

Methodology

Research Design

This study utilized a descriptive case study incorporating quantitative and qualitative evidence to answer the research problems. This type of research design attempts to present a rich and thick description of the phenomenon under study within its context (Merriam, 1998). In this case study, the phenomenon under investigation is the teacher's method of developing creativity in problem-solving among learners in physics classrooms.

Participants

The primary participants of this study were six purposively selected physics teachers from the senior high school program. These teachers have at least two years of teaching experience, have previously handled physics courses, and are currently teaching General Physics 1. The teacher also fostered creativity as they gained at least 3.5 as the overall mean value in the pre-survey, indicating the frequent practice of creativity-fostering teaching methods.

Table 2

Basic Information about the Teacher Participants

Teacher	Sex	Institution	Subject Specialization	Experience (years)	Average Rating
A	F	Public	Physics	2	4.12
B	F	Public	Chemistry and Physics	7	3.59
C	M	Private	Physical Science	4	3.89
D	M	Private	Physical Science	2	4.37
E	M	Public	Physics/ General Science	14	3.79
F	M	Private	Physics and Mathematics	14	4.57

Legend: 1.0-1.8 is almost never; *1.9-2.6* is once in a while; *2.7-3.4* is sometimes; *3.5-4.2* is often; *4.3-5.0* is almost always

Instruments

The following are the instruments used in the study. Purpose, development, and validation details are presented below:

Creative Problem-Solving Observation Checklist (CPSOC)

The CPSOC is a researcher-developed instrument, composed of two parts: (1) CPS teacher's checklist developed based on a review of related literature; and (2) actual observation notes that capture the actual teaching-learning process. This instrument was used to observe the implementation of the CPS model in the physics classroom. The CPS teacher's checklist comprises 28 statements on a four-point Likert scale ranging from excellent (4) to poor (1).

Creative Solution Diagnosis Scale (CSDS)

To determine the level of the students' creativity and problem-solving regarding artifacts, the researchers adopted and utilized the CSDS developed by Cropley et al. (2011), a 27-item scale based on five core criteria with Cronbach's alpha of .956. It uses a five-point Likert scale, ranging from *"very evident"* to *"not evident."*

Creative Teachers Checklist (CTC)

This checklist was adapted and used to determine the practices of teachers who cultivate creativity and problem-solving. The results from this survey provided the basis for selecting the participants for the case study. The CTC was divided into two parts: (1) a Demographic Profile of the respondents and (2) a Creative Teacher Checklist where items were adopted from the study of Hazam and Griffith (2006). It comprises 49 statements on a 5-point Likert scale ranging from *"almost always"* to *"rarely."*

Data Collection

First, the researchers conducted a survey using the CTC adopted from the study of Hazam and Griffith (2006). The survey forms were distributed to science teachers in the SHS program in the Division of San Pablo City. The survey came with an informed consent form explaining the purpose of the study, procedures, risks and benefits, confidentiality, and voluntary participation. The survey was distributed to all SHS science teachers in DepEd San Pablo City, from which the six qualified participants were selected.

Second, the researcher conducted classroom observations. Each of the physics teachers was observed on a mutually agreed schedule. The observation lasted for 45 minutes per session. This observation focused on capturing the teaching method for fostering creativity and problem-solving in the General Physic course. The researcher utilized the CPSOC as an observation form to rate the alignment of the teaching method with the CPS v6.1™ stages. The teachers were also asked to provide the learning outputs of their students for document analysis. The learning outputs were rated using the CSDS to evaluate the students' creativity. The results from the CPSOC and CSDS provided the quantitative data needed to address the research questions.

Lastly, the researchers conducted a semi-structured interview to elicit the views and opinions of the participants. The interview lasted for a maximum of 45 minutes. The semi-structured interview focused on gauging the strategies, methods, techniques, or ways of teaching creativity and problem-solving. The conversations were recorded using a smartphone recorder and were transcribed verbatim. The researchers also took notes to highlight the key points of the participant's response.

Data Analysis

Upon completing qualitative data collection, all of the field observation notes, interview responses, and documents were coded and analyzed to reveal common themes. These themes were drawn based on the lenses of research questions. Moreover, the themes were supported by specific examples from the data gathered to provide detailed descriptions of the themes. This study adopted the seven steps in the qualitative data analysis suggested by Creswell (2013). On the other hand, the results from evaluating students' learning outputs using CSDS and the observation employing CPSOC served as the quantitative data for this study. These data were treated using descriptive statistics like the mean and standard deviation to determine the students' creativity level in problem-solving and the extent of alignment of teachers' instructional practices to CPS v6.1™

Ethical Consideration

This study ensured proper communication with key personnel on the research site, explaining the purpose of the study, methodology, confidentiality, and potential ethical issues. The data were collected following appropriate research ethics and protocols, including validation of instruments, confidentiality, and objectivity. The study results accorded the participant's right to privacy and anonymity by assigning respondents codes. The results were shared with key school officials, parents, and students to inform them of the findings and give their comments.

Results and Discussion

On the Instructional Practices Used in Fostering Creativity in Problem Solving

This study revealed that the teacher participants used various ways to promote problem-solving in their respective physics classrooms.

Implementing Collaborative Work

All of the teacher participants agreed that collaborative activity is indeed an effective way to promote creativity in problem-solving among the students. In collaborative activity, the students could think and share ideas with their peers, which led to the formulation of solutions. This process is termed *brainstorming,* an effective tool to generate ideas. It promotes communication, thinking, and decision-making that fosters viewpoints and opinions (AlMutairi, 2015). In the collaborative process, teacher participants emphasized the importance of individual work where students can process the inputs in collaborative work. In this manner, students could refine ideas and select the most probable solutions to the problem independently.

> Through group activities kase nagbe-brainstorming sila. Nagshe-share sila ng different ideas and they come up with a presentation. Small group muna then big group. Minsan kapag maunti lang sila 'yung Think-Pair-Share, by diad. [Through group activities, they are brainstorming. They share their different ideas and come up with a presentation. We start with small groups and move to big groups. Sometimes when they are just few, we use Think-Pair-Share, by diad] -Teacher B

Conducting Hands-on Activities

Experiments, particularly hands-on experiments, have been a crucial element of physics learning. It has an important role in teaching creativity inside a physics classroom since it allows the creation of new and alternative inventions. In this study, all of the teacher participants revealed that they conduct hands-on tasks to enhance student's creativity in problem-solving. Shieh and Chang (2014) established facts about using hands-on tasks to foster creativity and problem-solving in conducting scientific projects. In the conduct of conventional science hands-on tasks, the students are expected to submit a laboratory report following a distinct format given by the teacher. However, it was found that teacher participants only provided learning goals, wherein they needed to design their laboratory procedures to meet these goals. As Chen and Chan (2021) contended in their study, freedom of exploration and self-directed elements to inquiry, discovery, and problem-solving processes must be considered in designing activities. Teacher A shared:

> In the catapult making, there are suggested materials like rubber bands, tape, glue, ruler, wood. But they are free to choose what materials are they going to do, as long as ma-meet nila 'yung objective [they meet the objectives], which is to apply the law of physics to design a catapult that can accurately launch a ping pong ball and hit a designated target. -Teacher A

Using Project-based Learning

In using project-based learning, five out of six teacher participants approved that this method can improve creativity and problem-solving. This type of learning enhanced creativity by requiring students to produce tangible and innovative products actively. In this study, most of the teachers required their students to develop a product that would encapsulate the learning competencies in General Physics 1. The project-based learning environment creates an environment that fosters creativity and problem-solving. It also promotes life-long learning since the students are involved in the decision-making process that affects their learning. They are given opportunities to choose how to solve problems, to select the tool that would help them the best, and to use technology that enables them to succeed. In addition, it caters to the different learning styles of the students and involves them in the whole learning development. Putri et al. (2019) contended that project-based learning effectively improves creativity in science classrooms. For instance, Teacher F elaborated on the project that he conducted with his previous class that focused on innovation of existing materials or products in the market

> An example is a trash bin or trash can, wherein they integrated an aroma type compartment because the problem with rubbish or garbage is that it is stinky or smelly. To eliminate the bad smell, they put something – aroma of leaves calamine I think and rose. That is one. The concept behind that is diffusion. –Teacher F

Encouraging Students to Think Critically

Critical and creative thinking skills are crucial to the scientific process. Thus, it must be placed at the center of science education. Integrating these two thinking skills into instructional design is essential for cultivating learners who have the potential to become scientists (Gupta & Sharma, 2019). This is to cope in the 21st century and information-based society in the global trends emphasizing the importance of nurturing higher-order thinking skills. In this study, the teacher participants suggested asking questions or implementing activities that let the students think outside the box. This is evident in classroom observation, where teachers encourage students to think differently about how to solve problems.

> Kailangan mo muna silang i-motivate. Ano ba 'yung meron sa creativity? Baket siya kailangan? So, minsan pinapasok ko 'yung scientists kung paano nila nagamit yung creativity nila, isa ito sa nagmo-motivate. I also ask them the same questions that scientists ask to themselves.

> [You have to motivate them first. What is with creativity? Why do you need it? So, sometimes I tell stories about scientists and how they used their creativity; this is one of the motivating factors. I also ask

> them the same questions that scientists ask themselves.] – Teacher E

Providing idea and Reflection Time

Reflective habits involve processing information and experiences before acting. The teachers can do this during observation, evaluation, and decision-making. Kolb's Experiential Learning Theory (2012) identified reflection as an essential stage of its learning model as a way of sensing information and experiences. Throughout the study, five teacher participants expressed their support for the importance of reflection and feedback in the current educational system. To impose reflection on the students, the teacher participants implement various activities such as idea generation through collaborative activity, group presentation and critique, and reviewing and feedback. Literature recognized reflective practice as a tool for developing creative abilities by supporting students as they develop awareness of their creativity.

> I help them, nagco-correct ako tapos inaayos ko yung project nila, then I give them time to implement it and reflect from it. I want them to identify 'yung strengths and weaknesses ng work nila.
>
> [I help them, I correct and then I fix their project, then I give them time to implement it and reflect from it. I want them to identify the strengths and weaknesses of their work.] - Teacher A

On the Alignment of Instructional Practices to CPS v6.1™

This study revealed that CPS v6.1™ is generally observed to a moderate extent by the participants. *Understanding the challenge* and *generating ideas* were observed to a moderate extent and a great extent, respectively. On the other hand, the observation registered both preparing for action and planning your approach to some extent. The alignment of the participants' teaching methods with the CPS v6.1™ model promotes the enhancement of creativity and problem-solving in the students in synergistically. Table 3 shows the extent of alignment of instructional practices employed by the teacher participants to foster creativity to CPS v6.1™.

Table 3

Teacher' Instructional Alignment to CPS v6.1™ and Level of Creativity of Students

Cases of Teachers	Alignment to CPS v6.1™					
	Understanding the Challenge	Generating Ideas	Preparing for Action	Planning Your Approach	Overall Mean	Description
A	3.57	3.43	3.00	3.00	3.25	ME
B	2.86	3.29	2.43	2.33	2.73	ME
C	3.29	3.14	2.43	2.33	2.80	ME
D	4.14	4.57	3.29	2.17	3.71	GE
E	3.00	3.29	2.43	2.17	2.72	ME
F	3.29	3.29	2.43	2.47	2.80	ME
Mean	3.36	3.50	2.67	2.41	3.00	ME

Legend: 1.0-1.8 is not at all (NA); 1.9-2.6 is to some extent (SE); 2.7-3.4 is to a moderate extent (ME); 3.5-4.2 is to a great extent (GE); 4.3-5.0 is to a very great extent (VGE)

Table 3 shows that Teacher A and Teacher D gained the highest overall mean value on the alignment to CPS v6.1™ model and creativity of the students on their projects. This suggests that the more aligned the instructional practices to the model, the more creative learning outputs can be produced by their respective students. Reali (2017) explained that the CPS model is a teaching method that incorporates active learning strategies to engage students in working with complex situations. Samson (2015) further claimed that the CPS model is a transformative teaching methodology that converts a traditional classroom to experiential learning through active learning.

On the Creativity in Problem-Solving of Students on their Learning Outputs

Table 4

Creativity in Problem-Solving of Students on their Learning Outputs

Cases of Teachers	Level of Creativity						
	Relevance and Effectiveness	Problematization	Propulsion	Elegance	Genesis	Overall Mean	Description
A	3.40	3.63	3.33	3.27	2.56	3.24	FE
B	2.94	3.22	3.13	2.86	3.17	3.06	FE
C	3.14	2.14	2.26	3.47	2.29	2.66	SE
D	3.54	3.42	3.20	3.50	3.00	3.33	FE
E	3.78	3.50	2.83	3.07	2.97	3.23	FE
F	3.08	3.17	3.00	2.96	3.04	3.05	FE

Legend: 1.0-1.8 is Not Evident (NE); 1.9-2.6 is Somewhat Evident (SE); 2.7-3.4 is Fairly Evident (FE); 3.5-4.2 is Evident (E); 4.3-5.0 is Very Evident (VE)

The results from Table 4 regarding the evaluation of the collected learning outputs were influenced by the teaching and learning activities they went through under their physics teachers. The most cultivated kind of creativity manifested on the projects was the criteria *problematization*, which was implemented through collaborative learning activities. Teachers D and E's students got the highest rating on the *relevance and effectiveness*. At the same time, Teacher C was able to foster an *elegant* type of creativity in the students' learning outputs. Ayob et al. (2013) highlighted the importance of the teachers' attitudes in shaping the students' creative attitudes. Teachers' instructional practices can enhance creativity in creative production, experiment without restrictions, and investigate investigation outside the classroom's conformity. Figure 2 below shows examples of students' learning projects.

Figure 2

Sample Learning Outputs

A. Rainwater Filter
B. Drainage Collector System
C. Door Sercurity Alarm
D. Retractable Storage/Table

Conclusions and Recommendations

This study described the instructional practices that foster creativity in problem-solving in K to 12 physics classrooms and the creativity of Grade 12 STEM students in the light of CPS v6.1™ and functional creativity models. This investigation provides an understanding of evidence-based instructional practices at the grassroots level viewed from the lens of empirically valid models.

This study revealed that creativity in problem-solving can be developed using constructivist-oriented teaching-learning activities, which allow students to actively engage in their own thinking process and knowledge construction. Likewise, the teacher participants employed the CPS v6.1™ model in their physics classroom to a moderate extent. Still, it does not have logical connections to provide a structured problem-solving process. The study further uncovered that teachers who employ student-centered approaches and with a higher extent of alignment to the CPS v6.1™ model are likely to foster creativity in problem-solving. This result implies that providing a structured learning process with opportunities for self-directed learning, exploration of more ideas, and thinking creatively results in creative products.

The physics curriculum can be reexamined to highlight creativity to produce innovative students who can become future scientists or inventors. The results of this study may also serve as the basis for developing teachers' training programs and in-service programs for physics teaching. The teachers must attend various seminars and workshops to improve their pedagogical knowledge. This will help them select appropriate approaches to develop the students' creativity in problem-solving. This study further recommends applying the CPS v6.1™ model in K-12 physics classrooms. Utilizing this model to teach creativity in physics will greatly help the teachers facilitate the students' divergent and convergent thinking activities.

There are certain limitations encountered in the study's conduct. This study only involved six cases of physics teachers to address the research objectives. Hence, the conclusion obtained is not generalizable to a larger population. Students' views and opinions were not also gauged since the study only underscores their creative projects as elaborated by their teachers. Similarly, the CPS v6.1™ was not empirically tested to determine its effectiveness in enhancing creativity.

For future research directions, it is also recommended to replicate a similar study with a larger sample to provide a more detailed and thicker description of the case eventually obtaining reliable results. Future lines of research can also consider widening the context of the study covering all physics subjects in grade levels in the K to 12 Science education curriculum. Likewise, an empirical investigation must be conducted in using the CPS v6.1™ model as an instructional approach to provide experience-based evidence on the effectiveness of the said model.

■ ■ ■

References

AlMutairi, A. N. M. (2015). The effect of using brainstorming strategy in developing creative problem solving skills among male students in Kuwait: a field study on Saud Al-kharji School in Kuwait City. *Journal of Education and Practice, 6*(3), 136–145.

Amabile, T. M., & Pillemer, J. (2012). Perspectives on the social psychology of creativity. *The Journal of Creative Behavior, 46(*1), 3 -15. https://doi.org/10.1002/jocb.001

Andal, E. Z., Panergayo, A. A. E., & Almanza, M. R. G. (2020b). Exploring the online learning self-efficacy of teacher education students at the Laguna State Polytechnic University: Basis for transition to flexible learning system. *Universal Journal of Educational Research, 8*(12), 6598 -6608. https://doi.org/10.13189/ujer.2020.081224

Ayob, A., Hussain, A. & Majid, R. A. (2013). A review of research on creative teachers in higher education. *International Education Studies, 6*(6), 8-14. http://dx.doi.org/10.5539/ies.v6n6p8

Birgili, B. (2015). Creative and critical thinking skills in problem-based learning environments. *Journal of Gifted Education and Creativity*, 71-71. https://doi.org/10.18200/JGEDC.2015214253

Blessinger, P., Sengupta, E., & Yamin, T. S. (2018). Human creativity as a renewable resource. *International Journal for Talent Development and Creativity, 6*(1), 17-26. https://files.eric.ed.gov/fulltext/EJ1296855.pdf

Chen, P., & Chan, Y. (2021). Enhancing creative problem solving in postgraduate courses in education management using project-based learning. *International Journal of Higher Education*, *10*(6), 11. https://doi.org/10.5430/ijhe.v10n6p11

Creswell, J. W. (2014). *Research designs: Quantitaive, qualitaive and mixed-method approaches 4th Edition*. SAGE Publications, Inc.

Cropley, D. H. & Cropley, A. J. (2005). Engineering creativity: A systems concept of functional creativity. In J. C. Kaufman and J. Baer (Eds.), Creativity across domains: Faces of the muse (pp. 169-185). Lawrence Erlbaum.

Cropley, D. H., & Cropley, A. J. (2008). Elements of a universal aesthetic of creativity. *Psychology of*

Aesthetics, Creativity, and the Arts, 2(3), 155-161. http://dx.doi.org/10.1037/1931-3896.2.3.155

Cropley, D. H., & Kaufman, J. C. (2012). Measuring functional creativity: Non-expert raters and the creative solution diagnosis scale. *Journal of Creative Behavior*, *46*(2), 119–137. https://doi.org/10.1002/jocb.9

Cropley, D. H., Cropley, A. J. & Sandwith, B. L. (2017). Creativity in the Engineering Domain. In J. Kaufman, V. P. Glaveanu, and J. Baer (Eds.), The Cambridge Handbook of Creativity Across Domains, Chapter 15, (pp. 261-275), New York, NY: Cambridge University Press.

Cropley, D. H., Kaufman, J. C., & Cropley, A. J. (2011). Measuring creativity for innovation management. *Journal of Technology Management & Innovation*, *6*(3), 13–30. https://doi.org/10.4067/s0718-27242011000300002

Cropley, D. H., Patston, T., Marrone, R. L., & Kaufman, J. C. (2019). Essential, unexceptional and universal: Teacher implicit beliefs of creativity. *Thinking Skills and Creativity*, *34*, 100604. https://doi.org/10.1016/j.tsc.2019.100604

David, P., Jamie, D. B., Kimberly, S. H. et al. (2013). Teaching people to manage constraints: Effects on creative problem solving. *Creativity Research Journal, 25*, 335-347.

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

Department of Education. (2016, August). *K to 12 Curriculum Guide for Science Kindergarten to Grade 10.* (Pasig City: Department of Education, 2016).

Effendi, A. (2017). Implementation of creative problemsolving model to improve the high school student's metacognitive. *Journal of Physics*. https://doi.org/10.1088/1742-6596/812/1/012065

Fahrisa, N., & Parmin, P. (2022). Creative Problem Solving (CPS) learning to improve ability an strudent's critical and creative thinking on science materials. *Journal of Environmental and Science Education*, *2*(2), 98–105. https://doi.org/10.15294/jese.v2i2.55641

Gupta, P., & Sharma, Y. (2019). Nurturing scientific creativity in science classroom. *Resonance, 24*, 561–574. https://doi.org/10.1007/s12045-019-0810-8

Hu, R., Su, X., & Shieh, C. (2017). A study on the application of creative problem solving teaching to statistics teaching. *Eurasia Journal of Mathematics, Science and Technology Education*. https://doi.org/10.12973/eurasia.2017.00708a

Isaksen, S. G. (2023). Developing creative potential: The power of process, people, and place. *Journal of Advanced Academics, 0*(0). https://doi.org/10.1177/1932202X231156389

Isaksen, S., Dorval, B., & Treffinger, D. (2000). *Creative approaches to problem solving: A framework forchange* (2nd. Ed.). Williamsville, NY: Creative Problem Solving Group-Buffalo.

Kolb, A. Y., & Kolb, D. (2012). Experiential learning theory: A dynamic, holistic approach to management learning, education and development. In *SAGE Publications Ltd eBooks* (pp. 42–68). https://doi.org/10.4135/9780857021038.n3

Osborn, A. F. (1963). Applied imagination: Principles and Procedures of creative problem solving (3rd Revised ed.). Scribners.

Panergayo, A. A. E. (2023). Students' conceptual understanding, self-efficacy and scientific creativity in science learning: A multivariate analysis. *International Journal of Educational Management and Development Studies, 4*(4), 139–159. https://doi.org/10.53378/353027

Putri, S. U., Sumiati, T., & Larasati, I. (2019). Improving creative thinking skill through project-based-learning in science for primary school. *Journal of Physics*, *1157*, 022052. https://doi.org/10.1088/1742-6596/1157/2/022052

Ramankulov, S., Usembaeva, I., Berdi, D., Omarov, B., Baimukhanbetov, B., & Shektibayev, N. (2016). Formation of the creativity of students in the context of the education informatization. *International Journal of Environmental and Science Education, 11*(16), 9598-9613.

Runco, M. A., & Leckelt, M. (2012). The standard definition of creativity. *Creativity Research Journal*, *24*(1), 92–96. https://doi.org/10.1080/10400419.2012.650092

Saeidah, B., & Nooreen, N. (2013). Investigating relationship between creativity and academic achievement of Malaysia undergraduates. *Jurnal Teknologi Malaysia, 65*, 101-107.

Schroth, S. T. (2016). Teaching children creative thinking and problem-solving skills: Strategies for building creativity through classroom instruction and interventions. *Torrance Journal for Applied Creativity, 1,* 21-26. http://www.centerforgifted.org/TorranceJournal_V1.pdf

Schwab, K. & Samans, R. (2016). *The future of jobs: Employment, skills and workforce strategy for fourth industrial revolution. Geneva, Switzerland:* World Economic Forum.

Schwab, K. (2018, January 14). The fourth industrial revolution: What it means and how to respond. https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/

Shieh, R., & Chang, W. (2014). Fostering student's creative and problem-solving skills through a hands-on activity. *Journal of Baltic Science Education, 13*(5), 650–661. http://dx.doi.org/10.33225/jbse/14.13.650

Sidek, R., Halim, L. & Buang, N. (2022). Pedagogical approaches to inculcate scientific creativity among secondary students. *Creative Education, 13,* 1779-1791. https://doi.org/10.4236/ce.2022.135112

Sidek, R., Halim, L., Buang, N. A., & Arsad, N. M. (2020). Fostering scientific creativity in teaching and learning science in Schools: A systematic review. *Jurnal Penelitian Dan Pembelajaran IPA*, *6*(1), 13. https://doi.org/10.30870/jppi.v6i1.7149

Siew, N. M., Chong, C. L., & Chin, K. O. (2014). Developing a scientific creativity test for fifth graders. *Problems of Education in the 21st Century, 62*, 109-123. https://doi.org/10.33225/pec/14.62.109

Sophonhiranrak, S., Suwannatthachote, P., & Ngudgratoke, S. (2015). Factors affecting creative problem solving in the blended learning environment: A review of the literature. *Procedia - Social and Behavioral Sciences, 174,* 2130-2136. https://doi.org/10.1016/j.sbspro.2015.02.012

Sternberg, R. J., Kaufman, J. C., & Pretz, J. E. (2002). *The creativity conundrum: A propulsion model of kinds of creative contributions.* New York: Psychology Press.

Sumners, S. (2016). Visions of the future: The work of E. Paul Torrance. *Torrance Journal for Applied Creativity, 1,* 11-15. http://www.centerforgifted.org/TorranceJournal_V1.pdf

Tawil, M., & Dahlan, A. (2017). Developing students' creativity through computer simulation based learning in Quantum Physics learning. *International Journal of Environmental and Science Education, 12(*8), 1829-1845.

Treffinger, D. J., Isaksen, S. G. & Dorval, K. B. (2006). Creative problem solving: An introduction. (4th Ed). Prufrock Press.

Treffinger, D. J., Schoonover, P. F., & Selby, E. C. (2013). Educating for creativity and innovation. Waco, TX: Prufrock Press

Treffinger, D.J., & Isaken, S. G. (2013). Teaching and applying creative problem solving: implications for at-risk students. *International Journal for Talent Development and Creativity 1*(1), 87-97.

Treffinger, D.J., Selby E. C., & Isaken, S. G., (2008). Understanding individual problem solving styles: A key to learning and applying creative problem solving. *Learning and Individual Differences, 18,*349-401. http://dx.doi.org/10.1016/j.lindif.2007.11.007