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STEM Training for Lesson Plan on Bioplastic and Environment: Does it Affect the teachers?

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Abstract

This study aimed to see how STEM training affected teachers' knowledge of STEM learning, how they applied chemical ideas in manufacturing bioplastic goods, and how they developed STEM lesson plans with an environmental focus. A one-shot case study was performed as the research method. This study involved 30 instructors from diverse parts of Indonesia who were given online training. The p-value is less than 0.05, according to the Wilcoxon test. The study showed that STEM training can help teachers improve learning. Teachers, on the other hand, are unfamiliar with how to use scientific or mathematical concepts as a framework for project problem-solving. The general teacher is already familiar with incorporating EDP activities into lesson planning. According to the statistics, 93% of teachers are concerned about how to build a successful project but have yet to address how students will learn science subjects through the project. This gap can be used to improve future STEM training for programmers. Professional development should incorporate content and pedagogy in a collaborative and supportive environment with opportunities for application, reflection, and correction.

Keywords: *Bioplastic, Chemistry concept, Engineering design process (EDP), Environment, STEM education.*

1. Introduction

The quality of a teacher has a significant impact on student achievement [1]. Teacher training builds professional knowledge, which enables teachers to utilize appropriate actions in teaching circumstances, resulting in student achievement [2]. Like their counterparts in affluent countries, policymakers in developing nations have established teacher professional development (PD) programs, aware of the significance that teacher quality may play in boosting student learning results [3]. Recognizing the importance of teacher professional development programs in assisting teachers in gaining subject-specific knowledge and skills, using appropriate instructional practices, and developing positive attitudes and values (all of which have substantial positive associations with student achievement) [4]. Despite these noble goals, teacher professional development programs may fail to improve teacher and student outcomes if the content is of poor quality or relevance if it is delivered ineffectively, if there is no follow-up to help teachers put what they have learned into practice, or if trainees are not held accountable for their work [5]. The content areas of science, technology, engineering, and mathematics (STEM) are inextricably linked. The context of solving real-world problems is one method to appreciate the complicated interrelationships. *Engineering* is a scientific subject that uses mathematical computation and scientific knowledge to create processes or products (i.e. technologies) to solve issues [6]. In turn, technologies are employed to increase scientific and mathematical knowledge and engineering design. Most societies rank having sufficient STEM knowledge and the capacity to integrate these resources to find solutions for new problems as a fundamental capability. A society's collective ability to develop STEM knowledge affects its global standing. As a result, there has been a surge in interest in integrated STEM education [7,8]. One aspect of such recognition would be the requirement to develop teachers who are well-versed in STEM disciplines and engineering design. Furthermore, engineering content and methods are unfamiliar to teachers [9]. As a result, there is a definite demand for STEM Education teachers' training. Additionally, research indicates that children learn more effectively when involved in meaningful activities [10] that result in authentic artifacts [11]. The huge increase in the world population and consumption habits over the last two centuries has had various negative effects on the environment. The high level of public consumption causes an increase in the use of plastic for wrapping foods, etc. Plastic is widely used as a container because it is more flexible and water-resistant when compared to wood or metal. Because of their properties, plastics are widely used in industry and the economy. Plastic wastes account for around 12% of the world's solid garbage, and their annual production has been steadily increasing since 1950, surpassing 6 billion tons of rubbish generated between 1950 and 2015 [12]. The increase in the use of plastics causes environmental and health problems, as the volume of plastic entering the oceans increases sharply. Plastic can cause pain and hinder the digestion of food. This concern arises from the harmful chemical content of plastics as additives or those adsorbed from seawater [13]. Plastics can transfer toxic chemicals from marine organisms [14]. On the other hand, specific uses of bioplastics may represent areas of potential large-scale replacement [15]; for example, biodegradable materials for packaging and other short-lived use sectors are viable, as they account for a significant portion of total plastics production [16].

Awareness of the dangers of environmental pollutants needs to be instilled early. One of the efforts to instill that awareness is through education [17]. In this case, the teacher as facilitator in the classroom plays a vital role in appropriately conveying the message to preserve the environment [18]. For the message to be adequately conveyed, an attractive learning design with a STEM approach is needed for students.

2. **Plastic, Bioplastic, and Environment**

Sustainable development has risen to prominence as a global goal in the modern era [19,20]. The rise of plastic garbage is one of the impediments to sustainable development, making attractive many researchers to focus on it [21-29]. Plastics, primarily derived from petrochemicals, are widely used in daily life, primarily for packaging purposes.

Regrettably, a significant portion of these plastics are non-biodegradable and harm the environment, including carbon dioxide (CO_2) emissions and long-term build-up [30]. Additionally, hazardous chemicals in some plastic packaging, such as bisphenol A, antimony, and phthalates, can leach into food products [31] and cause varying degrees of harm to human health. Chemical concentrations in mm-size plastic trash collected from the open ocean, urban, and rural beaches are shown in Figure 1 [32].

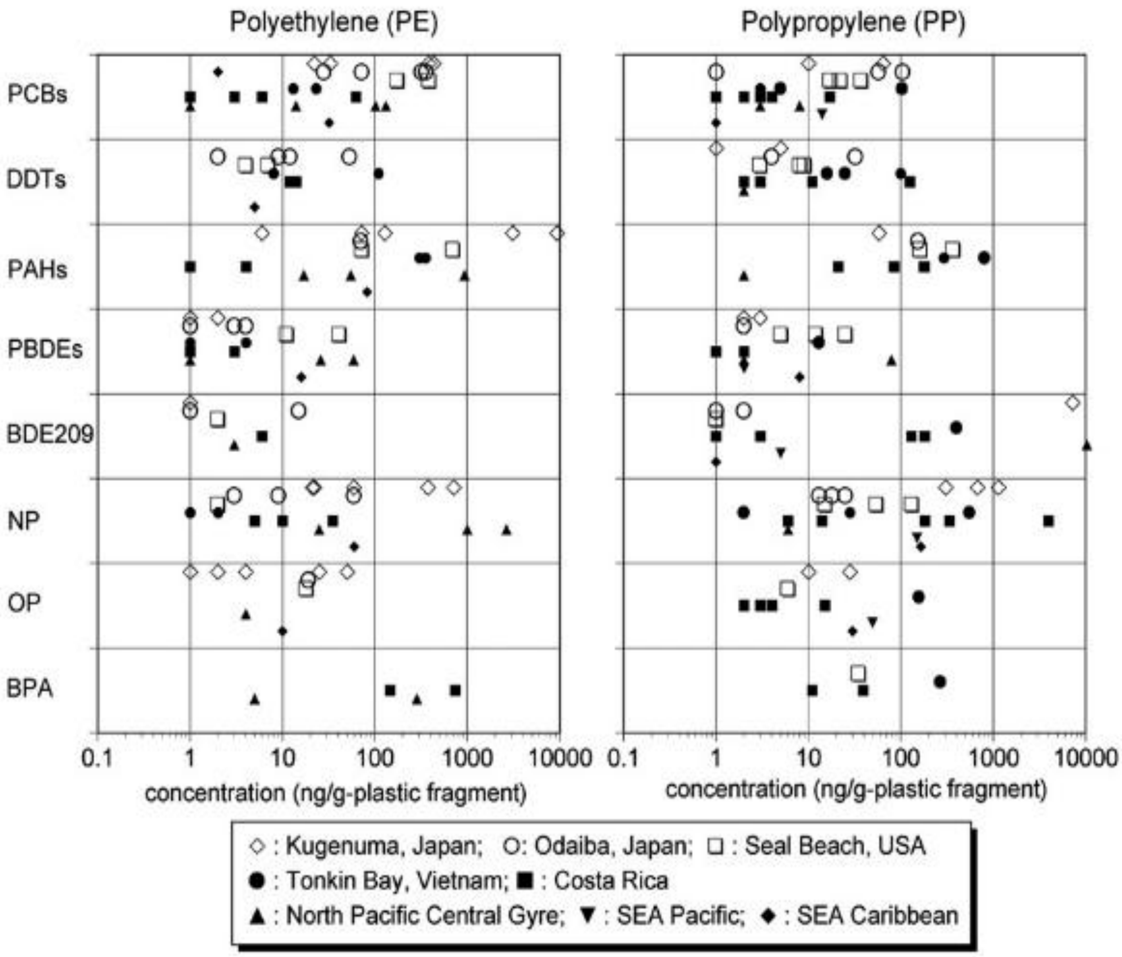


Figure 1. Concentrations of organic micropollutants in marine plastic fragments[32].

The chemicals in figure 1 include polychlorinated biphenyls (PCBs), chlorodiphenyltrichloroethane and its metabolites (DDTs), polycyclic aromatic hydrocarbons (PAHs), polybrominated diphenyl ethers (PBDEs), nonylphenols (NP), octylphenol (OP), and bisphenol A (BPA). Their concentrations varied from one to ten thousand nanograms per gram. They come from two different places. Additives like BPA, which were originally added to plastic items, are one type of chemical. Hydrophobic substances such as PCBs and DDT that were sorbed from the surrounding saltwater make up another type of chemicals. However, strategies for managing plastic garbage can help mitigate these detrimental consequences, including recycling, reuse, and incineration. Sadly, recycling and reuse do not eliminate harmful chemicals or nonbiodegradability, and incineration contributes to environmental damage. Alternative degradation mechanisms such as photodegradation, thermal-oxidative degradation, and biodegradation are being considered [33]. *Biodegradation* is when lengthy polymer chains are broken down into smaller units of dimers or monomers that are easily degradable by microbial enzymes [34]. Thus, the spread of synthetic plastics created from petrochemicals has developed into a severe issue for public health, the environment, and the economy [35]. The

application of microorganisms to environmental restoration has received considerable attention in various fields of scientific research [36]. The global trend is to outlaw single-use plastic packaging made of petrochemicals to combat this proliferation. In this setting, developing bio-sourced and biodegradable plastics from indigenous resources looks to be a viable alternative to non-biodegradable petrochemical plastics [37]. Starch is widely used to make simple bioplastics. Starch is a water and alcohol insoluble polysaccharide made up of amylopectin and amylose molecules, both of which are made up of monomers of D-glucose (Figure 2) and are the primary storage carbohydrate in vegetative cells.

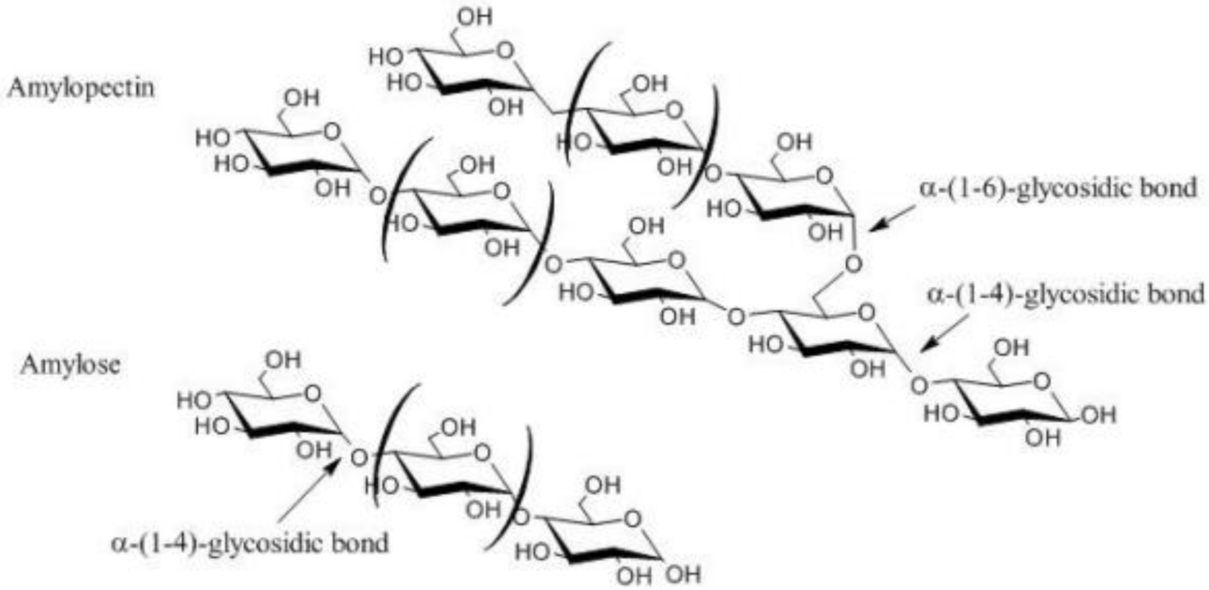


Figure 2. Amylose and amylopectin starch structure are represented [38].

The hydroxyl group and oxygen atoms in amylopectin and amylose form intermolecular connections that connect the native starch molecules. Amylopectin and amylose are linked together by hydrogen bonds, rendering them insoluble in cold water. However, when exposed to gelatinization temperatures, the molecules undergo considerable modifications, resulting in the dissolution of hydrogen bonds between starch components due to the availability of heat energy in an aqueous solution (Figure 3). Apart from the hydrogen bond breaking, the viscosity of the starch solution increases between amylose and amylopectin due to amylose leaching, starch structural loss, birefringence, and interactions between water and starch via free hydroxyls [39]. As a result, gelatinization begins in the polymer's amorphous areas.

When produced without additives, polysaccharide-based bioplastics are brittle, non-continuous, hard, and fragile [40], as are plasticizers' molecules utilized to form continuous bioplastics [41]. Glycerol and sorbitol are two plasticizers that are compatible with polysaccharides. The plasticizer effect leads to an increase in the interstitial volume of the polymeric matrix, which results in increased flexibility of the bioplastics [42].

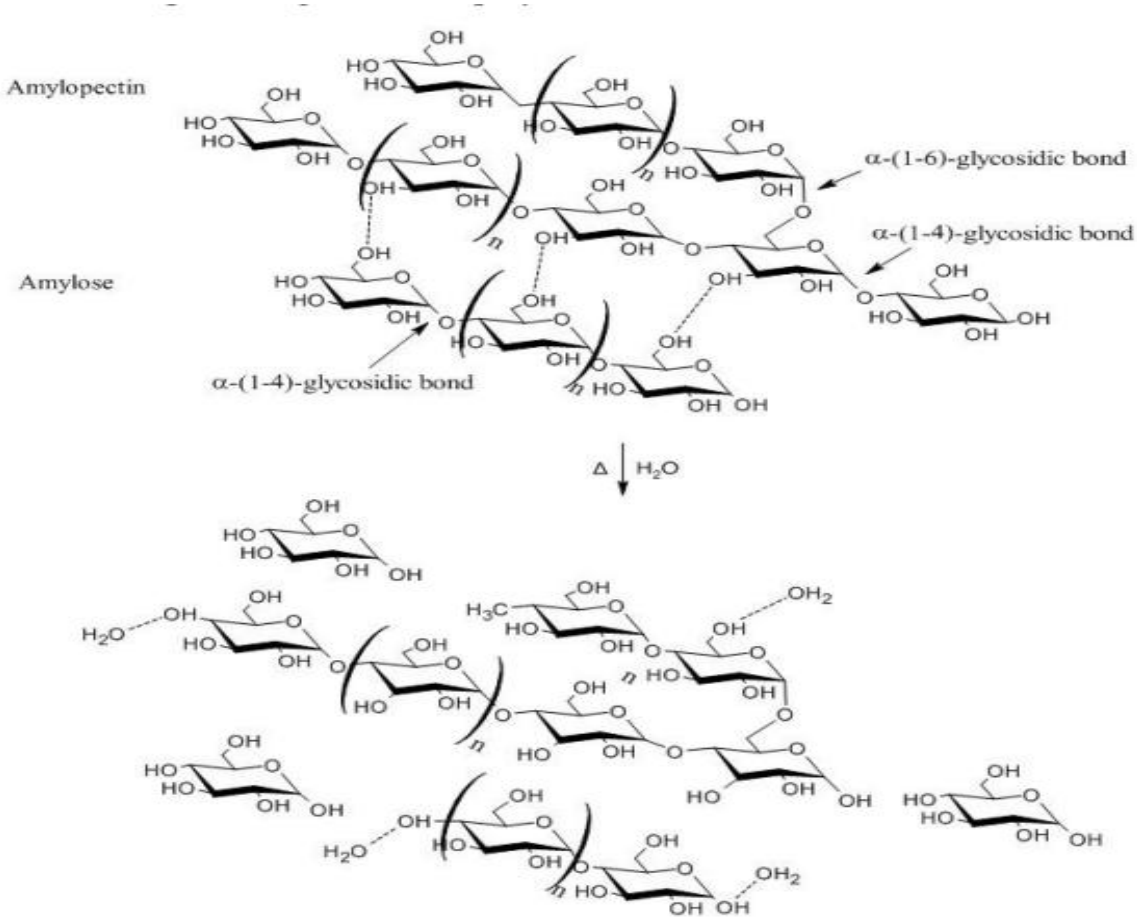


Figure 3. Starch gelatinization [38]

3. **Methods**

This research study method is the one-shot case study, where the trainees were given treatment in the form of online training using the Moodle Learning Management System (LMS). The training was held for ten days and attended by 30 junior high school science teachers. There are three sessions in this training. Each learning step is made restrictive, so teachers can continue learning activities if they have already done the previous activity. Session 1 studied the material characteristics of STEM education and 21st-century education. The learning activities in this session were zoom meetings to explain the material, a discussion forum to discuss the 21st-century learning paradigm, the relationship between STEM learning and 21st-century skills, and the characteristics of STEM learning. The last activity in this session is to create a concept map from the teaching materials attached to the LMS. In session 2, teachers practice Engineering Design Process (EDP) by making bioplastics an alternative inspiration from petroleum plastics widely used today. This is applied by teacher in STEM learning [43]. At the beginning of the session, participants identified the problem after watching a video about the condition of the Indonesian sea, which is a haven for plastic waste. Then in the discussion forum, participants discuss solutions to solve the problem. The last activity in this session is to upload the design, manufacture, and evaluate the bioplastics. This activity is expected to stimulate teachers to design STEM learning plans with other projects. In session 3, the training participants made a lesson plan with the theme “Environment.” The teacher does another project in the lesson plan besides bioplastics. The instrument to test the teacher's understanding of STEM learning uses pre-post test questions and is measured using effect size. The Hedges equation is used because it accommodates a relatively small sample size. Then the significance was tested with the Wilcoxon test.

The teacher's report on the manufacture of bioplastics is used to determine the extent of the teacher's understanding of the chemical concepts regarding the differences in bioplastic properties from petroleum plastics [44]. It can be seen from how the teacher discussed why bioplastic is easier to decompose in water and soil compared to petroleum plastic. The instrument used to determine the teacher's ability to make STEM lesson plans is a rubric. The rubric is used to analyze the suitability of the lesson plans made by the teacher with STEM learning activities. The suitability of the teacher's learning plan with STEM learning activities is to analyze the learning steps that have invited students to carry out the science process and EDP, which are the characteristics of STEM learning.

Table 1. STEM Online Training Design

Session	Material Description	Goals	Data Obtained
Session 1	This session discusses material about the characteristics of STEM learning and how STEM learning can support students in acquiring 21st-century skills.	Teachers understand STEM education	Pre-post scores on teachers' understanding of STEM
Session 2	The practice of EDP in STEM learning through the manufacture of bioplastics	Inspire teachers on how to implement EDP in the classroom	Chemistry Concept from Bioplastic Project in Teacher's Report
Session 3	Create a STEM lesson plan	Teachers can make STEM learning plans with an "environment" theme	STEM Lesson Plan

4. **Results and Discussions**

4.1. Teacher's Understanding of STEM Learning

In session 1, the teacher learns about STEM learning through teaching materials, discussion forums, and zoom meetings. To ensure that all activities in training are practical and have a positive effect on teachers' understanding of STEM [43]. A non-parametric test (Wilcoxon Rank Test) is carried out. By testing the effect size, the data obtained that g = 5.264, and the effect size is categorized as a firm effect size [45].

Table 2. Tests of Normality.

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Siq.	Statistic	df	Siq.
Pre-Test	0.215	30	0.001	0.934	30	0.064
Post-Test	0.361	30	0.000	0.358	30	0.000

a. Lilliefors Significance Correction

These findings indicate that the training provided to teachers has a strong positive effect on improving their learning outcomes. Table 2 shows the results of the normality test. The normality test shows that the pre-test and post-test data are not normally distributed (p-value less than 0.05) so the significance test (test the hypothesis using a non-parametric test (Wilcoxon Rank Test) [46, 47]. Table 3 is the result of hypothesis testing (significance test) using the Wilcoxon

rank test. This Wilcoxon test shows that the p-value is less than 0.05. These findings indicate that the training provided to teachers significantly increases their academic achievement.

Table 3. Wilcoxon Signed Ranks.

		Ranks		
		N	**Mean Rank**	**Sum of Ranks**
Post-Test-Pre-Test	Negative Ranks	1[a]	28.50	28.50
	Positive Ranks	29[b]	15.05	436.50
	Ties	0[c]		
	Total	30		
a. Post-Test < Pre-Test				
b. Post-Test > Pre-Test				
c. Post-Test = Pre-Test				
Test Statistics[b]				
	Post-Test – Pre-Test			
Z	-4.224[a]			
Asymp. Sig. (2-tailed)	0.000			
a. Based on negative ranks.				
b. Wilcoxon Signed Ranks Test				

4.2. **Chemistry Concept from Bioplastic Project in Teacher's Report**

Making a bioplastic project is the second session of this program. This project attempts to motivate teachers to create STEM learning plans with an environmental focus. Motivation is important in the teaching and learning process, making many people putting many strategies to improve it [48-53]. We looked at teacher reports to see how they used chemical and scientific principles to create bioplastic designs, as well as the results of their evaluations. Table 2 highlights the reports of teachers who took part in STEM training. Examples of chemical concepts contained in the teacher's bioplastic project report are:

(i) Plastic is an organic material that contains elements such as carbon (C), hydrogen (H), nitrogen (N), chlorine (Cl), and sulfur (S).

(ii) The chemical structure of bioplastics is almost the same as the chemical structure of petroleum plastics.

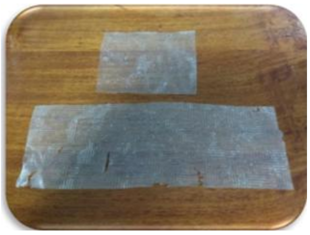
(iii) Glycerin can improve the flexibility of the bioplastic produced.

(iv) Bioplastic is easy to decompose at a high temperature.

(v) Hydrophilic.

The teacher merely cites these principles in the report but does not go into detail regarding the chemical reactions that occur when glycerin is added to starch [28, 31, 32], or why bioplastics break down quickly in hot temperatures or soil. The fact that more teachers do not analyze the resulting bioplastic items suggests that teachers do not understand how to use scientific or math concepts as a foundation for problem-solving in a project.

Table 2. Teacher's bioplastic report.

	Teacher's Report Type:		
	A	**B**	**C**
Bioplastic Composition	Starch, water, glycerin, vinegar	Corn starch, water, glycerin, vinegar, dye	Starch, water, glycerin, vinegar
Bioplastic			
Load Test	 100	 Example Load = 70 grams	No-load test
Examine how quickly bioplastics break down in the soil.	Not examine how quickly bioplastics break down in the soil.		Not examine how quickly bioplastics break down in the soil.
Product Variation	Water volume	--	--
The number of reports that contain pattern:	6	1	23

4.3. **Teacher's STEM Lesson Plan**

Integrating scientific and engineering methods into the learning process is one of the features of STEM learning. This adds appeal to STEM instruction and can boost students' desire to learn science. As a result, it's crucial to look at how teachers include these science and engineering principles in their lesson plans. In their lesson plans, the general teacher already knows how to implement EDP activities. Figure 8 shows that more than 60% of teachers have included all EDP steps in their learning activities, but only two teachers out of thirty have included the science process to enable children to understand concepts before producing designs. This indicates that 93% of teachers are concerned with how to create a good project but have not yet considered how students will learn science subjects through the project. This shortcoming can be used to improve the future STEM training program. Content and pedagogy should be

integrated into professional development in a supportive and collaborative atmosphere with chances for implementation, reflection, and correction [47].

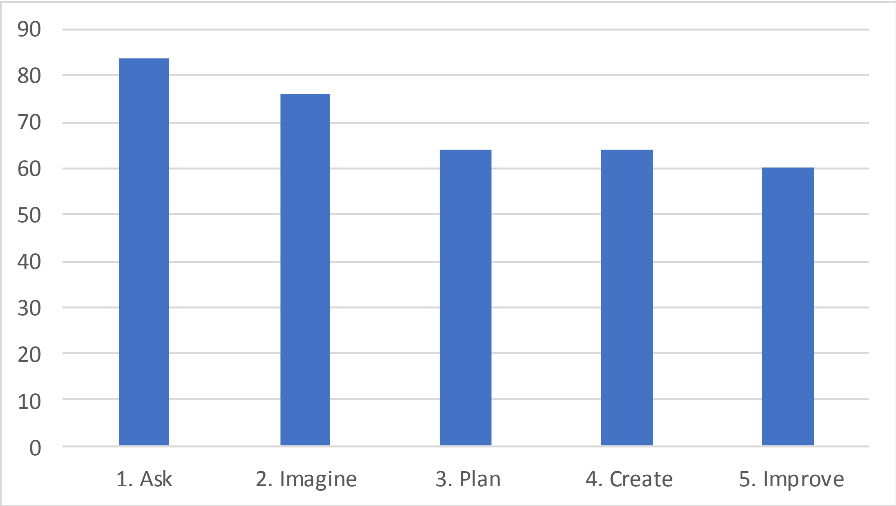


Figure 4. Percentage of teachers that include activities from each EDP stage in their lesson plans.

Conclusion

The results show that STEM training can increase teachers' academic achievement. But teachers don't know how to employ scientific or mathematical concepts as a framework for project problem-solving. The general teacher already knows how to integrate EDP activities into their lesson plans. According to the findings, 93% of teachers are concerned about how to construct a successful project but have yet to address how students would learn science subjects through the project. This gap can be used to improve future STEM training programs. Professional development should integrate content and pedagogy in a supportive and collaborative setting with chances for application, reflection, and correction.

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