

## Impact of Continuous Professional Development on Performance in High School Biology: A Systematic Review

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### Abstract

Continuous professional development (CPD) is necessary for the goal of upgrading professional skills and abilities. Although CPD has been the subject of various research, biology instructors have had very little biology-specific teacher professional development. This systematic review's goal is to evaluate how CPD affects teachers and students' performance in biology subject. An overview of 35 articles from peer-reviewed journals that were published between 2006 and 2022 is given in this article. Qualitative content analysis was used to examine the data. A total of 35 publications from 27 journals underwent in-depth analysis. The analysis' primary areas of focus were CPD strategies, learning settings, cognitive and psychomotor abilities, attitudes and emotions, and evaluation techniques. The qualities of effective CPD techniques were also explored, and their implications for teaching and learning were highlighted. The academic performance of the students in biology was found to be significantly improved in various ways by a total of 22 different CPD approaches. The CPD strategies that strongly involved teachers and active student participation were those that were most heavily highlighted. The findings of this research revealed that CPD improved the student's performance and the teacher's competence towards Biology subject.

Keywords: continuous professional developments; biology education, biology students' performance; upgrade professional skills

### Introduction

It is commonly accepted that increasing the caliber of teachers is vital to enhance the skills, knowledge and abilities towards teaching and learning practice via capacity development activities (Qablan et al., 2015). Thus, it is crucial to support instructors' Continuous Professional Development (CPD) in order to caliber the teaching and learning procedures (Lindberg, 2011). According to Garet et al. (2008), CPD is the best strategy for enhancing teachers' attitudes, practices, and beliefs in the classroom as well as the academic performance of the students.

Researchers from several countries have looked at how difficult it is for pupils to study biology (Atilla, 2012). Thus, many biological topics including the mitosis and meiosis, water transport in plants, physiological processes, hormonal regulation, photosynthesis, protein synthesis, Mendelian genetics, central nervous system, etc., are thought to be abstract and challenging for high school students to understand (Dede et al., 2009). Then, CPD is therefore required to enhance the caliber of biology-related teaching and learning around the world (Garet et al., 2011). The CPD has therefore played a crucial role in the teaching of biology in

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France, along with five areas of pedagogical such as lesson planning, managing a lesson and students, assessing learning and using relevant tasks (Burnaford, et.al, 2007).

The integration of CPD into high school biology curricula in Finland, Sweden, and Denmark placed an emphasis on biotopes and ecosystems, animal and plant life cycles, and processes that support life, such as photosynthesis, respiration, and biodiversity, but leaves out other aspects of teaching methodologies (Avalos, 2011). In fact, it is for this reason that we emphasize CPD methods in our study. Our goal is to determine and describe how CPD methods affect the ability of biology teachers and the performance of biology students in high schools (Kaur, 2012). As mentioned above, the growth of pedagogy and andragogy towards biology teaching and learning, and it has merely found that CPD is the engine for making education goals realist (Barber & Mourshed, 2007).

### **Theoretical Background**

The CPD has been more essential in empowering science teachers regarding passive and productive skills in teaching biology concepts which exist especially in the fields of ecology, biodiversity, conservation and system biology (Garet et al., 2008). According to Knight (2002), the ability to identify species is important for better understanding of biodiversity and issues concerning the environment and sustainability, not only for comprehension of certain branches of biology. Therefore, when biology education is given in connection through CPD approaches such as experiential, collaborative, process-based and problem-based experimental learning and computer-assisted methods can be useful in teaching and learning practices (Dede et al., 2009).

### *Common CPD Principles toward biology performance*

The CPD has been coherently enhancing quality of science subjects teaching and learning towards better outcomes, with that regard the biology performance can be resulted and achieved throughout effective CPD by active teaching methods such as the process-based instruction, problem-based learning, and participants-based are recommended by several researchers' conferences (Gersten et al., 2010). Therefore, process-based instruction focuses upon developing learners' independence in learning and problem solving by providing a framework into which curriculum activities can be placed (Bush, 1984). Indeed, problem-based learning, learners use "triggers" from a problem case or scenario to define their own learning objectives in CPD (Ball, 1995). Recently, the collaborative and inquiry-based study approaches have been investigated in the computer-assisted study biology subject in science (Carpenter et al., 1989). Thus, the studies have scientifically indicated that inquiry-based learning can be applied to the context of computer-assisted collaborative learning and that collaborative technology facilitates high-level cognitive and social interaction while students work together toward deeper understanding biology topics or concepts (Bautista et al., 2015). In fact, these skills are actually important when solving multifaceted science problems in teaching in order to work more capacity building for biology performance through skills development (Putnam & Borko, 2000).

### *CPD strategies for biology performance and general science*

The planning of future outcomes includes learning about biodiversity, climate change, sustainable use of natural resources, health, cultural heritage,

multiculturalism, and global welfare via CPD activities. In order to teach science effectively, it is necessary to highlight the effects of students' own behavior and employ CPD techniques (Bautista et al., 2015). Notably, students have authentic and dynamic experiences and opportunities for experiential learning through CPD in biological field-based activities like fieldwork and field trips, which piques their interest and improves their learning (Desimone, 2009). Additionally, students' participation in field-based activities is crucial to their understanding of biology (Borko, 2004). In particular, fieldwork gives students the chance to observe nature and the environment while applying the lessons they have learned in class (Desimone & Garet, 2015). This has a positive impact on the students' knowledge, attitude, and behavior, which are crucial elements in enhancing academic performance (Opfer&Peder, 2011).

#### *Outdoor education, as a CPD, towards biology performance*

Biology is one of the science subjects where the CPD is most prominently needed since it offers a variety of learning opportunities, including content exchange, hands-on activities, and learning environments that are also associated with improved educational outcomes (Lindberg, 2011). All activities are set up in authentic, frequently natural settings, allowing students to connect their theoretical understanding to encounter with diverse forms of real nature (Ball, 1995). Fieldwork and field trips are thus forms of outdoor learning, and in addition to outdoor pursuits, outdoor education also covers a broad range of transdisciplinary aspects of the environment outside of the classroom (Martín, 2015). Therefore, cultivating a relationship with nature is a crucial first step in comprehending the function of CPD in the biology teaching and learning

process (Burnaford et al., 2007). For this reason, various strategies for outdoor education and outdoor learning such as fieldwork, field trips, and nature studies are crucial for enhancing the outcomes of ecological literacy (Carpenter et al., 1989). Conversely, the most significant influence in sparking interest in biology is outdoor natural encounters (Hill et al., 2013). Several studies have shown that pupils learn substantially more effectively when they engage in hands-on activities and study in real-world settings, such as farms and the outdoors (Kazemi et al., 2008).

#### *Research aims and questions*

The goal of the CPD review was to provide an important response to the topic of how to teach biology in high schools in a way that is both successful and efficient while also highlighting the influence of CPD and strategies for improving biology performance in high schools. Hence, no prior research has compared and evaluated various CPD methodologies and strategies to address this challenge. The purpose of this study is to identify and characterize practical CPD approaches and methodologies in biology instruction as well as the effects of CPD on biology outcomes in high schools. Effectively, the findings are put to use in the creation of high school biology courses and instructions. The following research questions serve as a guide for the study:

1. What CPD strategies are used to enhance biology instruction and learning in high schools?
2. What are the characteristics of the effective CPD techniques for high school biology performance and instruction?

To address these questions, we looked at the CPD techniques, goals for the growth of emotions and attitudes, knowledge and cognitive abilities that are needed to be learned, learning environments, and how accomplishments were evaluated in order

to find answers to the first study question. We also examined the characteristics of effective CPD strategies and their potential effects on curriculum development, biology instruction, and high school biology performance.

## **Methodology**

### *Selection Criteria*

Having framed the review questions stated above, the team continued the systematic review by considering the selection criteria or reasons for inclusion and exclusion of studies in the review, which included the following:

1. *Scope*: National and international research;
2. *Type of research*: Empirical studies on CPD strategies for learning and teaching biology;
3. *Period*: 2006 – June 2022;
4. *Target groups*: students in high schools and pre-service biology teacher education;
5. *Languages*: English;
6. *Quality*: Published academic works in peer-reviewed journals.

### *The Systematic Literature Searching*

The researchers proactively developed the selection standards to be taken into consideration, employed the standards with systematic review software (or online tool) to select peer-reviewed journal articles, and examined these articles using specific, definable standards and dimensions (Knight, 2002; Zawacki-Richter, Kerres, Bedenlier, Bond, & Buntins, 2020). In this study, Purdue Online Writing Lab (OWL) was the systematic review software used to search academic databases (or citation managers) like Google Scholar, Science Hub, Web of Science, Academia, AJOL and ResearchGate.

The search technique was based on a systematic organization, categorization,

and selection of keywords associated with biology education and performance. Consequently, a word search was done involving the terms biology education, CPD approaches, high schools, science education, education for better achievements, outdoor education, fieldwork, excursions, and study trips, problem-based learning, project-based learning, experiential learning, game-based learning, value-based learning, place-based learning, collaborative learning, computer-supportive learning, inquiry-based learning, and teacher training. A common search strategy was created for the databases examined, tailoring it to the specifics of the respective platform. All searches were conducted in English, and we chose to use these keywords. Thoughtfully, the search fields were essentially restricted to the article titles and abstracts based on the demands of each database. Reviews and bibliographies were also employed, in addition to manual examinations of important research publications in biology education and students' accomplishments, including CPD.

We limited the review to academic papers published in peer-reviewed journals because they have undergone rigorous review and are therefore high-quality documents, even though we are well aware of the existence of other types of documents that could have been analyzed, such as dissertation theses, research reports, books and book chapters, and conference proceedings. Due to this, we also removed any publications that did not directly mention CPD strategies for biology instruction, including student achievement in that subject.

### *Appraisal and synthesis*

The research combines quantitative and qualitative elements. Then, we looked at the 40 journals on biology performance and education that were chosen. 35

publications altogether that discussed CPD strategies were included. Out of these, we chose 27 publications with 35 papers for in-depth examination. We used a qualitative content analysis approach for the analysis. Then, CPD techniques, learning environments, characteristics of practical CPD approaches, and consequences were examined using inductive content analysis (Ling, 2015). Deductive content analysis was therefore employed to examine evaluative methodologies, knowledge, and skills in addition to psychomotor abilities, emotions, and attitudes (Little, 1993).

All findings from the examined papers were first independently analyzed by selecting information units, categorizing them, and then categorizing the results again in order to confirm the process's dependability. The dialogical aspect of the analytical process and the generalizability of the findings stem from the choice of the studied data (Lam, 2015). I therefore made the decision to read the entire article before classifying it in order to ensure that our category choices were founded on a thorough grasp of the material.

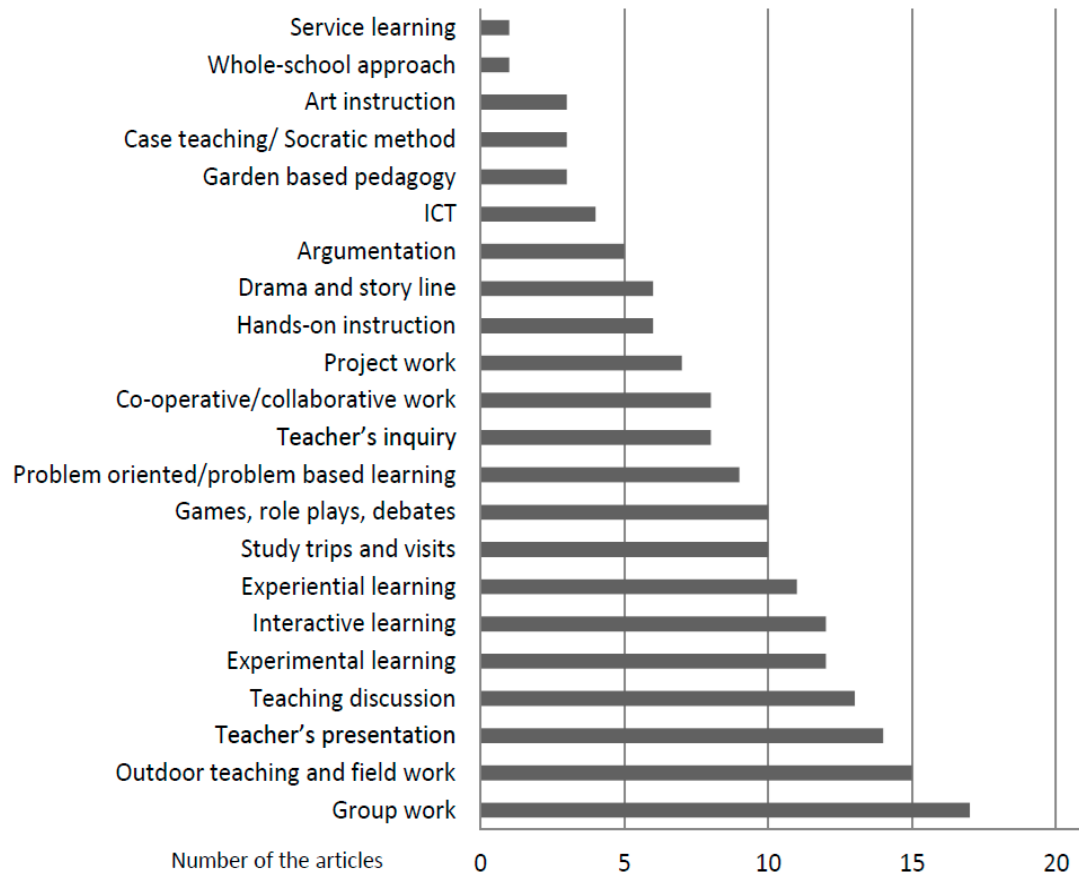
Thoughtfully, I also based on what the writers of the publications had specifically stated rather than what I sometimes believed I could infer from their intents by reading between the lines. Joint discussions about each article were crucial in determining which aspects of the instructional process the article emphasized because such decisions always involve elements of subjective interpretation. This procedure ensured that decisions were not based on a single person's first impression of an article but rather on well-argued joint discussions, so researcher triangulation was an essential part of our analysis process.

## **Findings and Discussion**

There are numerous publications discussing investigations and comparisons of CPD approaches in relation to other concerns in the studies of biology performance in high schools that were under the study. The CPD practices were studied and measured in different areas addressing their flaws and strengths. CPD strategies can be thought of as objective-oriented activities and information exchange between teachers and students. Because CPD approaches have an impact on all forms of learning in the cognitive, emotional, and psychomotor domains, investigations of CPD approaches are crucial (Martn, 2015). To attain the intended learning by pupils, teachers must adopt the ideas and methods employed in traditional biology instruction, which is deductive in nature. Teachers are at the center of this form of teacher-centered method of instruction. According to Darling-Hammond et al. (2009), alternative CPD methodologies are inductive, where education starts with observations, experimental data to interpret, or a real-world problem to be solved. Academic learning is monitored via objectively scored tests and assessments. Teachers and students both actively participate in the learning process while using a student-centered approach to instruction. The curriculum's aims are provided by the learning objectives, which also make it easier to choose and organize the content and allow for the evaluation of the learning's outcomes. As a result, the choice of CPD methodologies is

**Figure 1 CPD approaches found in the analyzed articles**

(Source: Bush, 1984)



influenced by the learning objectives (Dooner et al., 2008). Hence, in the investigated CPD approaches, a number of positive characteristics are highlighted and have consequences, particularly for building curricula and teaching methods for enhancing learning outcomes.

#### *CPD Approaches*

The evaluated papers contained a total of 22 distinct CPD approaches (Figure 1), and it was discovered that the approach that allows students to work in groups and actively engage in the learning process is the most widely used.

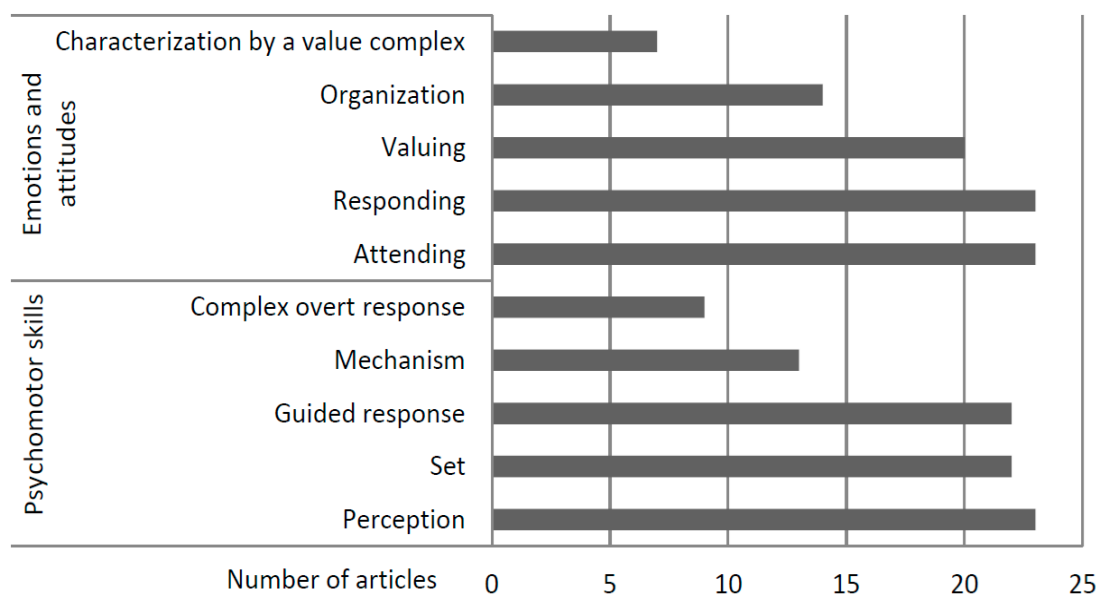
The most commonly mentioned CPD approaches were outdoor education and fieldwork, experimental, interactive, and immersive learning in today's science education (Yoon et al., 2007). As a result, presentations by teachers and classroom discussions were also well-liked, and it should be noted that they were frequently utilized to introduce students to the task and to goals.

Recent research has demonstrated that active CPD-learning processes in biology instruction greatly increase knowledge retention, improve motivation, and promote higher-order learning as well as the development of practical skills (Putnam, 2000). Hence, more than one-fifth of the publications focused on problem-oriented/problem-based, cooperative/collaborative, and argumentative CPD techniques. They thereby played a crucial role in the learning processes of pupils and, when utilized in conjunction with information and communication technologies, can improve learning results. On the other hand, collaboration encourages students to make their own ideas evident (Tan et al., 2014), which aids in their understanding of biology concepts (Penuel et al., 2007). When local features, phenomena, and challenges are used as context and scaffolding for biology curriculum in whole-school and service-learning settings, place-based learning in neighborhood environments and communities can be considered as a component (Sherin et al., 2004).

*CPD- objectives model for the Development of Psychomotor Skills, Emotions and Attitudes*

The psychomotor domain, which is linked to physical abilities and the use of the body in dance or athletics, was therefore evaluated as being improved by the CPD as effective teaching and learning techniques. As a result, the psychomotor domain focuses on the development of abilities for manual labor, physical mobility, and using instruments like computers and lab equipment (Bush, 1984). Perception, set and directed response, mechanism, and complicated overt reaction are thus its subdomains. According to Powell et al. (2010), perception is the capacity to integrate sensory information with motor activity and set to the readiness to act. The three initial subdomains were adequately represented in the articles (Figure 2), while the two last ones were not.

**Figure 2** The objectives for the development of the psychomotor skills (Source: Martin, 2015).





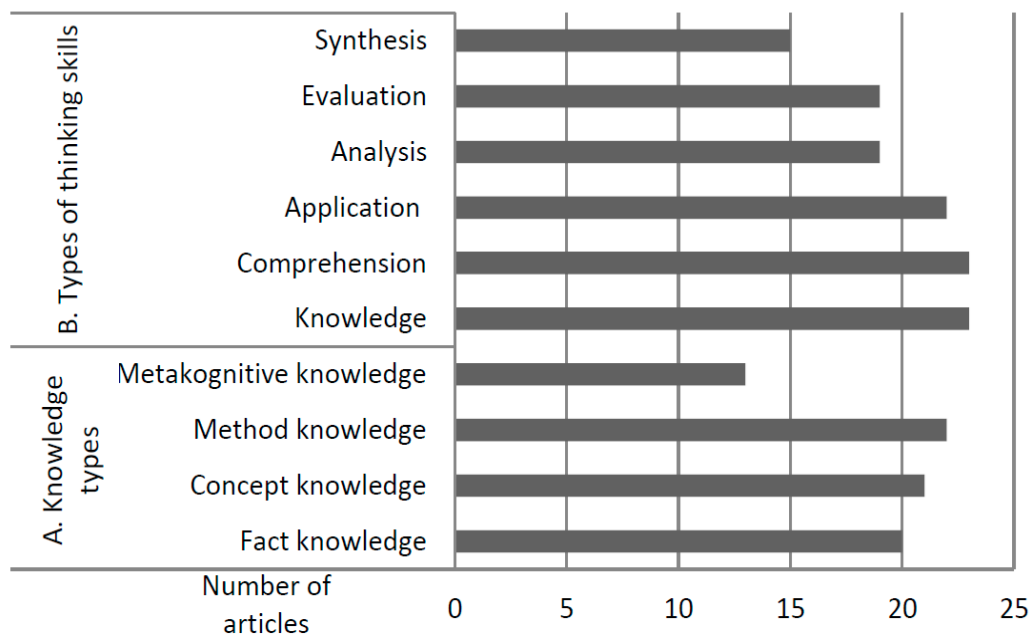
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*Knowledge and Thinking Skills to Be Learned throughout CPD*

Biology instructors' CPD has significantly improved students' knowledge and critical-thinking abilities in secondary schools. Odden (2002) identified four different categories of knowledge: factual knowledge, conceptual knowledge, procedural knowledge, and metacognitive

well as knowledge of subject-specific skills and algorithms, as well as subject-specific techniques and methods and criteria for knowing when to use appropriate procedures, are all included. Of these types of knowledge, metacognitive knowledge was the one that was least prevalent in the reviewed articles (Figure 3).

**Figure 3 Types of knowledge and types of thinking skills**  
(Sources: Borko, 2004; Darling-Hammond, 2010).



knowledge. In a nutshell, factual knowledge refers to the fundamental components (such as terminology and specific details) that students need to understand in order to understand a field of study or solve problems within it, while conceptual knowledge refers to the connections between those fundamental components within a larger framework that allow them to work together (Niemi, 2015). As a result, it also involves knowledge of theories, models, and structures as well as knowledge of classifications and categories, generalizations, and principles. Inquiry techniques, criteria for using skills, algorithms, techniques, and methods, as

*Learning Environments during CPD delivery*

In science lessons, CPD and the learning environment were closely related. To date, learning environments have been created to complement the chosen CPD methodologies, and both have an impact on students' academic success. Consequently, with 22 out of 35 articles mentioning them, classrooms were the most frequently used learning environment. Significantly, in addition to the customary instructor lectures and questions, learning experiences, recommendations, and conversations about the findings of observations and experiments were frequently conducted in



the classrooms. As a result, 14 articles stated outdoor and field learning environments, and different tourist destinations like museums, gardens, and nature parks were the third most popular learning environments (mentioned in 11 articles). Thoughtfully, these settings seem to be ideal learning environments since students learn much better when they have first-hand experiences and conduct their research in real-world settings (Schwab, 2015). In light of this, one explanation could be that emotionally supportive learning settings encourage students to use adaptive learning techniques like elaboration, organizing, and critical thinking (Darling-Hammond et al., 2010). Only five articles mentioned laboratory settings, despite the fact that these are locations where students may interact with real scientists and understand how research is conducted. Students can hone their experimenting skills in school laboratories by organizing and conducting small research. Two publications made reference to the internet and online forums. In order to facilitate cognitive process-oriented instruction, where the teacher's job is to encourage students' mental activity and promote self-control learning strategies, computer-assisted teaching and learning processes are a beneficial tool (Wei et al., 2009).

#### *CPD evaluation Methods towards biology performance*

The CPD was widely regarded as an efficient method for evaluating methods to scientific teaching and learning. Summative and diagnostic evaluations were also the most used CPD ways. As a result, assessment methods were studied using a standard classification of the teaching and learning evaluation kinds (found in 18 and 17 articles, respectively). Consequently, only 10 articles used formative evaluation. Summative assessment should be accompanied by formative and diagnostic evaluation since comprehensive evaluation is a crucial

component of teaching and learning processes. Because evaluation involves values and ideas that influence perceptions of assessment goals and targets that lead evaluation activities, the current evaluation culture should shift from being a measurement culture to a developing and supportive culture (Desimone & Garet, 2015). Thus, instead of teacher-centered assessment approaches as usually employed and students -centered evaluation is more encouraged as students can learn actively (O'Dwyer et al., 2010).

#### *Features of Useful CPD approaches and Implications*

The CPD activities have been really beneficial for learning and had a greater impact. In terms of productivity, the students' activity, participation, and interaction was the most stressed aspect of effective CPD techniques. This research thus highlights the need of CPD techniques that have a strong introduction, encouraging guidelines, and involve active involvement and interactivity. First-hand experiences, locally and place-based education, and continuous professional development are also stressed in the results, which support Guskey's research from 2002. On the other hand, systematic biology instruction, teachers serving as role models, ongoing improvement of teaching and learning outcomes, positive reinforcement, and whole-school strategies were unpopular (mentioned only twice in articles). Also, despite only being discussed in one article along with the notions that CPD should be considered at all educational levels and that there should be enough time for CPD, neither continuous teacher and staff education nor differentiation were well-liked. As the goals of CPD are not always reached in practice, various sorts of hurdles faced by individual students and teachers in learning and teaching outcomes, and familiarity with the CPD setting are possible causes, they may be similar to

those that Fullan & Miles (1992) reported in their study.

### **Conclusions and Implications**

The purpose of the study was to discover and describe practical CPD strategies for improving biology education and performance, including outdoor education, in order to enhance teaching and learning outcomes. Despite the fact that our evaluations of recent research on CPD approaches and their evaluation contained a number of specifics, a comprehensive comprehension of the educational processes is required to fully comprehend all consequences. All CPD strategies are, of course, subject- and context-specific, thus they cannot be ranked as the greatest or least effective strategies. The analyses, however, present ideas of how to combine these techniques together for increasing performance in teaching and learning process, and also of how to evaluate the whole process for the goal of curricula improvement. Thus, the study places a special emphasis on the importance of inductive CPD techniques with learners-centered approaches in real-world settings. The results strongly emphasized fieldwork and field trips, especially problem-based activities, as factors boosting students' interest and knowledge of sustainability, similar to earlier study (Garet et al., 2011). In fact, fieldwork appeared to have positive effects on students' attitudes and behavior regarding better academic performance (Desimone et al., 2002). Additionally, students' connections to and relationships with nature (Garet et al., 2001), environmental consciousness, and interest in biology are all crucial components in any effort to develop better scientists in the future (Darling-Hammond et al., 2009). The whole-school approach is thus something that should be given more consideration. It can improve school communities, Apple (2001) claims, by

fostering the growth of learning environments where kids feel comfortable, have a feeling of belonging, and gain the skills necessary to fully participate. The analysis' findings also highlighted the urgent need for numerous comparative studies of CPD strategies for improving science performance, especially biology, and their comprehensive evaluations in light of the desired outcomes. For the purpose of improving teaching and learning strategies and achieving better educational outcomes, we do highly advise all high schools, education officials, curriculum developers, science practitioners, and biology teachers to incorporate CPD effectively and efficiently.

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