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VOL. IX, ISSUE II, SPRING (JUNE-2024)

Global Educational Studies Review
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Article Title

Influence of Teachers' Professional Development in Integrated STEAM Pedagogy on Teachers' Practices

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Abstract

The study explored the influence of teachers' professional development (PD) on teachers' practices. The professional development training focused on integrated STEAM pedagogy, design thinking, and inquiry-based learning spanning three cycles of four weeks. Seven teachers from two schools for the underprivileged were a part of this qualitative action research study. A semi-structured interview protocol was used for data collection in three rounds of focus group interviews. Results from the thematic analysis report that the professional development helped enhance creativity, critical thinking, and innovation among the teachers. They gained a deeper understanding of the integration of STEAM pedagogy in their lessons. It also helped them empathize with the context of what is being taught themselves and foster it in their students too. They also reported higher levels of interest in active learning, confidence, and teacher agency, reflecting that the professional development training had a positive impact on teachers' practices.

Keywords: Professional Development, Design Thinking, STEAM Pedagogy, Action Research, Integrated STEAM, Teacher Agency

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Citing this Article

02	Influence of Teacher Professional Development in Integrated STEAM Pedagogy on Teachers' Practices				
	Author	Feza Mehddi Asma Shahid Kazi Abira Ismat Butt	DOI	10.31703/gesr.2024(IX-II).02	
Pages		11-20	Year	2024	Volume	IX	Issue	II

Referencing & Citing Styles	APA	Mehddi, F., Kazi, A. S., & Butt, A. I. (2024). Influence of Teacher Professional Development in Integrated STEAM Pedagogy on Teachers' Practices. *Global Educational Studies Review*, *IX*(II), 11-20. https://doi.org/10.31703/gesr.2024(IX-II).02
	CHICAGO	Mehddi, Feza, Asma Shahid Kazi, and Abira Ismat Butt. 2024. "Influence of Teacher Professional Development in Integrated STEAM Pedagogy on Teachers' Practices." *Global Educational Studies Review* IX (II):11-20. doi: 10.31703/gesr.2024(IX-II).02.
	HARVARD	MEHDDI, F., KAZI, A. S. & BUTT, A. I. 2024. Influence of Teacher Professional Development in Integrated STEAM Pedagogy on Teachers' Practices. *Global Educational Studies Review,* IX**,** 11-20.
	MHRA	Mehddi, Feza, Asma Shahid Kazi, and Abira Ismat Butt. 2024. 'Influence of Teacher Professional Development in Integrated STEAM Pedagogy on Teachers' Practices', *Global Educational Studies Review*, IX: 11-20.
	MLA	Mehddi, Feza, Asma Shahid Kazi, and Abira Ismat Butt. "Influence of Teacher Professional Development in Integrated Steam Pedagogy on Teachers' Practices." *Global Educational Studies Review* IX.II (2024): 11-20. Print.
	OXFORD	Mehddi, Feza, Kazi, Asma Shahid, and Butt, Abira Ismat (2024), 'Influence of Teacher Professional Development in Integrated STEAM Pedagogy on Teachers' Practices', *Global Educational Studies Review,* IX (II), 11-20.
	TURABIAN	Mehddi, Feza, Asma Shahid Kazi, and Abira Ismat Butt. "Influence of Teacher Professional Development in Integrated Steam Pedagogy on Teachers' Practices." *Global Educational Studies Review* IX, no. II (2024): 11-20. https://dx.doi.org/10.31703/gesr.2024(IX-II).02.

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Contents

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Abstract

The study explored the influence of teachers' professional development (PD) on teachers' practices. The professional development training focused on integrated STEAM pedagogy, design thinking, and inquiry-based learning spanning three cycles of four weeks. Seven teachers from two schools for the underprivileged were a part of this qualitative action research study. A semi-structured interview protocol was used for data collection in three rounds of focus group interviews. Results from the thematic analysis report that the professional development helped enhance creativity, critical thinking, and innovation among the teachers. They gained a deeper understanding of the integration of STEAM pedagogy in their lessons. It also helped them empathize with the context of what is being taught themselves and foster it in their students too. They also reported higher levels of interest in active learning, confidence, and teacher agency, reflecting that the professional development training had a positive impact on teachers' practices.

Keywords: Professional Development, Design Thinking, STEAM Pedagogy, Action Research, Integrated STEAM, Teacher Agency

Introduction

The popularity of STEAM (science, technology, engineering, arts, and mathematics) education in the past few years has grown as a pedagogical approach. It has proven to foster students' motivation in learning mathematics and science subjects, as well as learning and engagement across disciplines. However, STEAM as an intervention or approach cannot provide positive results unless teachers are equipped to carry out integrated lessons in STEAM effectively. Teacher effectiveness in this perspective is highly dependent on their professional development (PD). Unless they are provided the support and PD to improve their subject matter knowledge, as well as pedagogical content knowledge, they will not be able to deliver their best. This support has to be sustained and

not sporadic, and also contextualized to their workplace and needs (Boice et. al. 2024).

For effective STEAM implementation, PD has to be designed to provide guidance, dispel myths, clarify misconceptions, build expertise, and thereafter monitor and ensure a smooth transition and implementation of STEAM pedagogy (Romero-Ariza, Quesada, Abril, & Cobo, 2021a; Monkeviciene, 2020. To give their best, teachers need to have confidence in themselves, in the strength of collaboration and resource and knowledge sharing, and treading on the not-so-taken path to experiment. They need to have the desire to stay abreast of advancements in their areas of interest, and interdisciplinary approach. Such teachers prove to fare successfully in the adoption and delivery of STEAM pedagogy more effectively (Boice et.al. 2020, Martins & Baptista, 2024).

Research informs us that teachers also require autonomy, flexibility, and trust from the school administration to venture and explore new ways of teaching. This would vary for different classes and schools due to a host of reasons (Caton, 2021; DeJarnette, 2018; Wade et.al. 2023). Without support from the authorities, its implementation in classes cannot be successful.

Research is full of examples (Rodrigues-Silva, 2022; Herro (2017) where participation in STEAM PD boosted teachers confidence in planning and implementing STEAM lessons, as well as their own satisfaction and enjoyment of teaching. Boice (2021) reports how collaboration in STEAM PD had an impact on teachers' pedagogy, self-efficacy, and arts integration practices

This type of training does not empower the teacher alone, but also promotes creativity and purposeful engagement among students, promoting complex problems and developing critical thinking skills (Khan, Kazi, & Butt, 2023). In their study, Conradty & Bogner (2020) demonstrated that a long-term PD in STEAM teaching led to an increase in students' creativity and motivation, which can be attributed to the teachers' enhanced confidence and enjoyment in teaching STEAM.

This study investigates the influence of teachers' professional development training in Integrated STEAM pedagogy on their practices. An intensive training spanning over four to six weeks, focused on integrated STEAM pedagogy was imparted to teachers. During this period the teachers were provided extensive two days of formal training of about fourteen hours on design thinking, integrated STEAM pedagogy, interdisciplinary lesson planning, and

inquiry learning through design challenge activities. While the teachers developed and executed lessons on integrated STEAM, they were supported through informal training and facilitation for another eight to ten hours, spread over four weeks. They planned and designed lessons in collaboration, and executed them in sync with each other. Collaboration was possible face-to-face while they were in school. Besides that, a WhatsApp support community was formed for ease of collaboration outside of school hours. In the first cycle, teachers were provided with most of the material and instruction. In the second cycle of the intervention they collaborated and planned the lessons and design challenge activity with the researcher's facilitation and in the third and final cycle, they were given complete autonomy and supervised as and when required.

The intervention was conducted in three action research cycles, using the lens of design thinking, as explained in the method section in detail.

Research Question

How does teacher professional development (PD) in integrated STEAM pedagogy influence teacher practices?

Literature Review

Introduction to Design Thinking

Design thinking is a human-centered problem-solving approach that promotes creativity and innovation (Lor, 2017; Taşpınar, 2022). Design thinking can be applied in many fields like education, engineering, management, or technology. Incorporating design thinking in the field of education is important in developing 21st-century skills among teachers and students (Lor, 2017). Design thinking focuses on five phases, which are empathy, definition, ideation, prototype, and testing. Design thinking is an iterative process as it involves understanding a problem and finding a solution based on the user's need (Withell, 2013; Matthews, 2017).

STEAM Pedagogy and Interdisciplinary Approach

STEAM education is an approach that integrates Science, Technology, Engineering, Arts, and mathematics. Integration of arts in STEM resulted in STEAM education which fosters inquiry, critical thinking, collaboration, integration, and creative problem-solving. All of these skills are required to prepare students and teachers for the 21st century so that they

can face complex situations (Madden, 2013). The interdisciplinary nature of STEAM engages students in collaborative learning and real-world application in education. STEAM education promotes a holistic approach to the field of education (Psycharis, 2020; Costa, 2017).

STEAM Professional Development

Multiple studies have shared how professional development is an effective approach to support teachers in changing their beliefs, attitudes, and practices (Bush, 2016). STEAM Professional development training can enhance teachers' ability to integrate subjects and understand their implications in the real world (Herro, 2017).

STEAM professional development program enhances teachers' ability to develop students' STEAM competencies and apply relevant methods, approaches, or tools for effective learning both found that PD programs can enhance teachers' understanding of STEAM and their ability to integrate it into their teaching (Conradty, 2020). Further demonstrated that STEAM PD can positively influence students' creativity and motivation. These findings highlight the potential of PD in promoting effective STEAM education.

A few of the essential components that an effective professional development program include the use of technology and training should be prepared by keeping the teacher's needs and goals in focus (Monkevičienė, 2020). Professional development programs should prioritize activities that provide teachers with first-hand experience, getting feedback from experts, peers, or mentors (Phillips, 2008).

An effective professional development program includes the following components:

1. Professional development should be focused on the content of the subject matter so that teachers can apply it directly in their classrooms.

2. An effective professional development program should include an activity that allows them to collaborate and learn through first-hand experience.

3. In an effective professional development program teachers should be encouraged to collaborate and share their ideas with peers so they can experience what they should be expecting in their classrooms.

4. Effective professional development programs should provide teachers with appropriate feedback so they can

reflect on their practices and get a chance to change any future practices (Hasim, 2022).

STEAM Professional Development and Teacher Practices

Multiple researches have shown STEAM professional development has the ability to enhance teachers' practices (Cheung, 2024). STEAM education and design thinking both give importance to collaboration, the use of technology, and active learning (Herro, 2017).

The STEAM education framework relies on active and collaborative methodologies. These student-centered methodologies seek to solve contextual problems, investigate or discuss issues, searching for conclusions and possible solutions (Perignat & Katz-Buonincontro, 2020; Quigley et al., 2017; Sevian et al., 2018; Thibaut et al., 2018).

The professional development of teachers is considered to be a significant aspect of changing teachers' practices. Teacher training and professional development have many definitions, but their main goal is to promote teacher change toward better practice. A wide range of activities and interactions can increase teachers' knowledge or bring change to their practices (Desimone, 2011). Models of professional development have suggested a structured process that is needed to bring change in teachers' practices (Budarina, 2022; Peterson et al., 2009; Reinke & Sprick et al., 2009). Sustained professional development that challenges beliefs in a reflective community can empower teachers to implement new instructional approaches aligned with their evolving beliefs about teaching and learning (Thompson et al., 2018)

STEAM professional development is proven to be an effective approach to transforming teacher's practices and promoting students' active learning (Romero-Ariza, 2021b). STEAM professional development promotes collaboration among fellow teachers and between students and teachers. STEAM professional development program provides teachers with opportunities and resources to utilize training in their classroom with the help of experts and mentors.

Method

A qualitative action research method was adopted for the research. Two schools for underprivileged children were purposively selected as participants. These schools were selected as they give the researcher permission to carry out professional development with teachers on integrated

STEAM pedagogy, and its implementation in the classes. The teachers were given intensive training on design thinking, inquiry learning, and integration of Science, Technology, Engineering, Arts, and Mathematics, using the lens of the Stanford Design Thinking model. They were exposed to the use of design challenges using the interdisciplinary approach of STEAM. They went through three intensive cycles of implementation. The duration of each cycle was 3-4 weeks. They were taught to integrate lessons and plan design challenge activities accordingly.

Table 1

Professional Development in Integrated STEAM Pedagogy through Design Thinking

Empathy	For each design challenge, Teachers were expected to prepare worksheets, stories, and lesson plans which would help in building a connection between content and the real world, and thereby empathy. The A in STEAM was covered through English and Social Studies subjects. Teachers were trained to collaboratively design lessons focused on building relevance and evoking empathy among students, through stories in English and social studies subjects for three integrated STEAM design challenge cycles. This process was carried out for three weeks and each design challenge activity was based on the empathy that was created throughout the week.
Defining the need	Based on the empathy that was created, the teachers practiced how to brainstorm the need for the different design challenges in varying contexts with their students, e.g. for ramps, sun-blocking structures, and solutions. These questions served as the starting point for coming up with a design challenge activity. This was also done by all the teachers collaboratively, and executed during their respective classes in Science, Language Arts, Social Studies, and Mathematics
Ideation	This phase was put into effect during the last week of the intervention when teachers planned the execution of a design challenge activity in detail, where students were provided with low-cost material to carry out a scientific inquiry. Teachers were asked to encourage students to produce creative, original, and innovative solutions and models for the problem presented.
Prototype	The teachers through intensive PD were made to practice to give their students the freedom to choose materials of their liking and build two prototypes in groups of five. A prototype is a scaled-down version of the model. Contrary to their normal practice, they were told to allow their students to experiment and explore. They were also told to not teach specific content, but explore related ideas while carrying out the design challenge activity. For this activity to be successful they planned together the material required and their respective roles and tasks for the design challenge activity.
Testing	The teachers took on the role of a facilitator and allowed students to test their prototypes. They were required to give their students some liberty and allow them to experiment and draw logical conclusions on their own. This phase was focused on teachers asking questions about "what is working or not? And why? Instead of instructing students on what was working or not. They were expected to allow students to "re-test and re-plan" according to their own understanding.

Participants of the Study

The participants of the study were seven teachers from two schools. These schools were part of a welfare network specifically catering to low socio-economic status, and underprivileged children. The teachers taught Mathematics, Science, English, and Social Studies to grade 5. In school, the same teacher taught Mathematics and Science. Their break up is presented in the following Table 2.

Table 2

Participant Information

Subject	School 1	School 2
Math	1	1
Science		1
English	1	1
Social Studies	1	1

Research Instruments

A semi-structured interview protocol was developed by the researcher, encompassing the questions that would elicit responses related to the teacher's practices. Attention was given not to ask direct or leading questions which would serve as a prompt for possible answers. The instrument was validated by experts and piloted with three teachers to ensure it elicited valid and reliable results.

Data Collection

Data was collected after each action cycle of the intervention. In each cycle, the teachers planned, developed, and executed integrated STEAM lessons and collaborated to carry out the design challenge activities. After each cycle, a focus group interview was conducted with them. In this way, the teachers provided in-depth data through six focus group interviews, three from each school. The interviews were recorded and then transcribed. The transcribed data was sent back to the teachers for verification, in case something was omitted, misinterpreted, or added. After this, the data was coded and analyzed thematically.

Data Analysis

Data from the focus group interviews was transcribed, coded, and then analyzed for emerging themes. The detailed thematic analysis is presented as under:

Results and Findings

Emphasis on Problem-Solving and Interdisciplinary Learning

According to the majority of teachers, they believe that design thinking and STEAM promote problem-solving techniques and interdisciplinary learning. Going through training helped teachers in realizing how subjects are integrated and they can develop lessons, worksheets, or stories by understanding the main concept of the topic. Teachers were able to integrate their subjects and implement them into their practices.

Enhanced Creativity and Innovation

Design thinking promotes creativity and innovation. Professional development training showed teachers how to only facilitate during lessons instead of lecturing or dictating/instructing. Teachers realized how students came up with multiple creative and innovative ideas. As the teachers experienced this positive change among students, teachers expressed their desire to keep using design thinking in STEAM in their classrooms. Teachers preferred how employing this training brought a positive change in their classes and resulted in an active classroom.

Developing Empathy and User-Centered Design:

As teachers had to develop lessons and stories to build empathy they realized how subjects have connections with the real world. As teachers prepared lessons they tried to relate it with the students' surroundings and environment. During implementation, students had more examples to share with teachers. This experience showed teachers how subjects are present in the real world and can be used to relate to students' interests. Using already topics from their course and developing lessons shifted the teacher's lens to view courses with real-life implications instead of isolated subjects.

Encouraging Active Learning and Project-Based Learning

Analysis of teachers' statements revealed how they believe that design thinking encourages active learning and project-based learning. As the important part of the implementation

was conducting design challenge activity, teachers planned their lessons considering what activities could be planned. As teachers expressed, students were excited during lessons because they knew they were supposed to build a prototype based on the lesson. Teachers shared how students' responses to conducting activities made them realize how conducting activities promotes active learning. According to teachers, learning through project-based methods promotes effective learning. They shared their desire to keep employing this approach to learning as they experienced firsthand the results of this method of learning.

Fostering Critical Thinking and Reflection

Thematic analysis reveals that the training was successful in invoking critical thinking and reflection among the participating teachers. This is also an essential component of STEAM education. Through establishing empathy, and by adhering to the five design thinking principles themselves, the teachers expressed that they could pass on these skills to their students as well. Allowing students to work independently in teams, without the teacher leading them, they noticed that their students were effective in contexts of problem-solving and decision-making in STEAM. One of the teachers reported that it was difficult not to provide answers to the students, as that is what they were most used to. The Social Studies and English teachers from both the schools were very happy to have a link of what they were teaching in class with the real world and also with other subjects. In fact they expressed the desire to explore science with a different and new perspective. They reported " I was not sure what I would do in the scientific inquiry and design challenge" and that "I was skeptical what a Social Studies teacher has to do with technology, science and mathematics". A math teacher gave the view that "We compartmentalize our teaching and learning." Almost all the teachers reported that they had a better perspective of how integrated STEAM worked. These views are supported by other researchers as well. Bassachs et.al. (2020) report an increase in critical thinking among students as a result of STEAM PD. Thapaliya (2023) stressed that teachers need to be critical, and adaptable to understand their learners to effectively implement the integrated STEAM approach.

The practical Inquiry Model was seen by Roberg (2018) to have the potential to foster critical thinking skills in teachers. Raikou (2014) highlighted the importance of reflective skills for prospective teachers and emphasized these to be

strengthened during their training. These studies collectively suggest that STEAM approaches can play a crucial role in developing critical thinking and reflection in teachers, ultimately enhancing the quality of education.

Building Collaborative and Interdisciplinary Teams

Design thinking encourages collaboration and interdisciplinary teamwork among the teachers, which is essential for STEAM education. A major shift in their practice was initially teachers collaborated more with teachers who were teaching in the same discipline e.g English and social studies teachers were collaborating more with each other like science and math teachers were collaborating with each other more than other disciplines teachers.

Almost all the teachers expressed that "I don't remember asking so many questions from my students". I didn't think allowing students to discuss among themselves was a smart strategy as it would cause chaos in class". They all expressed that after incorporating design thinking principles, I realized that not just us the teachers, but also the students can build more effective and collaborative teams, leading to more innovative and effective STEAM education. Collaboration among teachers revolved around lesson planning, lesson sequencing of concepts across subjects for coherence, suggestions and opinions, feedback, and assessment.

Design thinking has been found to be a valuable tool in promoting collaboration and interdisciplinary teamwork among teachers, particularly in the context of STEAM education (Fredrick, 2008). This approach has been shown to shift teachers' practice towards more effective and innovative education, with a focus on student-centered learning (Weitze, 2017).

Enhancing Teacher Agency and Capacity Building

The teachers were in complete agreement on the value and significance of the professional development training. They agreed that they felt themselves to be more confident, and have a deep understanding of integrated STEAM pedagogy, especially the mathematics and science teachers. Design Thinking provides a structured approach for STEAM education. Design thinking elevates teachers' professional development by providing clarity and enhancing their ability to effectively integrate STEAM into teaching practices thus promoting an engaging learning experience for the learner. Also, it helps in bringing creativity and innovation to STEAM projects.

This finds support in the work done by Zarate-Pérez et.al. (2023) that by integrating design thinking in STEAM-based teacher professional development the learning experiences of the teachers are enhanced which provides a better understanding and brings out the creativity in STEAM subjects. It makes the teachers feel more in control of their teaching, experiment with approaches, and contribute to STEAM activities development (Moghal & Kazi et.al. 2020). Jia, Zhou & Zheng, (2021) advocated that this approach promoted learning across disciplines, motivation, and self-efficacy of pupils in elementary schools. The role of professional learning communities in supporting STEAM education training of teachers has gained recognition. Through fostering knowledge sharing, and collaboration, the teachers are equipped with tools and strategies to enhance their teaching capacity.

Conclusion

The study findings showed that the teachers' professional development helped develop a deep understanding among the teachers how seemingly separate disciplines can be integrated creating an engaging learning experience for the students. Developing empathy and connecting to real-world experiences, helped me to see the practical application of learning. The training encouraged the teachers to incorporate active learning, and project-based strategies in their teaching.

The study highlighted that professional development training helped equip teachers with skills to cultivate critical thinking, collaboration, creativity, and innovation. Positive change in teachers' practices was observed. The study suggested that professional development pieces of training had a positive impact on teachers' practices and enhanced their capacity to foster an engaging environment for the students.

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