ISSN 2301-251X (Online)
European Journal of Science and Mathematics Education
https://www.scimath.net
Vol. 10, No. 2, 2022, 243-255

OPEN ACCESS

The Role of Knowledge and Epistemological Beliefs in Chemistry Teachers STEM Professional Development and Instructional Practices: Examination of STEM-Integrated Classrooms

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Received: 19 Oct. 2021 ◆ Accepted: 5 Feb. 2022

Citation: Adebusuyi, O. F., Bamidele, E. F., & Adebusuyi, A. S. (2022). The Role of Knowledge and Epistemological Beliefs in Chemistry Teachers STEM Professional Development and Instructional Practices: Examination of STEM-Integrated Classrooms. *European Journal of Science and Mathematics Education, 10*(2), 243-255. https://doi.org/10.30935/scimath/11799

Abstract:
The goal of this study is to examine the role of knowledge and epistemological beliefs in the relationship between STEM (science, technology, engineering, and mathematics) professional development programme (SPDP) and instructional practices in a longitudinal study. To achieve this goal, it first determined the relationship and impact of SPDP on the implementation of instructional practices by comparing two groups (experimental and control group) of chemistry teachers after two years SPDP in Ekiti State, Southwestern, Nigeria. Data were collected from 90 teachers after the programme at two different measurement points through chemistry STEM-integrated knowledge assessment, questionnaires, and classroom observation checklists. Data were analyzed using t-test, bivariate correlation and structural equation modeling (SEM). Results indicated that teachers in the experimental group scored higher than their counterpart in the other group on all measures of instructional practices at both time intervals. However, there was no significant difference on overall instructional practices at time 1 but given the time interval, a significant difference exists. Teachers' participation in the SPDP was found to be highly correlated with STEM knowledge but weakly correlated with epistemological beliefs at time 1. Most importantly, STEM knowledge and epistemological beliefs mediated the relationship between SPDP and instructional practices at time 2. Implications for educational bodies, researchers, teachers and organizations planning to invest in teachers' SPDP as well as recommendations for future research directions are discussed.
Keywords: STEM professional development programme, STEM knowledge, epistemological beliefs, instructional practices, chemistry teachers

INTRODUCTION

One goal of science education in recent times is a focus on integrating science, technology, engineering, and mathematics (STEM) into the science curriculum. However, the decline reported in the number of students pursuing careers in STEM fields can be regarded as a tragedy for developed and developing countries alike, as workers in these fields are needed to alleviate the challenging economies of various countries (Adams et al., 2014; McDonald, 2016; Thibaut et al., 2017). In the quest to increase and retain students that can function in these areas, integrated STEM education has become a more necessary tool for ameliorating this problem. Integrated STEM education requires the teaching of science, technology, engineering, and mathematics in a more integrated way where engineering design helps students to solve real world problems. Evidence from research emphasized interdisciplinary study and collaborative work instead of isolated disciplines, which take place in contemporary classrooms (Al

Salami et al., 2017; Dasgupta et al., 2019; Kelly & Knowles, 2016; Nadelson & Seifert 2017; Parks et al., 2021; Thibaut et al., 2018). The place of integrated STEM education in chemistry is naturally ordained as chemistry subject itself is central to science, mingled with mathematics from inception and modern with the copulation of technology and engineering. Students ought to experience this integration to improve learning outcomes and become better chemists (Tunc & Bagceci, 2021). The educational stakeholders saddled with the responsibility of making the integration work out as expected in turn to retain students in STEM disciplines are the in service teachers.

In service teachers have therefore been engage in various professional developments programmes (PDP) in other to acquire knowledge on ways to integrate STEM activities into their instructional practices to improve students learning outcomes. Al Salami et al. (2017) described PDP as a complex process in which teachers must be cognitively and emotionally involved and enumerated different factors (structure of PD, context, and teacher characteristics) required for a successful PDP. Recently, science educators and researchers emphasize the importance of PDP for in service STEM teachers and investigated the effect of PD on students learning outcomes (Chirume, 2017; Du et al., 2019; Fletcher-Wood & Zuccollo, 2020; Tunc & Bagceci, 2021). In particular, Barlow et al. (2014) reported that teachers that consistently attend PD are more effective than teachers who do not which in turn result to higher grade for students of the PD teachers. Moreover, existing research have shown that PDP is associated with teachers' content knowledge in various disciplines (Gardner et al., 2019). Nevertheless, the optimal benefit of translating the knowledge acquired in PDP is not always evident in teachers overall instructional practices particularly those in STEM integrated classroom (Gardner et al., 2019; Thibaut et al., 2018). The non-implementation of part or all of the STEM instructional practices may result to render the resources and effort imbedded into it futile. In service teachers, especially those with large years of experiences coupled with other characteristics and environmental factors may be at a disadvantage in achieving positive professional educational outcomes probably because they have recorded students' success over the years (Toropova et al., 2019). Thus, it is important for these teachers to engage in a purposeful and structured PDP instead of the conventional PDP to minimize the losses incurred during most of these PDP. One way to verify that teachers implement the training they get from the PDP should entails examining the teachers' instructional practices before and after the PDP to ensure the objectives of the programme are achieved.

One of the main outcomes that can be utilized to determine the quality of teachers in the classroom, particularly when STEM teaching approaches are applied, is instructional practice (Holzberger et al., 2013). STEM Instructional Practices refers to the methods, tactics, approaches, and strategies utilized to convey educational information in a way that incorporates science, technology, engineering, and mathematics. There have been proposed teaching approaches that improve student learning results and reflect a STEM-integrated classroom. Though many of these common tactics are well-documented, the strategies identified in Thibaut et al.'s (2018) study are unique and adopted in the present study. The instructional practices in a STEM integrated classroom should be STEM-integrated (S-INT), problem-based, design-based, inquiry-based and project-based teaching strategies. A focus on connections, representations, and misconceptions between the STEM-disciplines as related to Chemistry should be emphasized in pedagogy of teachers (Du et al., 2019; Walker, 2007). The benefits of teachers using an integrated STEM approach are that students will be able to link chemistry concepts to solve real life problems. Researchers opined that instructional practices of teachers can be improved if teachers have adequate knowledge of content through an effective PD. For example, Barlow et al. (2014) through observations and interviews found that PD had low, medium and high influence on participants' instructional practices. Gardner et al. (2019) found that teachers' participation in PD had effect on instructional practices. In like manner, Du et al. (2019), observed that teachers implemented more effective STEM teaching strategies and had more positive perceptions regarding overall STEM.

In considering the diversity of approaches experienced in a STEM integrated classroom, it is crucial for in service teachers to be knowledgeable of these dimensions of STEM instructional practices in order to practice them. Chirume (2017) reported a study in which 85% of the participants had low to moderate levels of STEM knowledge. Another study by Jamal et al. (2018) revealed that 50% of the participating teachers neither had an understanding of STEM education nor can implement it in the classroom. The aforementioned statistics showed that teachers have limited knowledge about STEM content and its instructional practices. These necessitated researchers to recommend SPDP as a way out of the disheartening situation and researchers have shown it to improve researchers STEM knowledge over the years. Shahali et. al. (2015) reported that participants scores improved based on the result of their pre-posttest scores after been expose to a STEM intervention programme. Many studies in integrated STEM further concentrated on investigating the influence of STEM knowledge on attitude, perception or intention of teaching STEM in the classroom. Lin and Williams (2015) showed that knowledge and attitude were indirectly related to STEM teaching intention. Kurup et al. (2019) likewise reported that pre-service teachers despite have intentions to teach STEM in their future career. However, perception, intention or attitude does not mean the same as observed instructional practices. While the goal of recent SPDP is to enhance teachers' knowledge of STEM instructional practices, translation of this knowledge acquired to actual instructional practices can be hindered by negative beliefs (Walker et al., 2017).

Self-efficacy is one of the most widely explored beliefs in the literature, with multiple empirical studies attesting to its favorable association with teacher knowledge, attitude, and practice (Acharya, 2019; Gardner et al., 2019; Walker et al., 2017; Wang et al., 2011). Epistemological beliefs are another sort of belief that has received little attention among in-service teachers. Epistemological beliefs, according to Schommer (1990), are personal and implicit belief systems or individual assumptions regarding the nature of knowledge and its acquisition. The following five epistemic beliefs have been identified: (a) certain knowledge, (b) simple knowledge, (c) omniscient authority, (d) quick learning, and (e) innate ability. Researchers further grouped these beliefs to sophisticated and naïve beliefs (Acharya, 2019; Deng et al., 2014; Hashweh, 1996). Deng et al. (2014) submitted that teachers that have sophisticated beliefs tend to have the constructivist (student centered) approach towards teaching and learning while those that have the naïve beliefs embrace and utilize the traditional (teacher centered) approach to teaching. STEM instructional practices require teachers to be more constructivists in their approach to teaching (Mcdonald, 2015). It is however possible that the success of STEM instructional practices in the classroom depends on the teachers' epistemological beliefs concerning transition from their regular practices, to a more challenging environment where they have to go out of their comfort zone to promote students learning outcomes. Therefore, the current study posited that successful implementation of STEM instructional practices may be largely affected by teachers' epistemological beliefs (Bishaw, 2010).

Furthermore, according to Aksit (2007), teachers' beliefs should be examined before, during, and after professional development programs to see if they have changed. When creating PDP for teachers, however, most educational facilitators do not appear to take this advice into consideration. Furthermore, Wallence (2014) discovered that in-service instructors are adamant about not modifying their long-held opinions. As a result, the purpose of this study is to look at the role of STEM knowledge and epistemological beliefs in the relationship between SPDP participation and instructional methods.

CONCEPTUAL FRAMEWORK

The framework of this study was built on the Guskey (2002) model as it was used in Al Salami et al. (2017) who assessed changes in teacher attitude after participation in a STEM professional development programme. The model proposed that teachers' participation in PDP will lead to a change in instructional practices in the classroom only after they have experience a successful implementation. However, the present study posited that successful implementation may only take place if teachers knowledge and beliefs are properly channeled towards the change. Hence it was hypothesized that teachers STEM knowledge and epistemological beliefs will mediate the relationship between participation in SPDP and their instructional practices as shown in **Figure 1**.

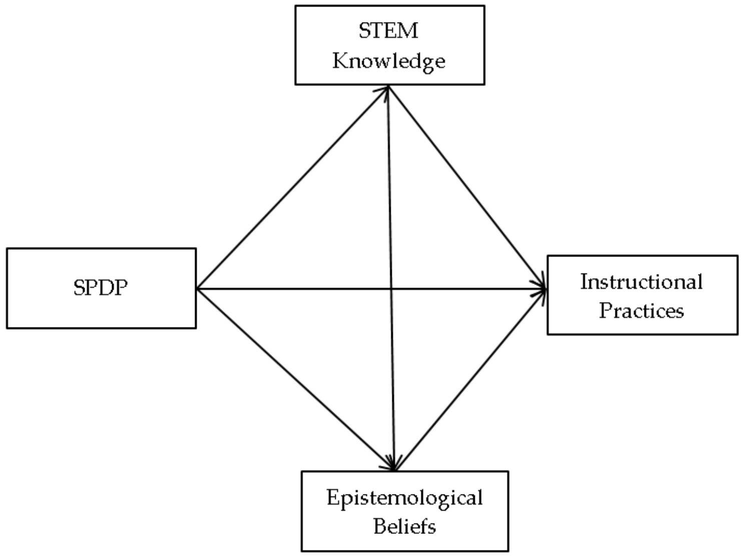

Figure 1. Hypothesized model for the present study

Purpose of the Study

The study aims to investigate the impact of SPDP on the implementation of STEM instructional practices in the classroom. To achieve this, the difference between two group of chemistry teachers STEM knowledge, epistemological beliefs, and instructional practices was examined, furthermore, the role of STEM knowledge and beliefs in the relationship between participation in SPDP and instructional practices was analyzed. The following hypotheses were hence formulated.

Hypothesis

1. There is no significant difference between teachers that participated in the SPDP and those that did not participate on their STEM knowledge, epistemological beliefs, and instructional practices.
2. There is no significant correlation between teachers' participation in SPDP, STEM knowledge, epistemological beliefs, and instructional practices.
3. There is no mediation effect of STEM knowledge and epistemological beliefs in the relationship between participation in SPDP and instructional practices.

METHODOLOGY

The study was quantitative and employed an ex post facto research design. An ex post facto research design was employed because the intervention (SPDP) was not modified by the researcher. As a result, despite a full description of the intervention being provided, the intervention could not be controlled for. The population from which the sample was drawn was all chemistry teachers in Ekiti State, Nigeria's southwestern region. The study enlisted 90 teachers from two (experimental and control) purposively selected groups from this population. Teachers who took part in the STEM professional development programme (SPDP) between 2017 and 2019 were recruited to make up the experimental group. They were chosen at random from the STEM department's database at the Ministry of Science and Technology Education in Ado Ekiti. These teachers were tagged group 1 (N=47), while those who did not participate in the SPDP formed the second group. They served as the control group and were tagged as group 2. Demographic information obtained indicates that out of the 47 teachers in the experimental group, 37 were female and 10 were male. The mean age of the experimental group was 38.2 (±1.21) years old and for the control group was 37.1 (±3.21) years. The mean years of teaching experience for the experimental group was 12.14 and 13.0 for the control group which showed that the teachers that participated in the study were not naïve to the profession. In relation to the highest

Table 1. Homogeneity between experimental and control group

	Experimental group (N=47)	Control group (N=43)	p
Gender			
Male	10(21.28%)	8(18.60%)	0.92
Female	37(78.7%)	35(81.4%)	
Age	38.2	37.1	0.57
Teaching experience (years)	12.14	13.0	0.89
Highest qualification			
BSc.	90%	85%	0.90
MSc.	10%	15%	

qualification obtained, 90% of the teachers in the experimental group indicated they possess Bachelor's degree in Education (BSc. Ed.) while only 10% indicated to have a Master's degree (MSc.) and for those in the control group, about 85% indicated to have BSc. Ed. while 15% indicated to have (MSc.). This demographic data was gathered to ensure homogeneity between the two groups of chemistry teachers' general characteristics. The analysis as shown in **Table 1** did not show any significant difference; hence the two groups possessed similar characteristics, which indicate that participants are homogeneous.

Intervention for the Experimental Group

During the years 2017-2019, the World Bank, in collaboration with the Ekiti State Government, organized a series of STEM professional development programs for science teachers dubbed "DIGI STEM," and some science teachers from sixteen local governments were selected based on the criteria that they were in charge of preparing students for external examinations.

The facilitators also gave practical demonstrations of robotics, Minecraft instruction, and scratch programming. Participants were given the opportunity to work in groups to create lesson plans using one of the robotics, Minecraft, or scratch applications, then share and compare their plans with their colleagues. Additionally, participants were required to list the objectives of different topics and discuss ways of maintaining a student-centered teaching technique in the classroom. Consistently, all the workshops are comprised of at least eight hours of lecture and demonstration for three days, after which a short quiz will be administered to the teachers by the facilitators. The control group teachers did not participate in the SPDP; they go about teaching in the classroom the usual way.

After the SPDP, trained observers saw the two groups of teachers during two 45-minute live lessons, with their lesson notes in their separate classes, and rated them using the STEM instructional practice observation checklists (Thibaut et al., 2018). The multiple choice items to assess STEM knowledge and the epistemological beliefs questionnaire to assess these teachers' knowledge and beliefs were also administered by these trained observers at two different intervals. A follow-up was conducted two weeks following the SPDP (Time T1), and the second measurement was conducted one year later (Time T2) by the same observers.

Research Instruments

Chemistry teachers STEM-integrated knowledge assessment (CTSIKA)

This scale was developed in relation to the modalities of the activities that should take place in a STEM-integrated classroom and also in compliance with the dimensions of the teachers' specialized knowledge (TSK) model mentioned in the literature by Aguilar-Gonzalez et al. (2019). An initial 30 items were generated based on the teachers': (a) knowledge of practices/strategies/approaches needed to teach effectively, tagged as "STEM Activities", (b) knowledge of topics and content in the specialized area, tagged as "chemistry knowledge", and (c) knowledge of features needed for students to learn, tagged as "students participation" and in relation to two topics taught in chemistry classes during the SSII second term chemistry curriculum; acid-base titration, water, and solutions. The items were sent to experts in the field of chemistry education for content validation, and some of the questions were rephrased in line with the suggestions and comments made by the experts to suit the purpose of the study. Field testing of the instrument was also carried out by administering the instrument to 35 non-participating chemistry teachers in Ekiti State. The scores from this field testing were subjected to item analysis in order to determine the difficulty level and the discriminating indices of each item. The approach of the upper 25% and lower 25% was used for the computation of the discrimination index (D). The discrimination index for each item was then calculated by subtracting the correct upper group score from that of the lower group, divided by the number of respondents in each group. The difficulty index (P) was computed by dividing the number of respondents that got the item right by the total number of respondents that participated in the assessment exercise. The range for the difficulty index was based on D'sai and Dionaldo (2017), who stated that the difficulty index ranged between 0.25-0.80 were ideal items, while items that were below 0.25 were deleted. Five out of the thirty items were deleted after the pilot study as they did not fall within the stated difficulty and discrimination index range, leaving a total of 25 items. The reliability coefficient was calculated to be 0.84.

Chemistry teachers' epistemological beliefs questionnaire (CTEBQ)

The CTEBQ is a quantitative measure of epistemological beliefs, and this measure included 25 items using a six-point Likert type scale (6=strongly agree to 1= strongly disagree) developed by Schraw and Olafson (2003). Schraw and Olafson (2003) questionnaire was designed to measure beliefs according to five subscales: certain knowledge, simple knowledge, quick learning, omniscient authority, and innate ability. This scale was refined to indicate sophisticated (student-centered) and naïve (teacher-centered) forms of teachers' belief about technological practices in the classroom. Following the same procedure provided by Swan (2007), the scale was constructed by reserve coding teacher-centered statements (items 1, 2, 4, 11, 16, 20, 23, and 25) and summing the ratings obtained. The scores ranged between 25 and 150 with higher scores reflecting more student-centered technology practices tagged as sophisticated epistemological beliefs and lower scores represent more teacher-centered technology practices tagged as naïve epistemological beliefs. Cronbach alphas were above 0.74 for all the five subscales of epistemological beliefs.

Teachers STEM instructional practices observation checklists (TSIPOC)

The original version of the Thibaut et. al. (2018) questionnaire on five subscales of instructional practices was adapted to mean teacher exhibition of STEM instructional practices. It is a 20-item scale with five factors. The five factors are STEM integration (S-INT); sample of items in this factor includes, teachers' shows examples, applications, and analogies from various STEM domains. The next factor is the problem-based teaching (PBT). Sample of PBT item includes: teachers allows students to develop their own experiments. Inquiry-based teaching (IBT) items include; teacher's allows students to evaluate the process, participate in research, and critique the process's pros and cons. A sample of the design-based teaching (DBT) item includes; teachers allow students to design a task of their own and the cooperative teaching (COT) sample item consist; teacher provides opportunities for face-to-face interaction between students. The scale was rated by three observers according to five proficiency levels, from 4 (very proficient) to 0 (non-usage), with a higher score implying more use of STEM-integrated instructional practices. Pearson product moment correlation was employed to analyse the three sets of scores obtained from the administration of the TSIPOC. The correlations between the three scores ranged from 0.96 to 0.80, which was averaged at 0.81. The instrument was hence found to be satisfactorily reliable.

RESULTS

The impact of the SPDP on teachers' instructional practices, STEM-integrated knowledge and epistemological beliefs was investigated. This was carried out by evaluating differences between the scores of teachers in experimental and control groups using descriptive statistics of group means (M), standard deviations (SD), and t-test analysis. The results of the analysis for both measurement points are summarized in **Table 2**.

Table 2. Statistical results for t-tests of the variables in the study comparing experimental and control STEM teachers at two measurement points

		Experimental			Control			
Variables	Measurement points	N	M	SD	N	M	SD	p
STEM KNW	Time 1	47	15.19	4.19	43	12.15	3.36	.000
	Time 2	46	15.81	3.85	44	11.47	3.00	.000
S-INT	Time 1	47	13.26	2.06	43	12.29	2.01	.028
	Time 2	46	13.48	1.95	44	12.06	2.04	.001
PBT	Time 1	47	11.93	2.73	43	10.79	1.99	.025
	Time 2	46	12.14	2.86	44	10.57	1.93	.002
IBT	Time 1	47	8.49	2.88	43	7.91	2.47	.312
	Time 2	46	8.93	2.68	44	7.48	2.49	.009
DBT	Time 1	47	6.63	2.64	43	6.49	3.07	.820
	Time 2	46	7.05	3.02	44	6.09	2.64	.113
COT	Time 1	47	6.88	2.90	43	6.26	2.81	.300
	Time 2	46	7.00	3.21	44	6.13	2.43	.153
INTPRAC	Time 1	47	45.67	8.95	43	42.94	7.91	.127
	Time 2	46	47.36	9.11	44	41.26	6.68	.001
EPB	Time 1	47	99.74	15.82	43	93.96	16.35	.092
	Time 2	46	101.09	15.03	44	94.07	15.41	.031

Note. *p<.05. INT: STEM-integrated teaching; PBT: Problem-based teaching; IBT: Inquiry-based teaching; DBT: Design-based teaching; COT: Collaborative teaching; INTPRAC: Overall instructional practices

The results indicated that there was a significant difference, $t_1(88)=3.76$, $p=.000$; $t_2(88)=5.93$, $p=.000$, between the STEM knowledge of experimental group teachers and control group teachers, with experimental teachers ($M_1=15.19$, $SD_1=4.19$; $M_2=15.81$, $SD_2=3.85$) scoring higher than the control teachers ($M_1=12.15$, $SD_1=3.36$; $M_2=11.47$, $SD_2=3.00$) at both time intervals. The results of the independent sample t-tests for each group of teachers also showed differences in only three of the five dimensions of instructional practices at time 2. These were the areas one would expect to see differences for teachers who had participated in professional development (PD) on the use of STEM instructional strategies. Teachers that participated in the PD showed that they had more knowledge of STEM instructional techniques that could breach out the commensurate integration outcomes; for STEM-integrated teaching $t(88)= 3.41$, $p=.001$; problem-based teaching $t(88)=3.22$, $p=.002$; and inquiry-based teaching $t(88)= 2.66$, $p=.009$. However, the results showed that there was no significant difference, $t(88)=1.72$, $p=.08$, between participation in SPDP and teachers overall instructional practices. Despite these insignificant difference identified, teachers that participated in the SPDP ($M=47.36$, $SD=9.11$) had a slightly higher scores in the assessment of instructional practices than the teachers that do not participate in the PD ($M=41.26$, $SD=6.68$). Nevertheless, there was also no significant difference, $t(88)=1.70$, $p=.09$, between the two group of teachers epistemological beliefs at time 1 but given the space of time, a significant difference was recorded.

Further analysis was carried out to evaluate the interaction effect of STEM professional development programme on each of the outcome variables. This was done by carrying out a group (experimental and control) by time (T1 and T2) repeated measures analysis of variance. Results of these analyses showed a significant group by time interaction effects for STEM knowledge, $F(1, 89)=56.21$, $p<.001$, $r=1.02$; overall instructional practices, $F(1, 89)=264.60$, $p<.001$, $r=.01$; and epistemological beliefs, $F(1, 89)=7.54$, $p<.001$, $r=.04$. Specifically, it can be implied from these results that the mean of teachers increased overtime (after the professional development) on all variables with teachers in the experimental group scoring more than those in the control group.

Bivariate correlations were carried out on the total sample for preliminary examination of the pattern of relationship between variables.

Table 3 shows high correlation between participation in SPDP and STEM knowledge at both measurement points ($r_1=.38^{**}$, $r_2=54^{**}$, $p<.01$) indicating that teacher's SPDP and STEM knowledge are strongly related. The relationship can be said to be positive and of large effect size (Cohen, 1992). The

Table 3. Mean scores, standard deviations, and bivariate correlations of the variables in the model at two measurement points

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
SPDP	-																
STEMKNWT1	.38**	-															
STEMKNWT2	.54**	.88**	-														
INTT1	.23*	.68**	.65**	-													
INTT2	.34**	.69**	.69**	.80**	-												
PBT T1	.24*	.51**	.50**	.53**	.54**	-											
PBT T2	.33*	.44**	.51**	.54**	.53**	.82**	-										
IBT T1	.11	.49**	.44**	.49**	.48**	.54**	.88**	-									
IBT T2	.27**	.31**	.43**	.48**	.49*	.55**	.54**	.90**	-								
DBT T1	.02	.22*	.29**	.24**	.29**	.28**	.29**	.14	.54**	-							
DBT T2	.17	.31**	.31**	.29**	.21*	.28**	.28*	.54**	.53**	.83**	-						
COT T1	.11	.45**	.29**	.30**	.29**	.30**	.30**	.04	.05	.03	.04	-					
COT T2	.23*	.64**	.39**	.29**	.29**	.30**	.30**	.64**	.04	.04	.04	.82**	-				
INTPRAC T1	.16	.64**	.69**	.69**	.69**	.68**	.69**	.35*	.63**	.61**	.06	.61**	.60**	-			
INTPRAC T2	.33**	.39**	.33**	.33**	.32**	.35**	.34**	.62**	.39**	.27*	.26	.25**	.24*	.39**	-		
EPB T1	.17	.27**	.37**	.37**	.37*	.15	.16	.20**	.20	.22*	.21	.12	.11	.29**	.29**	-	
EPB T2	.25*	.25**	.42**	.31**	.42**	.25**	.25**	.21**	.21	.14	.14	.07	.07	.28**	.21*	.82**	-

Note. *p<.05; **p<.01, two tailed. INT: Integrated teaching; PBT: Problem-based teaching; IBT: Inquiry-based teaching; DBT: Design-based teaching; COT: Collaborative teaching; INTPRAC: Overall instructional practices; T1: Time 1; T2: Time 2

result also showed that participation in SPDP has relationship with most of the variables at time 2. Particularly, a weak correlation between participation in SPDP and epistemological beliefs was observed (r_2=.23**, p<.01). Although, the result did not show relationship between SPDP and overall instructional practices, there was an identified relationship with some factors of instructional practices at time 2. For integration (r_2=.34**, p<.01), problem-centered teaching (r_2=.33**, p<.01), and inquiry-based teaching (r_2=.45, p<.01). This correlation observed established that there still existed a relationship between SPDP and instructional practices.

High positive correlations were found between STEM knowledge and all other constructs at both measurement points in general, however, the correlation strength among variables differs. For example, the correlation between STEM knowledge and the STEM-integrated factor of instructional practices, and epistemological beliefs at time 2 is stronger than for time 1 which is 0.68, whereas the correlation coefficient between these knowledge and teachers' overall instructional practices was higher in time 1.

In sum, the table demonstrated that participation in SPDP significantly correlated with few numbers of observed variables at time 1. Nevertheless, given a space of time, it correlated with all variables except for design-based teaching factor of instructional practice.

To investigate the direct and indirect effect of STEM knowledge and epistemological beliefs on instructional practices, a SEM analysis using the model constructed for the purpose of the study in fig 1 was carried out. The results of the analysis are shown in **Table 4**.

The SEM analysis on **Table 4** showed that for the total sample, there was a significant direct effect of participation in SPDP on both T2 STEM knowledge (B=.51, p<.001) and T2 epistemological beliefs (B=.25, p<.001). This implies that participation in the professional development programme leads to higher STEM knowledge and in turn to higher epistemological beliefs. However, there was no direct influence of participation in the SPDP and the teachers' instructional practices. Sequel to instructional practices, there was also a direct effect found between STEM knowledge and instructional practices. Nevertheless, both STEM knowledge and epistemological beliefs at T2 mediate the relationship between participation in STEM PD and instructional practices. This finding explains that when STEM teachers engage in SPDP, their beliefs are as equally important as the knowledge they benefit from the programme.

Table 4. Direct, indirect effects of teachers' STEM knowledge, epistemological beliefs variables on instructional practices

Variables	SEB	B	p	LL95% CI	UL95% CI
Direct effects					
PART IN SPDP → STEM KNW	.744	.51	.001	2.663	5.519
PART IN SPDP → EPB	2.93	.25	.014	1.447	12.710
PART IN SPDP → INS PRAC	1.57	.002	.995	-2.882	2.913
STEM KNW → INS PRAC	.194	.55	.001	.676	1.552
EPB → INS PRAC	.049	.28	.001	.067	.266
Indirect effects					
PART IN SPDP → STEMKNW→INSPRAC		4.415	.001	2.690	6.808
PART IN SPDP → EPB → INS PRAC		1.068	.009	.249	2.451

B: Unstandardized beta weight; SEB: Standard error of the unstandardized beta weight

Furthermore, an indirect effect of STEM knowledge (B=4.415, p<.001) and epistemological beliefs (B=1.068, p<.05) was identified in the relationship between participation in SPDP and overall instructional practices according to the hypothesized model in **Figure 1**.

The result also showed that about 30% of the variation in overall instructional practices can be explained by STEM knowledge, whereas 15% of the variation in teachers' instructional practices is explained by epistemological beliefs

DISCUSSION

One goal of the study was to see if experimental Chemistry teachers' STEM knowledge, epistemological beliefs, and teaching techniques changed from their peers in the control group. When the results of the two groups are compared, it can be seen that the experimental group scored much higher than the control group after engaging in the SPDP. Furthermore, their average STEM knowledge score improved with time. This demonstrates that involvement in SPDP boosted participants' knowledge, particularly among those who work in STEM-integrated classrooms. As a result, instructors should be exposed to professional development programs that will improve their expertise on a regular basis. The results of the present study are consistent with previous study of Shahali et al. (2015) on improving participants STEM knowledge. This previous study found significantly higher scores for participants' scores on the STEM knowledge content. The current findings also reflect those of Corlu (2012) who found that the group that was trained in an integrated STEM teaching performed more than their counterparts that remained departmentalized. An explanation for this finding may be that these teachers possess higher content knowledge.

On the other side, Gardner et al. (2019) found that STEM PD did not improve participants' STEM knowledge at the end of the program. This could be due to the fact that the study did not compare PD participants to other colleagues who did not take part in the PD. Furthermore, it's possible that considerable progress takes time to show.

In terms of epistemological views, there was no significant difference between the two groups at time 1, while there was a significant difference at time 2. This result supports Guskey's (2002) hypothesis, which was corroborated by Deng et al. (2014). This negates the findings of Al Salami et al. (2017) who concluded that one year is not enough for teacher change in their attitude.

In the extent of teachers' applicability and planning about instructional practices, the result shows that at time 1, there was no significant difference between the group, but eventually revealed that the experimental group differed from their peers at time 2. This implies that change in teachers' instructional practices may not be immediate, but at the long run, with increase in knowledge from continuous structured PD, they will definitely adjust their instructional practices. The finding mirrors that of Gardner et al. (2019) on teachers change in instructional practices. The researchers concluded that using qualitative analysis, teachers' instructional practices changed from the traditional practices to new practices that reflected implementation of STEM instructional practices.

Another purpose of the research was to see if there was any association between the variables for the entire sample at both measurement dates. The bivariate correlation analysis revealed that STEM training was substantially associated with STEM knowledge, epistemological beliefs, and instructional methods in both groups, particularly at time 2. This conclusion implies that an increase in instructors' knowledge and beliefs leads to an increase in instructional practice implementation and vice versa. The findings are consistent with earlier research on the impact of beliefs on instructional methods (Gardner et al., 2019; Polly et al., 2013). This study also revealed important findings regarding transition of knowledge and beliefs to practice. Noticeably is the result of the SEM analyses which showed the direct and indirect effect of participation in STEM professional development programme, knowledge, and beliefs on instructional practices. Consistent with the reports in the literature, STEM knowledge (Acar et al., 2018) and epistemological beliefs (Deng et al., 2014) were significant individual predictor of instructional practices for the two groups at time 2. However, there was no direct effect of participation in SPDP on teachers' instructional practices. This finding supports Barlow et al. (2014) study whose result also revealed that PD does not also have effect on some of the participants' instructional practices. These set of people that PD had no effect were tagged the no impact group and discovered to be those whom the objective of the PD negates their interest. They could also be regarded as those with naïve beliefs concerning the proposed instructional practices in the present study.

The hypothesized model (see **Figure 1**) posits that knowledge and epistemological beliefs can indirectly influence instructional practice and serve as a link between PD and implementation of instructional practice. Thus, these findings are in line with the hypothesis generated in the study. It also confirmed the claim of and empirically demonstrated the need identified in the work of Holzberger et al. (2013), where it was posited that knowledge and beliefs may account much of the variance observed in teachers' instructional practices.

Extensive research evidence has shown that different factors can be responsible for the non-implementation of STEM programs in the classroom. Some include cognitive (knowledge), behavioral contexts (attitude and beliefs), and school and management factors (Shernoff et al., 2017; Tanak, 2018; Thibaut et al., 2018). In line with these previous studies, this present study shows that participation in SPDP, knowledge, and epistemological beliefs are important factors responsible for the variation observed in teachers' instructional practices.

As a result, knowledge and beliefs serve as mediating variables in the translation of PD involvement into practice. Furthermore, the study's model confirmed the process by which professional development programs may be created to help instructors better implement instructional methods in the classroom. Thus, STEM training, knowledge, and epistemological attitudes can be inferred as essential variables in improving teachers' instructional approaches.

Implications and Recommendation

Several practical implications can be drawn from the findings of this study. The finding that there was a significant difference in the STEM knowledge of experimental and control teachers suggests the importance of teachers to attend more professional development programmes geared towards improving their knowledge of STEM instructional practices.

The results also indicated that the overall instructional practices of the two groups of teachers was not significant at time 1 corroborating the findings of prior studies that attending professional development programme does not necessarily translate to practice. However, if teachers are consistently provided with resourceful PD, overtime, it will translate to productive instructional practices. Though, the epistemological belief of teachers' variables seems less influential on their instructional practices, its contribution cannot be ignored. Thus, future studies need to address the epistemological beliefs of teachers at the beginning and end of the PDP.

The discovery that STEM knowledge and epistemological beliefs mediated the relationship between participation in STEM professional development programmes and instructional practices emphasized the importance of organizers of future educational professional development should take cognizance of training teachers to develop their beliefs alongside the proposed new instructional strategy to be introduced. Naive beliefs of teachers can be upgraded to sophisticated beliefs by regularly exposing them to professional development programmes. It is hence critical that teacher PDP address teachers' negative beliefs when introducing new instructional strategy. The study also elucidates the need for additional research to investigate other factors that may be influential on the instructional practices of teachers in STEM integrated classrooms.

Limitation of the Study

Despite the potential contributions of this study to the literature, it however has some limitations. The first limitation was the configuration of our study population. The participants in the present study were a self-selected group with interest in improving their STEM education knowledge and teaching, and therefore may not be representative of the larger teacher population. Additional research with a broad selection of teachers with a wide range of interest and motivation for increasing their STEM teaching capacity may be needed to fully substantiate the findings of the present study.

The second limitation was that the longitudinal data was collected over the space of one year after the participation in PD which some scholars suggest may not be enough period of time for a longitudinal research but should be three years and above (White & Arzi, 2005).

The limitations pointed out in the study provide excellent background and directions for future studies in this line of STEM education research.

CONCLUSIONS

This study's findings reveal a picture of the outcomes of professional development programmes in Southwestern, Nigeria. Further, it provides a valid conceptual model that explains the role of STEM knowledge and beliefs in the relationship between participation in PDP and instructional practices. Finally, the study indicated that teacher characteristics barriers constitute an important area that needs to be explored and addressed further to aid STEM instructional practices among in service teachers' through attending a structured PDP.

Author contributions: All authors were involved in concept, design, collection of data, interpretation, writing, and critically revising the article. All authors approve final version of the article.

Funding: The authors received no financial support for the research and/or authorship of this article.

Declaration of interest: Authors declare no competing interest.

Data availability: Data generated or analysed during this study are available from the authors on request.

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