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Research Trends in In-service Science Teacher Professional Development from 2012 to 2016

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This paper presents a content analytic approach to research related to in-service science teachers' professional development. The research under consideration was published in four international science education journals and three international conference proceedings specialized in science education from 2012 through 2016. A total of 204 articles (44 published in journals and 160 published in conference proceedings) were examined to identify the fields of concentration within continuous professional development (CPD) programmes, which are; focus of professional development, Types of Professional development, research purposes, research tools, Types of the data, the context of the in-service CPD programmes. The result indicated that there is increasing emphasis on pedagogical content knowledge (PCK), inquiry, problem-solving and thinking. Most of the journals and conferences provide CPD as in-school and long-term training programmes subject to systematic evaluation.

Keywords: professional development, research trends, in-service science teacher education, teachers' professional development

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INTRODUCTION

In the teaching profession, teachers are expected to acquire and upgrade teaching competencies, incorporate contemporary teaching strategies and become apprised of advancements in subject knowledge (Donaldson, 2010). Training sessions and workshops conducted for Saudi Arabian in-service science teachers have usually been too short and too rare to foster a change in teachers' classroom practices. The current challenges of reform in science education can be met if we help schools and other educational institutions to face such challenges. It is necessary to design extensive CPD programmes, which include the use of successful strategies to reach the ultimate goal of CPD (Darling-Hammond, Wei, Andree, Richardson, Orphanos, 2009; Wei, Darling-Hammond, Andree, Richardson, & Orphanos, 2009; Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003; Hofstein, 2005). Previous research on PD (Harris, 2016; Darling-Hammond & Richardson, 2009) has shown that active, reflective, sustainable, and job-embedded professional development programmes are the most effective forms of PD.

Studies on science teacher professional development (Jeanpierre, Oberhauser, & Freeman, 2005) have revealed that the characteristics of the training programmes, which can help teachers to successfully implement teaching methods and strategies in the classrooms, include the following: deep science content and process knowledge with numerous opportunities for practice, the requirement that teachers demonstrate competence in a tangible and assessable way, and the setting of high expectations for learning and the capability to facilitate multifaceted and inquiry-based experiences. Additional research (Thomson, & Kaufmann, 2013; & Crippen, Biesinger, & Ebert, 2010) has proved that good CPD may improve science classroom practices and ultimately student learning. Therefore, such programmes should focus on improving teachers' knowledge and skills. The following are the common characteristics of effective professional development practices in high-achieving countries (Wei et al, 2009, p 18):

- *Extensive opportunities for both formal and informal in-service development;*
- *Time for professional learning and collaboration built into teachers' work hours;*
- *Professional development activities that are embedded in teachers' contexts and that are on-going over a period of time;*
- *School governance structures that support the involvement of teachers in decisions regarding curriculum and instructional practice;*
- *Induction programmes for new teachers with release time for new teachers and mentor teachers, and formal training for mentors.*

Inquiry is an important part of the PCK knowledge and is required to be mastered by science teachers. This is a model that emerges from constructivist theory, which is based on observation and scientific study and which describes the nature of human learning

through real-world interactions (Kolb, 1984). According to this theory, people should construct their own understanding and knowledge of the world by experiencing things and reflecting on those experiences. acording to Piaget, (1973), the students' developmental stage plays an important role in their learning. Meanwhile, Vygotsky (1978) considered learning social in nature because it involves interaction between learners and their teacher and among the learners themselves.

To gain a better understanding of science teacher professional development, it is important to consider research trends for academic articles related to CPD published in respected journals and well-known conferences proceedings. The literature reported many studies (Rennie, 1998; Eybe & Schmidt, 2001; Tsai & Wen, 2005; Lee, Wu, & Tsai, 2009, Cavas et al. 2012) that analyse journals in the framework of science education in general. Other studies on science education have addressed specific themes within science education. Among the examples of such studies are; scientific literacy (Deboer, 2000; Laugksch, 2000), development (Chiappetta, 1976; Driver & Easley, 1978), the nature of science (Lederman, 1992; Abd-ElKhalick & Lederman, 2000), the laboratory in science education (Hofstein & Lunetta, 2004; 1982), attitudes towards science (Gardner, 1975; Gauld & Hukkins, 1980; Osborne, Simon, & Collins, 2003), and argumentation (Duschl & Osborne, 2002; Ozdem, Erduran, & Park, 2011). No studies have been found in literature that analyse journal articles for the purpose of identifying research trends in in-service science teacher professional development.

The consideration of research trends adopted by this study has been the approach of many educators (Chiappetta, 1976; Abd-El-Khalick, & Lederman, 2000; Cavas, Cavas, Ozdem, Rannikmae, & Ertepinar, 2012; Lee, Wu, & Tsai, 2009; Cavas, 2015). Other educators (Menand, 2010; Klein, 1990; Lattuca, 2001) have agreed that this approach is necessary in order to expose complex problems. We argue that such studies may enhance the quality of research and its measurements, thus meeting the demands of all of the stakeholders in the field of science teachers' CPD.

A recent study on research trends, which has some commonality with our study, was conducted by Walter and Briggs (2012). They analysed the results of 35 evidence-based studies of teacher professional development, which proved that effective teaching makes a difference for teaching skills and student learning. Crucially, they also defined the characteristics of professional development that make the most difference for teachers:

1. *Are concrete and classroom-based*
2. *Brings expertise from outside the school*
3. *Involves teachers in the choice of the areas to develop and the activities to undertake*
4. *Enables teachers to work collaboratively with peers*
5. *Provides opportunities for mentoring and coaching*
6. *Is sustained over time*
7. *Is supported by effective school leadership*

No studies that are related to research trends on science teachers' continuous professional development have been found, in literature, especially regarding in-service science teachers. Such studies may enhance the quality of research and its

measurements. In addition, analysing research studies related to in-service science teachers' Professional development published in well-respected refereed journals would also improve the quality of future PD programmes in Saudi Arabia. It would also help in determining research priorities related to PD in Saudi Arabia, whether for faculty members of higher education graduate students. It might contribute to the reform attempts targeted teacher preparation programs in KSA. Therefore, our study contributes to these fields. It investigates articles related to science teacher professional development published in well-respected journals. The targeted journals include the following: *The Journal of Science Education, Journal of Research in Science Teaching, International Journal of Science Education* and *Journal of Science Teacher Education*, in addition to conferences organised by well–known organisations, such as the National Association for Research in Science Teaching NARST, the European Science Education Research Association ESERA and the East-Asian Association for Science Education EASE.

METHOD

The research articles were analysed to extract the value and appropriateness of the trends with respect to the focus, types, and context of PD, the goals and tools of research and the types of data collected. First, we identified the trends in this analysis of these journal publications, specifically by comparing journals between 2012 and 2016. We conducted the analysis to identify the variables specified in the focus question of this study. By answering this question, we aimed to uncover the trends that might help us in the following ways: First; the answers may help us in proposing solid, effective, and sustainable CPD programmes for science teachers. Second, the answers may help us in proposing a systematic research map for the Excellent Research Centre of Science and Science Education and for our graduate students who are willing to perform research in the field of teachers' professional development.

Selection strategy

We conducted a search of SDL, Dar Almandumah, EduSearch and SCOPUS databases from 2012 through 2016 to find the targeted journals and conferences. We selected, from various parts of the world, four English-language journals (*Journal of Research in Science Teaching* (JRST), *International Journal of Science Education* (IJSE), *Journal of Science Education* (JSE) and *Research in Science Education* (RISE), and three conferences, National Council of Teachers of Science (NCTM), The International Group for the Psychology of Science Education (PME) and Science Education Research Group of Australasia Incorporated (MERGA) (see Table 3). To identify and collate the articles to be analysed, we searched for the following terms: 'science', 'teacher', 'continuous professional development' (CPD), 'Professional growth' and 'professional training'. The search resulted in 204 articles related to the professional development of science teachers (44 published in journals and 160 published in conference proceedings). Finally, we used the analysis tool to explore the following categories:

1. *A focus on professional development, which includes seven sub-themes: inquiry, PCK, problem-solving and thinking, action research, communities of practice and learning, and the beliefs and perspectives of teachers and students*
2. *The types of professional development, which encompass four sub-themes: training programmes and workshops, professional development models, CPD programmes (communities of practice, action research, teachers' research), and the characteristics of PD (teacher needs, teachers' perspectives towards PD.)*
3. *Research purposes, which includes three types: developmental, evaluative, and descriptive.*
4. *Research tools, including observations, surveys, tests, interviews and analyses, whether they are used alone or with other tools.*
5. *The types of data, including quantitative, qualitative, or both.*
6. *The CPD context, which includes three types: location (in or out of school), timing (during the workdays or in the summer), and on-site or distance.*

It is worth clarifying that during the analysis of the research papers, we derived some of the needed information from the abstract and other information from the text. However, for most of the analysed papers, we read the entire article to obtain all of the information or data we needed.

Sample

The selection of the sample was performed in three steps. First, we selected three international conferences and 4 well-known international journals. Second, we scanned the content of all of the selected journals and conferences to search for studies addressing science teachers' professional development. The total number of the articles is (6425), including (4956) articles or abstracts published in conferences and (1469) articles published in journals. Third, the scanning process produced (204) articles on science teachers' professional development, with (160) of them published in conferences and (44) published in journals.

In approaching the task, we decided to investigate the trends in articles related to professional development published in four English-language journals and three international conferences between 2012 and 2016 based in Europe (International Journal of Science Education, IJSE), the United States (Journal for Research in Science Teaching, JRST) and East Asia (Journal of Science Teacher Education, JSTE) and (Research in Science Education, RISE). The percentages of the PD papers in the journals and conferences ranged from 8.07% for JRISE to 1.55% for JRST. It should be noted that ESERA held conferences only on od years, 2013, 2015. Similarly, EASE held conferences every two years. Therefore, no articles are found in the years, 2012, 2014, and 2016 for ESERA, and no articles are found in the years, 2012, and 2014 for ESERA.

Table 1
Total Articles and Professional (PD) Articles in the Samples Taken From English-Language Journals and Conferences

Journal & conference	Year												% 0f PD papers
	2012		2013		2014		2015		2016		Total		
	All	PD	All	PD	All	PD	All	PD	All	PD	All	PD	
JRST	48	0	47	0	46	1	60	3	62	1	323	5	1.55
IJSE	127	3	128	3	130	1	137	0	127	5	649	12	1.85
JSE	42	2	58	1	44	0	31	1	37	0	212	4	1.89
RISE	59	3	105	4	39	4	40	6	42	6	285	23	8.07
NARST-C	755	19	779	13	697	24	745	7	679	28	3655	91	2.49
ESERA-C	0	0	339	27	0	0	326	9	0	0	665	36	5.41
EASE-C	0	0	277	0	0	0	316	10	43	23	636	33	5.19
Total											6425	204	3.18

Validity and Reliability

The researchers prepared the analysis tool in its initial version, which consisted of nine areas for the dependent and independent variables. To ensure the validity of the analysis tool, the initial study was submitted to a number of specialised experts from the department of curricula and instruction, and the tool was changed or modified according to their expert feedback. For example, the dependent and independent variables, the number of researchers, and the number of the samples were removed, and some linguistic expressions were modified. The final version of the tool consisted of six areas: the focus of professional development, the types of professional development, the context of professional development, the purpose of the research, research tools, and the types of collected data. Then, to ensure the reliability of the analysis, we selected (18) articles (3 from each year), comprising about (10%) of the English-language research articles. Then, to ensure reliability, two experienced raters were assigned to analyse these articles. The coefficients' values for the English-language articles fall between (.72) and (.83), which means that the agreement varied between good and moderate. According to Altman (1991), the extent of the agreement is very good if the Kappa values fall between (.81) and (1.00); good if they fall between (.61) and (.80); moderate if they fall between (.41); and (.60), and poor if they are less than (.20). Accordingly, the levels of the agreement between the two raters were between very good and good.

The two raters coded selected sample of the articles from each year. The inter-rater reliabilities were determined using kappa reliability coefficients (Table2).

Table 2
Cohen's Kappa Values for Inter-Coder Reliability Coefficients

Source	Years				
	2012	2013	2014	2015	2016
Articles in journals & conferences	.72	.79	.73	.77	.83

These results indicate that the agreement values between the two raters were high enough to allow us to use the analysis tool for the selected articles

FINDINGS

Six themes dominate the analysed studies on in-service science teacher professional development. Table 1 includes frequencies of the categories under the first theme (focus of professional development). Approximately 204 articles were found in the field of in-service science teacher CPD. Approximately 45 articles concentrated on constructivist approaches (inquiry, problem-solving, learning cycles, thinking skills, and other strategies and teaching methods), and 89 articles related to PCK. Similarly, 12 articles concerned lesson study and 34 articles related to the beliefs and perspectives of teachers and students. The remaining subjects included in Table 1, such as STEM, lesson study, and action research, received less attention from researchers.

Table 3
Focus of Professional Development

Focus on professional development	Year					
	2012	2013	2014	2015	2016	Total
Inquiry, problem-solving and thinking	10	6	6	11	12	45
PCK	10	15	13	16	35	89
STEM	0	0	2	0	4	6
Lesson study	0	5	0	3	4	12
Action research	1	1	4	1	1	8
Communities of practice and learning	4	2	2	0	2	10
Beliefs and perspectives of teachers and students	2	19	3	5	5	34
Total	27	48	30	36	63	204

Regarding the second theme, namely, the types of professional development, it was found that there were four types of CPD, as seen in Table 4. CPD programmes (communities of practice, action research, and teachers' research) received the most attention from researchers, with 93 out of the 204 analysed articles addressing this type of PD. The characteristics of PD (teacher needs and teachers' perspectives towards PD) came in second, with 48 of the articles addressing this type of issue. Additionally, 45 professional development themes were found in the analysed articles. These results can be presented as follows:

Table 4
Types of Professional Development

Types of professional development	Year					
	2012	2013	2014	2015	2016	Total
Training programmes and workshops	0	4	1	3	10	18
Professional development models	8	8	11	4	13	45
CPD programmes (communities of practice, action research, teachers' research.)	14	27	10	19	24	93
Characteristics of PD (teacher needs, teachers' perspectives towards PD.)	5	9	8	10	16	48
Total	27	48	30	36	63	204

For research purposes, Table 5 shows that among the 204 articles published, most of them were descriptive articles (116). The remaining research articles contained either developmental (36) or evaluative (23) themes.

Table 5
Research Purposes

Research purposes	Year					Total
	2012	2013	2014	2015	2016	
Developmental	4	10	2	9	11	36
Evaluative	1	9	1	3	9	23
Descriptive	17	19	24	19	37	116
Not determined	5	10	3	5	6	29
Total	27	48	30	36	63	204

In accordance with the results shown in Table 3, it is clear from Table 4 that observations (64), surveys (50), interviews (50), analyses (37), and tests (35) were found among the 204 analysed articles. It is clear that observations increased over the years (from 7 in 2012 to 26 in 2016). Similar trend also happens with survey and analysis. However, observation was used more be researchers. This might indicate that observation is considered as the right tool to evaluate the effectiveness of CPD or to report teacher effectiveness in the classroom. It might also indicate that researchers used both observation and surveys in their PD studies.

Table 6
Research Tools

Research tool	Year					Total
	2012	2013	2014	2015	2016	
Observation	7	15	5	11	26	64
Survey	4	13	3	13	17	50
Test	8	4	11	3	9	35
Interview	7	18	5	7	16	53
Analysis	2	6	6	10	13	37
Not determined	6	11	9	3	10	39

Table 7 includes the type of the data collected by the research studies. In accordance with data shown in Tables 3 and 4, most of the studies (121) were of a qualitative (69) or mixed (52) nature. The remaining (45) articles were not determined.

Table 7
Types of Data

Types of Data	Year					
	2012	2013	2014	2015	2016	Total
Quantitative	6	4	9	10	9	38
Qualitative	9	15	8	15	22	69
Mixed	7	15	4	6	20	52
Not determined	5	14	9	5	12	45
Total	27	48	30	36	63	204

Table 8 includes the context of the CPD, which includes the location of the CPD (in or outside school, on-site or distance) and the period (the length of the time of the CPD). Regarding the location of the CPD data in Table 6, most of the CPD programmes were conducted inside school (59) or both inside and outside school (7). The rest (4) were held online or at a distance. Regarding the times during which CPDs were held, it is clear that almost all of the programmes (115) were held during the school year (long), while the rest of them were of either of medium (between six and two months) or a short (less than two months) duration.

Table 8
PD Context (Location and Period)

Axes	PD context	Year					
		2012	2013	2014	2015	2016	Total
Location	Out of school	6	5	4	3	5	23
	Inside school	12	4	15	6	22	59
	Inside and outside school	1	1	2	1	2	7
	Distance	0	0	0	1	3	4
	Not determined	8	38	9	25	31	111
	Total	27	48	30	36	63	204
period	Short	0	1	0	3	4	8
	Medium	0	7	0	3	4	14
	long	18	26	20	17	34	115
	Not determined	9	14	10	15	21	67
	Total	27	48	30	36	63	204

DISCUSSION

This study analysed research articles from different parts of the world. We argue that this can lead to many factors for the successful implementation of new approaches to in-service science teachers' professional development in many ways. First, it might supply providers with a clear vision of effective continuous professional development. Second, it can provide valuable information that may convince concerned officials of the type of programmes needed for the effective and sustainable continuous professional development of in-service science teachers. Third, it might provide a basis for the allocation and organisation of all of the necessary resources, which reinforces the effectiveness of all types of teacher professional development.

The analysis addresses six major themes: the focus of professional development, the types of professional development, the context of professional development, the purpose of the research, research tools, and the types of collected data.

Regarding the first theme, some of the analysed research papers concentrated on PCK and the constructivist approaches (inquiry, problem-solving, learning cycles, thinking skills, and other strategies and teaching methods). A few articles addressed lesson study, action research and STEM. Educators (Garet, et al., 2001) have proven that inquiry-based approach, as an example of constructivism, can provide an alternative to conventional approaches, which are more promising than the currently used continuous professional development programmes, as they guarantee education for sustainable development. Constructivist teachers can encourage students to select and assess activity that may help them improve their understanding of science concepts. By questioning themselves and their strategies, students in the constructivist classroom ideally become 'expert learners'. This gives them ever-broadening tools to keep learning. With a well-planned classroom environment, the students learn how to learn. We think the focus of analysed research on professional development is greater in the field of PCK because we as educators think that teachers who have strong background on PCK can produce better effect on student learning. Similar argument could be established for inquiry, where inquiry represent the major teaching strategy that would enhance students' understanding of concepts and their acquisition of scientific skills. On the other hand, research articles but little focus on other strategies such as lesson study, because this strategy is new to the field of professional development. It was recently initiated in Japan, and lately adopted by other education systems in other parts of the wold.

Concerning the second theme, the types of professional development, it was found that there were four types of CPD. Good quality and effective professional development programmes for in-service science teachers are particularly important when initiating reforms in teaching and learning. Therefore, these programmes should be continuous and conducted as in-school-based inquiry activities (Britton Paine, Pimm, & Raizen, 2003). Furthermore, PD should follow up with a continuous programme of career-long professional development, support, and supervision, thus building on previously acquired knowledge and skills. These professional development programmes should

take into consideration data about teachers' competencies and their students' performance (Schwille & Dembélé, 2007).

The results of the third theme showed that most of the research articles were descriptive. The remaining research articles were either developmental or evaluative. These results are reasonable because descriptive studies may be performed by observation or by observational instruments, whereas developmental research may involve the study of behavioural change over time and can be regarded as a descriptive research. Therefore, more time is needed for such research to be completed. Evaluative research is also one type of descriptive research, but its purpose is to evaluate the results according to the hypothesised standards. Descriptive studies usually use surveys as tools for data collection. It uses summary data, such as measures of central tendency including the mean, median, mode, variation, percentage, and correlation between variables, to draw inferences (Nolan, McKinnon, and Soler's, 1992 Ali, & Bhaskar, 2016)). However, descriptive research may use the elements of both quantitative and qualitative research (Glass & Hopkins, 1984), where descriptions of phenomena can emerge from the qualitative nature of case studies, observational studies, interviews, and portfolio assessments, which have all been found to be richer and thicker than quantitative studies (Robinson's, 1994).

In accordance with the results related to the fourth theme" research tools", it was found that observation comes in first and that surveys and interviews come in second. Analysis and tests were the least used method. It is clear that observation increased over the years (from 7 in 2012 to 21 in 2016). This indicates that observation is the appropriate tool to evaluate the effectiveness of CPD or to report on teacher effectiveness in the classroom. Similar trend also happens with survey and analysis. This might also indicate that observation is considered as the right tool to evaluate the effectiveness of CPD or to report teacher effectiveness in the classroom. It might indicate that researchers used both observation and surveys in their PD studies. Research (Piburn, & Sawada, 2000; Gess-Newsome, Carlson, Gardner, and Taylor, 2010) indicated that used classroom observation protocol to measure Pedagogical Knowledge because PCK represents teachers' ability to implement general teaching skills in the real classroom.

Regarding the result of the fifth them "type of data", it was shown that most of the studies were of a qualitative followed by mixed data. This may indicate that studies related to professional development are thorough and deep. This may also imply that PD research should dig into the heart of the problem facing teacher in the classroom, and the PD programmes should be built based on deep and thorough investigations. Studies (Hopkins, 2002; Gess-Newsome, Carlson, Gardner, and Taylor, 2010) asserted that well planned and designed PD programmes should concentrate on and provides plenty of data and thorough information about the Pedagogy, teaching practices, and teaching skills looks at ways that schools may use them to support their own plans for improvement and how teachers may use them to further their own professional development.

The results of the sixth theme, context of the PD indicated that most of the PD programmes were conducted in-school, and as a result, most of these PD programmes

were long, 6 months to one year or more. These results are in accordance with the results from a study performed by Britton, Pimm, and Raizen, (2003), which indicated that PD should be continuous and should be conducted in in-school settings. The reason is because school-based PD allows researchers, teachers and PD providers to identify factors that have greater influence on students' learning and their behaviour (O'Brennan, Bradshaw, Furlong, 2014).

For all themes, we argue that it is important to review articles relater to professional development of science teacher who are still in the preparation stage, and did not have any real experience in science teaching. These types of study could develop a vision on pre-service science teachers' education and professional development programmes, and how they aligned with the recent standards (Mergler, & Spooner-Lane, 2012).

RECOMMENDATIONS AND SUGGESTIONS

Based on the findings of this study, we offer the following recommendations and suggestions:

- To achieve optimal benefits from the current emerging trends, science teachers and CPD providers need to learn about the emerging and successful CPD programmes, frameworks, approaches, and models.

- CPD providers need to have sufficient support and training with regard to the modes of evaluation available, and their evaluation should be comprehensive enough to allow for the tracking of the effects of CPD across the five levels of Guskey's model (Guskey, 2003; 2002).

- Effort should be made to provide modern and effective CPD activities and models for science teachers, taking into consideration the factors or features of more effective CPD programmes, which would ensure the attainment of positive outcomes for students, teachers, and schools.

- CPD for science teachers should be held in school, and experienced teaching staff in the colleges of education should be closely associated with the planning and implementation of the CPD content.

- Future research should be conducted to study the trends in pre-service science teacher education.

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