Teacher participation in science fairs as professional development in South Africa

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This research was undertaken to understand the perceptions of the Physical Sciences teachers who participate in the South African 'Eskom Expo for Young Scientists', regarding the educational significance of the science fair, and the extent to which expo participation provides an opportunity for professional development. The educational significance of this article is found in its contribution to the professional identity of teachers in their roles as organisers, mentors and judges. The model of Beijaard et al. (Teach Teach Educ. 2004;20:107–128) was used to characterise the teachers' professional identity in terms of professional knowledge, attitudes, beliefs, norms and values, as well as emotions and agency. Interviews with the Physical Sciences teachers were analysed using thematic analysis, ultimately interpreting and linking the categories of responses to the theme of professional identity. The study found that expo participation contributes to pedagogical knowledge, content knowledge (as both procedural and declarative or factual knowledge) and pedagogical content knowledge. Self-efficacy beliefs were strengthened, positive attitudes were developed, and strategies of inquiry-based learning and effective methodological instruction were observed during participation, which contributed to the participants' school-based teaching. Teachers learn both from their engagement with learners, and through networking opportunities with fellow teachers. Teachers themselves value these aspects, and consequently, science fair participation is a sustainable form of professional development. It is recommended that the opportunity for professional development that is provided by teachers' participation in such school-level science fairs should be acknowledged and promoted by schools and fair organisers.

Significance:

- Science expos offer professional development to participating teachers and improve learners' academic performance.

Introduction

In South Africa, academic performance and the improved skills of mathematics and science learners are priorities that the government supports through the Department of Basic Education and the Department of Science and Technology.[1] The Department of Science and Technology supports science fair events, which fall under the umbrella of the Eskom Expo for Young Scientists. This series of science fairs has taken place at schools at regional and national levels for several decades, having begun with leading high schools in 1980.[1,2] The vision of the Eskom Expo for Young Scientists (which we refer to simply as the Expo) is to encourage the participation of the most innovative and gifted learners across South Africa, from both rural and urban areas[1,3]

It is thought that science fairs help learners to improve in both mathematics and science.[4,5] Science fairs rely on teachers to motivate and assist learners to identify potential projects, and to help them to present their projects. The roles of teachers in science fairs include mentoring, organising, collaborating, networking and judging.[5] While teachers participate in science fairs in various roles, it is not clear why they do so, especially for those who participate over long periods.

It has been reported that teachers believe that science fairs enhance the skills, attitudes and knowledge of learners, and encourage future careers in scientifically orientated professions.[4] They also believe that science fair projects have educational significance, in particular, that science fairs challenge learners with academic rigour, establish useful skills, and complement other efforts to address the science achievement gap.[4-6] Bencze and Bowen[7] and McComas[8] find that science fairs benefit learners through science inquiry and provide an advantage in science literacy.

Problem statement

The literature that was reviewed explored learners' benefits in participating in science fairs, for example, Bigler and Hanegan[9] and Wirt[10] report that many learners who participate in science fairs improve their scientific skills, subject content knowledge, understanding, and interest levels. What this research sought to understand was the educational significance that teachers attach to science fairs.

The following research questions address the teachers' views on the significance of participation in terms of their professional identity, the details of their participation in these fairs, and what inspired them to become involved.

- What is the teachers' perceived educational significance of their participation in science fairs with regard to their professional identity and professional development?
- What is the educational significance of science fairs in the opinion of the teachers who participate as organisers, mentors and judges?

Conceptual framework: Professional identity and roles

The conceptual framework used in this study consisted of two aspects, thereby forming a simple systems model (Figure 1). The major elements of this model are the teachers' professional identity with its components, as posited by Beijaard et al.[11], the roles that teachers play in science fairs, and a postulated link between teachers' professional identities and their roles. It was further postulated that teachers' participation contributes to and benefits the teachers in terms of their professional development.

Professional identity is defined as the process of interaction between a person and their context, and may be characterised by professional knowledge, attitudes, emotions, norms and values, beliefs[11-13], and agency[11]. The concept of professional identity is used to characterise the dynamic aspects of science teachers in the context that frames their professional activities. The resulting choices made by the teachers link their professional identity to their roles, and hence are placed in the forward component of the 'process' element of the simple systems model. It is put forward that participation in science fairs strengthens or influences aspects of the teacher's professional identity (an assumption supported by Botha[14] and van Putten[15]); this link is shown as the feedback component of the framework (Figure 1).

Teachers' professional knowledge involves content (or subject matter) knowledge, pedagogical knowledge, which relates to processes and practices of teaching and learning[16], and pedagogical content knowledge (PCK)[17], which is an integration of content, pedagogical and other various factors. Rollnick and Mavhunga[18] refine PCK as topic specific PCK. Anderson[19] reports that teachers' beliefs about their goals of science education and the nature of science have a strong impact on classroom practice. Norms and values manifest in facilitation and contextual interaction. Science fair projects promote teachers' positive attitudes as facilitators of learning.[5,20-22] Collaboration, commitment and context are elements that contribute to teachers' attitudes[13] and may manifest as a caring attitude[23]. Collaboration and the acceptance of values manifest as emotions[24], and emotions involve caring attitudes[14,15]. Agency is the ability to pursue one's goals, and to pursue a goal that benefits an individual, based on his or her values.[11,12]

Participation in any of the three primary roles (mentoring, organising and judging) creates opportunities for secondary roles. These secondary roles comprise networking and collaboration, and integration (of activities, experiences and knowledge) into the curriculum (Figure 1). In the mentoring process, teachers have an opportunity to involve learners in inquiry-based learning.[25] It is argued that teachers are enriched with intuitive knowledge and skills for judging learners' projects.[5] Collaboration promotes networking, which provides teachers with the opportunity to teach content knowledge, use effective pedagogy and new teaching strategies, and escalate inquiry incorporation.[26] Teamwork amongst teachers in mentoring learners to carry out projects at science fairs informs teachers' content knowledge with more pedagogical techniques (technological knowledge and technological pedagogical content knowledge), and offers enhanced access to science, technology, engineering and mathematics resources. It was hypothesised that teachers' experiences through their role in the Expo affects their professional identity, and thus reinforces their professional development through the integration of resources. Teachers incorporate inquiry-based activities from science fairs into their science curriculum and form a repertoire of what they can and cannot do,[20,27] thus it influences their professional beliefs. This investigation sought to establish how teachers themselves linked the various roles to aspects of their professional identity.

Research methodology

The QUAL–quan research design and approach of this study was situated within an interpretive and descriptive paradigm, which was used to develop an understanding of high school Physical Sciences teachers' experiences and perceptions of their involvement in the Expo as mentors, judges and organisers.

Sample and participants

Both purposive and convenience sampling were employed in the study because the participants were chosen according to the pre-selected criteria, as suggested by the research questions.[28] Convenience sampling refers to the selection of participants who are easily and conveniently accessible to the researchers.[28] The teachers and researcher were based in the same area, Pretoria, thus it was convenient for the researcher to stay in contact with them. Only schools participating regularly (at least five times in the past 10 years) in the Eskom Expo for Young Scientists (Northern Gauteng Region) were selected. Five urban public high schools and 10 Physical Sciences teachers (two from each school) were identified to participate in this study. School principals and Heads of Department in the science departments of these schools decided which of the Physical Sciences teachers should be interviewed. The teachers were required to have taken part in the Expo more than once in order to be selected, thus it was expected that they would be able to provide deeply descriptive data for the purposes of this study.

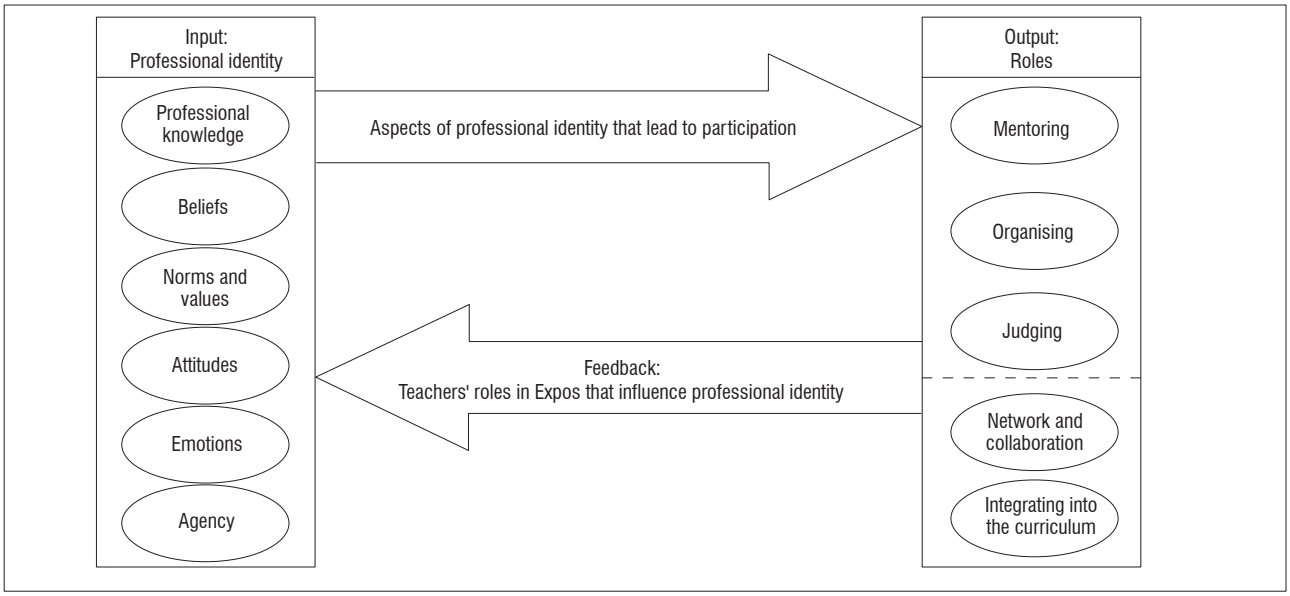

Figure 1: Conceptual framework of professional identity of teachers and their roles in science expos.

Research instrument and data collection strategies

The teachers took part in in-depth, face-to-face, semi-structured interviews. The semi-structured interviews allowed the participants to answer pre-determined interview questions, and allowed for further probing. With the permission of the participants, the researcher used an audio recorder to capture the interviews, which were then transcribed.[29] Written notes were also taken during the interview process. The selected teachers had already indicated that they would voluntarily participate, but they were again reassured that they were free to withdraw at any time if they felt either uncomfortable or inconvenienced by the study. The interview schedule was divided into two sections. Section A sought to establish the biographical data of the teachers, while Section B consisted of open- and closed-ended questions seeking to determine the teachers' opinions on the significance of the Expo to teachers.

Data analysis

The audiotaped interviews were transcribed verbatim. These transcriptions were then analysed through encoding the teachers' responses by identifying key words or phrases, which were grouped into subcategories, categories, subthemes and/or themes.[30] The responses to the open-ended questions in this study were analysed qualitatively through the use of open coding through inductive analysis. However, the responses to the closed questions were only analysed quantitatively. In each question asked, a particular key word or phrase was counted once, and further mentions of the same word or phrase in the answer to the particular question were not counted. The answers in which each key word or phrase were found, were counted and the counts expressed as a frequency of responses. The assignment of the key word and phrases to the subcategories was initially done by the first author, then all assignments were exhaustively checked individually by the second and third authors against all scripts. Disagreements were discussed until consensus on assignments was obtained. As each count occurred only once, the sensitivity of the relative frequencies of the subthemes and themes to the details of the assignment at the lowest levels is minimal.

Quality assurance

The interview protocol was piloted with two teachers from one school to verify its validity before it was used in the main study. Two experts in the field of science education validated the research instrument. In addition, the transcriptions of the interviews were sent to all of the participants for checking, and positive confirmation of the acceptability of the record was obtained from all.

Ethical considerations

Ethical approval to proceed with the study was obtained from the Faculty of Education at the University of Pretoria (SM 14/11/01). The Gauteng Department of Education, the school principals, and the participating teachers gave permission for the interviews to be conducted. To ensure confidentiality and privacy in this study, the schools' names and the teachers' names were replaced with pseudonyms or codes, and at no point are their actual names revealed.[31,32]

Findings and discussion

Biographical information

Of the 10 teachers who participated, 9 were women. The participants' ages ranged from 24 to 59 and their years of experience in teaching Physical Sciences (Physics, Chemistry or Physical Science) ranged between 1 and 30 years. All of the teachers had experience as organisers and/or judges and/or mentors in both school mini-science expos and regional science expos. The schools in which the teachers were employed at the time of this study were labelled as Schools A, B, C, D and E (Table 1).

All the schools were well-resourced schools. Schools A, C and E are within a high socio-economic environment. Schools B, D and E accommodate some learners from townships. Schools A, B and C had predominantly Afrikaans-speaking learners, with only a few black learners. To a large extent, the racial profile of the learners was affected by the languages offered: School D comprised learners from all racial groups, while School E comprised 70% white Afrikaans-speaking learners, while the other 30% were English-speaking learners who included black, Indian and coloured learners. The five schools were recognised as being amongst the top academic performers in the Gauteng Province, with one of these schools being the top performer in South Africa in terms of the Grade 12 performance of their learners in the recent national examinations.

Educational significance of teachers' participation in the Expo

Table 2 shows the benefits that teachers reported according to their roles in the Expo and the effects of these benefits on their professional identity, as categorised from the analysis of the interviews. Learners from all of the schools at which teachers were interviewed have excelled in both academic performance and the Expo competitions.

Table 1: Teachers' pseudonyms and biographical information

Pseudonym	School	Race	Gender	Teaching experience (years)	Qualifications
Annlin	School A	White	Female	5–10	HED[a], BEd, BEd Hons
Glory		White	Female	5–10	BSc, PGCE[b]
Bernie	School B	White	Female	20–30	BSc
Jacob		White	Male	20–30	BSc, HED, ACE
Carla	School C	White	Female	20–30	BSc, HED, BEd[c]
Jade		White	Female	1–4	BEd
Danielle	School D	White	Female	20–30	BSc, HED
Fransie		Indian	Female	5–10	BEd, BEd Hons
Harmony	School E	White	Female	20–30	BEd[c], BSc Hons
Ina		White	Female	1–4	BEd

[a]The HED (Higher Education Diploma) prior to 2001 existed as a 4-year university higher diploma as a first qualification. With a prior bachelor degree it was a post-bachelor degree higher diploma of 1 year, similarly to the Postgraduate Certificate in Education.

[b]PGCE, Postgraduate Certificate in Education.

[c]The BEd prior to 2001 (Report 116: Qualifications structure for universities in South Africa, National Department of Education, 1995) was a 1-year postgraduate qualification which followed the initial bachelor-level teacher qualification and is placed at the same level as the current BEd Hons (Higher Education Qualifications Sub-Framework of 2013).

Table 2: Teachers' participation in science Expos linked to their professional identity

Sub-themes[a]	Categories	Sub-categories	Responses: UT (T): [G, O, J, M][b]
Professional knowledge	Subject content knowledge	Procedural knowledge Declarative knowledge Knowledge of the curriculum Methodological integration	10 (317): [195; 44; 63; 14]
	Pedagogical knowledge	Assessment tasks Enhanced teaching skills	
	Pedagogical content knowledge	Critical thinking skills Skills of discovery Judgement skills Discovering misconceptions of learners	
Beliefs	Beliefs	Scientific literacy Knowledge broadened and enhanced Academic improvement of learners	10 (195): [101; 18; 10; 66]
Attitudes	Attitudes	Mentoring skills Organising skills Learners develop higher thinking skills Learners are offered science career opportunities	10 (168): [102; 24; 8; 34]
Norms and values	Norms and values	School ethos Administration /time management School support by hosting expos Acknowledgement and awards won by learners in school Budget for expo competitions Teachers collaborating within the school	10 (105): [42; 42; 6; 15]
Emotions	Emotions	Experienced enjoyment by interacting with the learners	10 (100): [42; 16; 19; 23]
Agency	Agency	Networking as a resource	7 (23): [17; 6; 0; 0]

[a]Grouping of responses according to Beijaard's et al.'s[1] professional identity model.

[b]UT refers to the number of teachers from the sample of 10 who provided a response (at least once) that was classified into a group referred to as 'unique teacher'; T refers to the total number of times a similar response was identified in the teachers' statements, at least once in a particular question (whilst repetitions were not counted). G refers to the response-count to direct questions on educational significance and their reasons for sustained participation, while O, J and M refer to the response-count of the various role-based questions – teachers as organisers, judges and mentors, respectively.

Beijaard et al.'s concept of professional identity[11,33] was used as a theme in the analysis, and formed the most important segment of the conceptual framework. Professional identity consists of professional knowledge, beliefs, attitudes, norms and values, emotions, and agency, with each of these treated as a sub-theme.

Of these sub-themes, a gain in *professional knowledge* was most prevalent in the teachers' responses, with all of the teachers mentioning examples of the knowledge gains that they had experienced as a result of their participation in the Expo. These perceived gains included content knowledge, pedagogical knowledge and PCK (Table 2).

The content knowledge improvements primarily included procedural knowledge, with some declarative knowledge and curricular knowledge enhancement. Pedagogical knowledge included the methodological integration of practices gained from participation in the Expo, critical thinking skills, assessment, and enhanced teaching skills. Their PCK was enhanced through the ability to judge student activities in relation to scientific knowledge, the guidance of discovery, and gaining awareness of the learners' misconceptions. One teacher – Fransie – mentioned that she had learnt to become aware of the learners' misconceptions and how they thought, both of which are aspects of PCK:

> *Understanding how the learner thinks, that's the most important. You understand how they grasp certain concepts, often when they are explaining to you, their project. You'll pick up on misconceptions that they may have, so you are more aware of how they think, how they understand knowledge, how they construct that knowledge.*

Many in-service teacher training programmes were offered to the teachers with a view to enhancing PCK.[34] This training was done as it was thought to facilitate science teaching and learning, particularly of learners in terms of science literacy and the nature of science using inquiry-based learning.[19] Seven teachers (Bernie, Carla, Jacob, Fransie, Glory, Jade and Ina) confirmed that they hosted mini-expos for learners in their school, and they indicated that they believed that the Expo was good for learners as they learnt how science functions beyond the normal expectation of school- or curriculum-bound science. Six teachers (Carla, Annlin, Bernie, Jacob, Ina and Jade) mentioned the methodological integration of science expo activities into the school science curriculum and stated that this was educationally worthwhile for both the teachers and learners.

The sub-theme of teachers' *beliefs* was deemed to be the most frequently occurring sub-theme according to the number of responses (Table 2). The teachers mentioned that, from their point of view, through participation in the Expo, their learners gained scientific literacy; improved their academic performance, scientific investigative and research skills; and gained enhanced science factual knowledge. This belief is in agreement with that of researchers, who argue that learners who participate in science fairs are exposed to a broad diversity of education.[7] In turn, it may be expected that such beliefs influence pedagogical strategies.[11]

In the sub-theme *attitudes,* all of the teachers reported that they were stimulated through mentoring and organising activities as they performed their roles in the Expo, and that their skills in enacting these roles were developed. The teachers' attitudes were empowered and strengthened when working with their learners, and in becoming successful at Expo competitions. Carla reasoned as follows:

> *I love thinking out of the box. I would be a great inventor, because I'm constantly looking for 'but why is this working in such a manner or in such a way and isn't there a possibility of bettering it?' So through investigation you become an entrepreneur, and I love being an entrepreneur, because I think you need to encourage children to become an entrepreneur.*

The teachers mentioned that learners participating in the Expo acquired discovery skills, critical thinking skills, presentation skills, and the desire to emulate professional scientists, and they were exposed to science career opportunities (enhanced interest in science careers, winning prizes and networking with both scientists and peers). This finding supports those of Egenrieder[20], Nath[21] and Sahin[22], who report that teachers who participate in science fairs develop facilitation attitudes (including positive experiences and willingness to mentor). Thus, these attitudes affect the role of organising.

The *norms and values* sub-theme involved sub-categories of administration and management, guiding, collaboration with peers, the school ethos, the budget for expos, hosting mini-expo evening exhibitions for learners, as well as the acknowledgement of learners and learners receiving awards after participating in the Expo. Most of the teachers (nine) argued that the Expo was part of their school's ethos, and was compulsory for both them and their learners, which many had internalised and accepted. According to the interview responses, the schools provided positive institutional support to the science teachers by enabling them to collaborate with one another in mentoring, organising, judging and guiding the learners with their projects. Thus, this support enriched the teachers with inquisitiveness and passion, which strengthened their commitment. The concepts of school ethos and the teachers' collaborative attitudes concur with Grant et al.[26], and You and Craig[35], who contend that collaboration promotes partnership within the institution, which further enhances teachers' attitudes[13].

In the sub-theme *emotions,* enhancement occurred through the teachers' opportunity to work with their learners (teachers gained enjoyment from interacting with the learners). The teachers mentioned that they were impressed by their learners' improvement in their scientific concept skills, and enjoyed seeing their learners being acknowledged and awarded by the school. This finding is in agreement with that of Botha[14], van Putten[15] and O'Connor[23], who have found that 'emotions' involve caring attitudes, collaboration, pedagogical expertise, commitment and effectiveness. The teachers were emotional in that they were passionate and eager to help learners to be successful in the Expo despite time limitations. Once learners are successful, teachers' emotions are elevated.

Agency refers to being active in the process of professional activities with the intention of pursuing educational goals through the use of available resources (and even creating resources).[1,12] The participants explained that the Expo offered them the opportunity to network with teachers from other schools in which they discussed the science curriculum. The teachers reported that they collaborated with teachers from other schools as they enacted their roles in the Expo through the sharing of experiences related to science curriculum content knowledge. Ina spoke positively about her collaboration with other teachers:

> *I always like to communicate with other teachers. Especially with Grade 10–12, especially with the science because I like from in my region, I like to talk to teachers in other schools to see where they are with the syllabus* (sic).

They further said that as they took part in the Expo, they gained some resources and, in return, they integrated these into their methodology and practices at their various schools. In addition, the schools' ethos was a further extrinsic factor that contributed to agency.

Professional development from teachers' participation in the Expo

The findings revealed that teachers who are involved in the Expo experienced growth in all dimensions of their professional identity, especially professional knowledge, which is often associated with the specific goals of professional development workshops. This participation strengthens their positive attitudes and beliefs (which includes pedagogical as well as self-efficacy beliefs), provides opportunities to improve their support structures through networking, and promotes positive emotions (through sharing in their learners' achievements in both improved learning as well as awards gained through learners' participation in the Expo). Hardre et al.[36] report that professional development addresses professional identity and self-perception; the teachers' experiences of learners' conceptions; collaborating and social networking with other teachers through new knowledge, resource benefits, reciprocal sharing and learning; complementary and innovative skills, as well as the practical integration of inquiry-based learning in classroom practices. Similarly, Zivkovic[37] contends that professional development involves the enhancement and provision of new knowledge, as well as sharing experiences with different teachers. These contentions are in accordance with the benefits described by the teachers regarding their participation in the Expo (Table 2).

Participation in the Expo provides both the enhancement of their professional identities and the correct setting for professional development. Readiness for professional development correlates with professional identity, and this readiness is influenced by both intrinsic and extrinsic factors[37,38], particularly if the teachers are themselves aware of the need for development[39].

Perceived educational significance of the Expo analysed by roles

Teachers' perceptions of the various Expo roles, specifically organising, mentoring and judging learners' projects were analysed. They gained new knowledge and were supported through the school ethos, as reflected in their job descriptions, by their schools hosting their own science expo. In addition, they found that their participation in the Expo provided opportunities for networking, which was a resource for collaboration and the sharing of experiences with fellow teachers, and similarly for the learners.

Mentoring

Ten teachers mentored learners during their Expo participation. The teachers mentioned how enriching their experiences were in this role.

From these findings, two sub-themes – the reinforcement of norms and values and pedagogical knowledge – were identified. The teachers noted that their mentoring function helped learners to be successful in both the Expo competitions and in their academic performance. They had the opportunity to interact with the learners and their colleagues, and to discover learners' misconceptions, as well as the difficulties that learners experienced in learning to perform investigations.

Norms and values include aspects of inquisitiveness, enjoying seeing learners being successful, and being passionate about science. The teachers also gained enjoyment from interacting with the learners, with ensuing positivity, which involves giving support to learners with their Expo projects, thereby demonstrating the teachers' caring attitudes towards their learners, as also found by O'Connor[23].

The participants mentioned that, as mentors, they had learnt more about the scientific reporting process and improved their process skills and data interpreting skills. As creative teachers, they also found that they began to teach their learners to be creative and eloquent in their communication during their presentations. The teachers further asserted that they had encouraged their learners to consider scientific topics that were related to daily challenges, and to come up with suggestions to solve these problems.

Judging

Eight of the teachers had acted as judges and reported that aspects of their norms and values were the most affected, as they enjoyed and were happy to see their learners gaining knowledge and showing success in the Expo competitions. They gained content knowledge and pedagogical knowledge equally from this role. Molefe[5] argued that teachers are enhanced with intuitive judging experience and skills for science projects.

Specific judging skills include developing critical thinking, recognising innovation and assessing practical work. The teachers stated that they also used some of the best projects to teach and demonstrate concepts to their learners in their classes. Furthermore, discovering new ideas and misconceptions was mentioned by six teachers as part of the gains in pedagogical knowledge in this role. One teacher, Glory, explained that as an Expo judge, she was also able to realise learners' misconceptions, and gained improved judging skills that assisted her in the methodology of her classroom practice. She again emphasised that, as a consequence of the Expo, she could address misconceptions, particularly with regard to variables: 'When we do the judging for the science fairs, we see that there are definitely learners who struggle with identifying the variables, for example.'

Organising

Teachers benefit by gaining organisational and prompting skills as Expo participants.[40] Seven teachers reported having organised school-level mini-expos. Six of these teachers mentioned networking as a resource (contributing to agency) as a particular benefit of this role. They gained the opportunity to interact with learners and network with teachers from other schools concerning issues in science education. The teachers mentioned that they had learnt more about scientific investigation processes while enacting an organisational role. Aspects of norms and values were more affected by organising than by the mentoring and judging roles.

Recommendations and concluding remarks

The findings in this study were based on the responses from 10 interviewed teachers from five urban, progressive public schools which were high performing in both academic and Eskom Expo competitions. A potential future research opportunity is thus to investigate under-performing and non-participating schools and their teachers in this regard. The findings regarding teachers teaching in under-resourced schools and low socio-economic environments might be different from those of the present study. The Expo is aimed at all schools, not only 'elite' schools. The sponsors of the Eskom Expos in recent years have focused on increasing the participation of learners from under-resourced schools.[41] A total of 1063 schools participated in the regional Expo in 2015, and of these schools only 167 (16%) were private schools, while in the national Expo in 2015 of 580 learners, 327 were medal winners of whom 137 (42%) were from under-resourced schools (Moodley P 2017, written communication, March 31).

The first recommendation is for a longitudinal study monitoring professional development and actual influence on classroom practice and change of professional identity over time to be conducted with three kinds of teachers: (1) beginner teachers in participating schools, (2) newly participating teachers from regularly participating schools, or newly participating schools for comparison, and (3) teachers who had participated in the past but had joined non-participating schools. In this respect, do these teachers continue to develop and participate and change the perspective of the new school on participation, or do they stagnate and regress? What are the reasons for either of these scenarios?

Workshops on scientific methods, the science curriculum, and Expo judging skills have to be provided for both teachers and judges (professional scientists) of science expos. This should be particularly provided at the regional level because the teachers in this study revealed that the Expo judges were often very strict as they expected precise scientific methods to be used by learners. This would provide a formal opportunity for the professional development of these teachers.

Finally, of significant importance, the study has shown that participation in the Expo should be recognised as an effective form of professional development. This is the case for teachers of Physical Sciences, but may be generalisable, which would need to be investigated further. This requires formal recognition of these activities through support and scheduling carried out by the provincial Department of Education.

In conclusion, it has been found that the Expo has educational significance for both the teachers and learners who are involved. Teachers, as participants in the Expo, have opportunities to interact with the learners during which they may discover learners' scientific misconceptions and gain new professional knowledge. Learners who take part in the Expo have an important opportunity to be inspired with ideas for future careers, and to improve their academic performance. The academic improvement of learners correlates with the findings of Kahenge[42], Ngcoza et al.[43] as well as Molefe[5] who found that Expo learners do well in both Expo competitions and their general academic performance.

The findings reveal that South African expos provide opportunities for professional development, particularly with regard to teachers' professional knowledge. In particular, the participating teachers were aware that their content knowledge (both within and beyond the curriculum), their pedagogical knowledge (such as gaining insight into inquiry-based learning approaches), and topic specific PCK were enhanced. Simultaneously, their professional identity was reinforced through networking and collaboration with other teachers, affecting their beliefs, norms and values, and their agency.

Scientific method processes were enhanced for both teachers and learners. The incorporation of science activities into the school curriculum also creates a conducive learning environment within which to develop deeper insight into the nature of science, as well as encouraging critical and creative thinking skills.

The sustained enhancement of professional identity through knowledge, skills, attitudes, emotions, and agency indicates that participation in the Expo is a process, opportunity, and mechanism for the professional development of Physical Sciences teachers. This professional development is expected to be applicable to teachers of other sciences and subjects. Furthermore, and more importantly, this specific benefit of participation in the Expo over a full range of subjects needs to be recognised and supported by professional educational structures, such as educator councils and the various regional and national Departments of Education.

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Authors' contributions

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