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Goals and Objectives of Teacher Training Programmes: Lessons Learned from a Multi-Stakeholder Analysis

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Abstract. Constant developments in science and technology are leading more high-school teachers towards updating their knowledge and skills through teacher training programmes. Consequently, various large research institutions are developing an increasing number of such programmes. Although quite some research has been done in the field of teacher training programmes, we know little about the expectations of the stakeholders in such programmes. Therefore, using a three-round Delphi technique, we investigated the expectations of the stakeholders of CERN's Teacher Programmes on goals and objectives of teacher training programmes in general and at large research institutions, such as CERN.

Keywords: Teacher Professional Development, In-Service Teacher Training, Delphi Study, Multi-stakeholder Analysis

INTRODUCTION

Demands on teachers across the world are overgrowing teachers' initial training (OECD, 2019). Indeed, constant advancements in science and changes in national curricula and functioning of the schools are driving teachers around the world to search for ways to advance their skills and knowledge (Hewson, 2007; Greene, 2013; Pena-Lopez, 2009). Such learning opportunities can be provided to the in-service teachers through teacher training programmes to further develop their instructional skills, pedagogical and content knowledge, expertise, and other teacher characteristics (Luft & Hewson, 2014; Pena-Lopez, 2009; Borko, 2004). As such, these programmes are an essential factor for the success of systematic educational reforms (Garet, et al., 2001; Corcoran, 1995; OECD, 2019; Borko, 2004). Additionally, the OECD Teaching and Learning International Survey (TALIS) in 2018 (OECD, 2019) showed positive correlations between teacher participation in teacher training and a higher level of job satisfaction and self-efficacy. Especially in countries that are struggling to keep teachers in classrooms, higher job satisfaction is a very desirable outcome (Perrachione, Rosser, & Petersen, 2008).

Although studies in this field are still sparse, they have shown that teachers' participation in high-quality teacher training programmes can lead to higher-quality teaching and, consequently, higher student achievements (Borko, 2004; Desimone, 2009). Therefore, many countries mandate participation in teacher training of some sort in order for teachers to maintain employment, for promotion, or salary increases (OECD, 2019). Consequently, various institutions around the world are developing a broad spectrum of different types of teacher training programmes. In 2018, on average, 94 % of primary, secondary, and high-school teachers had reported participation in at least one form of teacher training. Most of them, over 70 %, participated in courses or seminars in person (OECD, 2019). However, research on what teachers achieve by attending teacher training programmes and how that has been achieved is surprisingly sparse (Garet, et al., 2001; Desimone, 2009; Guskey, 2000). The majority of the studies is focused on the levels of teachers' satisfaction, change in their attitude, and their commitment to innovation (Guskey, 2000; Desimone, 2009). Although such studies are informative and essential for the developers of the programmes, they are not enough to ensure the quality of teacher training programmes. Indeed, the evaluation of what teachers gain in regards to the goals of the programmes is crucial.

Here, the clarification of the intended goals and the assessment of their perceived importance by those involved in teacher training programmes are the initial steps of a well-structured evaluation of said programmes (Guskey, 2000). At the same time, goals need to be clearly defined and perceived as important also for the participating teacher to be more likely to be more ambitious and to feel successful while learning (Zepeda, 2013). Traditionally, Smith & Gillespie (2007) list primary goals of traditional teacher training programmes as an increase of teachers' general knowledge, skills, and teaching competency, and the introduction of new instructional models or methodologies. Similarly, Garet et al. (2001) and Desimone (2009) emphasize that teachers participating in teacher training programmes should be able to enhance both their subject content knowledge and their pedagogical content knowledge. Additionally, Guskey (2000) mentions that effective professional development programmes also need to have an impact on teacher attitudes. However, the goals for science teacher training programmes can vary (Luft & Hewson, 2014). While programmes at institutions of higher education find cognitive goals to be the most important, programmes at informal science institutions focus more on increasing teacher comfort and confidence with the content (Astor-Jack, McCallie, & Balczerak, 2007). Although teacher training at large research institutions are generally developed, managed, and staffed by the academia, the setting itself is informal. Therefore, categorisation of teacher training programmes at large research institutions, such as CERN, is not trivial. This calls for a dedicated evaluation of the expected goals and objectives.

CERN's Teacher Programmes

CERN, the European Organization for Particle Physics, has been running teacher training programmes for in-service high-school science teachers from around the world for over 20 years. Indeed, CERN's Teacher Programmes yearly welcome about one thousand teachers through 35-40 programmes. Specifically, CERN offers two different types of teacher training programmes. The first type are CERN's national teacher programmes that run in the national language of the teachers (e.g. Serbian, Slovenian, German) and last between three to five days. The second type are CERN's international teacher programmes, that are held in English and welcome teachers from around the world for two weeks. Both types of programmes can welcome up to 48 teachers and contain a mixture of lectures by experts in modern science and technology related to CERN, visits to on-site research facilities, hands-on workshops, sessions for questions and answers, and social events. Additionally, the international programmes contain study groups, in which teachers focus on topics of the programme in smaller groups by discussing among others the implementation of these topics to their classroom.

METHODS

In general, group expert methods, especially face-to-face methods, often reduce the accuracy of the outcome through normative social influence (Clayton, 1997; Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003; Bolger & Wright, 2011; Hanafin, 2004; Rowe & Wright, 1999). Therefore, to elicit opinions it is necessary to find a structure that allows experts to discuss anonymously without any face-to-face interactions (Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003; Hanafin, 2004; Rowe & Wright, 1999). Here, the Delphi technique provides a robust indirect structure (Holey, Feeley, Dixon, & Whittaker, 2007) for a detailed critical discussion in a group of experts (Clayton, 1997; Powell, 2003, Green, 2014). Specifically, through repeated rounds of questionnaires more high-quality opinions can be elicited (Gupta & Clarke, 1996). This iterative process is supported by adding summaries of previous rounds and by repeatedly re-checking the experts' responses in light of the judgement of the others (Goldstein, 1975; Hanafin, 2004). In doing so, the iterative structure of the Delphi technique can be ideal for searching consensus in the expert group (Rowe & Wright, 1999; Williams, Boone, & Kingsley, 2004). However, it is most commonly used to seek the full understanding of the areas that are subject to different views (Linstone & Turoff, 1975; Hsu & Sandford, 2007; Gupta & Clarke, 1996). Indeed, even though the influence of the researchers is small during the research due to iterations with the experts, the findings can be open to many interpretations (Day, 1975), meaning that the impact of the researchers on the study is not necessarily negligible (Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003; Hsu & Sandford, 2007; Clayton, 2006). Therefore, to reduce the impact of the researchers on the study, researchers should not, in any case, focus on achieving consensus. At the same time, they should avoid the use of leading, highbrow, complicated, and irritating questions, and questions that use negatives (Hanafin, 2004). Questionnaires need to be structured and well-formed (Green, 2014) and should be focused on factual information to avoid putting respondents' personalities in focus (Bolger & Wright, 2011), all of which can be tested in the pilot testing phase before the final launch of the questionnaires.

Panellists

The expertise of the selected participants in the Delphi technique is crucial for the validity of the study (Clayton, 1997; Powell, 2003). Their expertise can be ensured by using a Knowledge Resource Nomination Worksheet to objectively assess their qualifications (Okoli & Pawlowski, 2004). The validity can be further increased by choosing a heterogeneous group of experts, especially as the participants are anonymous. Indeed, a heterogeneous group can provide more unique ideas due to its more extensive knowledge base (Rowe, Wright, & Bolger, 1991, Bolger & Wright, 2011; Murry & Hammons, 1995; Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003; Clayton, 1997; McMillan, King, & Tully, 2016; Enzer, 1975; Hasson, Keeney, & McKenna, 2000).

Therefore, we chose a heterogeneous group of experts for this study based on their knowledge and experience with CERN and its teacher programmes, relevant political influence, previous experience with teacher training programmes, and research in physics education. Ideally, expert groups consist of anything between 10 and 50 experts, who can provide different perspectives on the focus questions (Turoff, 1975).

After selecting the experts, we formed five smaller panels: (1) Researchers in physics education research with experience in organizing and/or researching teacher training programmes, (2) CERN national contacts, who help organizing national teacher programmes at CERN, (3) Members of the CERN Council and advisory boards (short: CERN management) with high knowledge of CERN and with political influence, (4) Teachers, who participated in one of CERN's teacher programmes in the past, and (5) Teachers, who have applied to participate in one of CERN's teacher programmes in the future. Furthermore, we included education experts from large research institutions similar to CERN (e.g., LIGO, Perimeter Institute) to make the study more applicable to a broader set of teacher training programmes.

The number of participants varied throughout the rounds, as seen in Table 1. Some of this variance was due to attrition, which is a standard occurrence in the lengthy Delphi technique. Additionally, some experts were added at later stages of the study. Furthermore, we added the fifth panel, the future participating teachers, only in the second round. Overall, the expert group is representing five different perspectives, with participants from 35 different countries and many different backgrounds.

Table 1. Key demographics of the five Delphi panels throughout the three rounds.

Panel	1st round	2nd round	3rd round
Physics education researchers	28	26	31
CERN national contacts	24	20	14
CERN management	16	10	10
Teachers: Past participants	13	28	13
Teachers: Future participants	-	16	5

Questionnaires and analysis

Traditionally, the Delphi technique starts with an open-ended questionnaireThe first-round questionnaire of the Delphi technique consisted of four open-ended questions, aimed to elicit broad ideas from the panellists. The first question regarded the goals and objectives of teacher training programmes in general, while the other three questions were specific to CERN's teacher programmes and teacher training programmes at similar large research institutions. The latter three asked about goals, objectives, and intended impact on education in home countries. The questionnaire was cognitively evaluated through semi-structured interviews with selected experts and pre-tested by physics education researchers in CERN's education group and at the University of Potsdam, and physicists without background in educational research to verify the unambiguity and intelligibility. Together with the final version of the questionnaire, the panellists received an information package with necessary information on CERN's teacher programmes and a description of the study itself.

After a month of gathering data, the responses were qualitatively analysed in MaxQDA, using inductive thematic network analysis. The themes that emerged from the analysis were grouped in seven broader categories, as shown in Table 2. Additionally, 15 % of the data was analysed for inter-rater reliability. Initially, we reached 80 % agreement with Cohen's Kappa of 0.72, which already represents substantial reliability (Landis & Koch, 1977). However, we were able to reach the 100 % agreement after discussions.

Table 2. Categories that emerge from the analysis of the first-round questionnaire arranged based on whether they are connected to teacher training in general or at CERN and other similar large research institutions.

Specificity	**Category**
In general	Goals and objectives of teacher training programmes in general
At CERN and similar large research institutions	Types of knowledge participants should update (e.g. content knowledge)
	Specific content that should be included
	Types of activities in the programme
	Follow-up activities
	Additional design features (e.g. resources, language, duration)
	Outcomes and influence on education in home countries

Additionally, we noted how many individual panellists mentioned each of the themes. This frequency was measured for the responses per panel and total. The total count was used as a basis for the final selection of the themes for the second- and the third-round questionnaire. Only themes that were mentioned at least five times were included in the final version of the questionnaire. This selection allowed for a shorter questionnaire, which can reduce the levels of attrition and respondents' fatigue.

The second-round questionnaire was developed based on the most often mentioned themes that emerged from the first round. Panellists were invited to rate each of the themes on the Likert-like scale of 1 – "Very unimportant" to 6 – "Very important". At the same time, they were asked to comment on their rating, the phrasing of the questions, and on any essential missing themes. The questionnaire was once again pre-tested by physics education researchers at CERN and the University of Potsdam, and physicists without background in educational research to measure the quality of the questions and the time complexity of the questionnaire. The questionnaire was sent to the panellists together with the feedback summary of the analysis of the first round. Here, the feedback summary contained all themes from the first round, including the ones that were not included in the second-round questionnaire. Finally, after the data had been collected, the ratings were analysed using R studio Likert package and the non-parametric Kruskal-Wallis test with a Bonferroni adjustment to check for similarities between groups. However, the provided responses showed a very prominent ceiling effect, which prevented any in-depth quantitative analysis from being done. The comments were analysed qualitatively by using the inductive thematic analysis.

The third-round questionnaire was composed of the same set of themes in most categories. The panellists were asked to rank the themes inside the categories from most to least important. Two categories had to be fragmented into several themes to achieve a better understanding of the category. Similarly, one category was split into several subcategories to increase the reliability of the rankings in the category. In all categories, the panellists were able to comment on their ranking and add any missing themes. Again, the questionnaire was pre-tested before distribution within the CERN education group. The final version of the questionnaire was sent to the panellists, together with the feedback summary of the second-round analysis. The results were again qualitatively analysed in R studio using the Kruskal-Wallis test with the Bonferroni adjustment to compare the rankings between the groups. As before, the comments were qualitatively analysed using inductive thematic analysis to extract any possible missing themes and help with interpretation of the results.

RESULTS

The inductive thematic analysis of the results of the first-round questionnaire showed compelling results and some differences between different panels and literature. In the second round, the panellists rated on the selected themes from the first round based on their perceived importance. On the six-point Likert-like scale, the ratings for all themes averaged above 4, and for a vast majority even above 5. The results showed that there are no differences between different panels in a vast majority of themes, most likely also due to the ceiling effect. After the additional qualitative analysis, two themes were promoted to a category, as the comments called for more detailed insights. Both categories were then filled with themes that emerged from the literature and interviews with CERN's physics education researchers and several other individuals. Admittedly, the panellists still had the opportunity to add a theme later in the questionnaire as well.

The results from the third round are showing to be more conclusive. The rankings of different panels on different categories were again compared using the Kruskal-Wallis test with Bonferroni adjustment. Overall, the panels agree on most of the rankings with the only slight disagreement of one of the panels in two of the categories. Below, we are presenting the entire results for the general category. The results of the rankings on the questions on the goals and objectives of professional development programmes, in general, are shown in Table 3.

Table 3. Results of the ranking in the third-round questionnaire in the category "Goals and objectives of teacher training programmes in general."

#	Teacher training programmes in general should …
1	... inspire, motivate, and excite teachers.
2	... help teachers to better inspire, motivate, and excite students.
3	... enable teachers to interact with other teachers and scientists.
4	... broaden teachers' general knowledge of the field.
5	... enable teachers to experience different teaching methods.
6	... provide teachers with resources that can be used in a classroom.
7	... enable teachers to learn about different teaching methods.
8	... enable teachers to learn about the discoveries in the field.
9	... serve as a way to promote science to the general public.

As already mentioned before, the rest of the categories are more specific to teacher training programmes at CERN and similar large research institutions. In this abstract, we only present a partial overview of the top three ranks of some of the categories, that are specific to CERN and similar large research institutions, as seen in Table 4. When looking at the top three, the panels agree with all the rankings. Although the panellists were able to add new themes to the categories still, they usually added the extra themes very low on the list, meaning they perceive it as not so important as well.

Table 4. Ranking of different influences by the teacher training programmes and the participating teachers, specific to CERN and other similar large research institutions. The importance is highest at number 1 and in the first column, then it falls towards the end.

#	Influence on Teachers	Influence on Students	Influence on Curriculum	Influence on General Public
1	Teachers are more motivated and inspired.	Teachers are able to motivate and inspire students even better.	Modern physics is introduced to the classroom as a context for the existing curriculum.	The general public is more aware of the importance of research.
2	Teachers improve their teaching methods.	Teachers are able to inspire more students to pursue studies in the field.	Modern physics is introduced to the classroom through extracurricular activities.	The general public knows how to use scientific thinking in everyday life.
3	Teachers continue networking with other teachers.	Students are more aware of the diversity and opportunities in science.	Modern physics is included in the national curricula.	The general public is more aware of the diversity and opportunities in science.
4	Teachers are more aware of the diversity and opportunities in science.		Modern physics is introduced to the classroom as an independent part of teachers' curricula.	
5	Teachers continue networking with scientists.			

DISCUSSIONS

The participating panels agree that motivation, excitement, and inspiration of teachers are the most important goal of teacher training programmes. High importance of affective goals is much more specific for teacher training programmes at informal scientific institutions. Although CERN and similar large research institutions are closely connected to the academia, they cannot necessarily be seen as institutions of higher education. Therefore, it is not that surprising to see that the expectations of the stakeholders are closer to those for informal science institutions. Indeed, cognitive goals only come in fourth, after affective goals for teachers and students, and building of teacher networks. Last on the importance scale is using teacher training programmes as a way to promote science to the general public. Indeed, the panellists believe outreach should be done via other channels as the impact on the general public is "a lot to expect from a teacher". What might be more surprising, is the perceived low importance of learning about new discoveries in the field, especially when we consider that many of those discoveries' origins are in the said institutions.

CONCLUSIONS

Goals and objectives of teacher training programmes are often mentioned in the research, but rarely explicitly specified. Furthermore, the hierarchy of importance of the goals and objectives of teacher training programmes, especially in science, is sparsely mentioned. Additionally, there is hardly any multi-stakeholder analysis of this question. Namely, most studies focus on views of the teachers and very few also on views of the providers and other stakeholders (Astor-Jack, McCallie, Balczerak, 2007). However, should we want to evaluate a teacher training programme, such a clarification is essential. Therefore, we designed a multi-stakeholder study on the goals and objectives of teacher training programmes in general and at CERN and similar large research institutions.

Over 80 experts from the field of physics, physics education research, physics education, and politics participated in the study and helped to find a better understanding of the differences and similarities between different panels' opinions. However, the results are biased towards the experience at CERN as the primary example of the large research institution in the questionnaire itself. Although professionals from other research institutions have been invited to participate, management representatives, teachers, and national contacts are all closely connected to CERN and its teacher programmes. Therefore their answers likely reflect CERN's teacher programmes more than the general image. Further interviews with representatives of other research institutes could help in making the results more generalisable. However, some representatives were already included in the study; therefore, the study is already not wholly focused on CERN.

When asked about the impact of the teacher training programmes at CERN and similar large research institutions, the story remains very similar. Again, teacher motivation and inspiration are perceived as the most important outcome, while the impact on the general public once more comes in last. Therefore, although it might be tempting to perceive teacher training programmes at large research institutions as another outreach activity, the programmes should not be organised as such. Their primary objective still should be education and training of the in-practice teachers.

Additionally, the question of the impact of these programmes asks specifically on the impact of teacher training programmes on the curriculum. Interestingly, the impact on the national curricula and introduction of new topics to the teachers' personal curricula is not perceived as very important. Indeed, in the comments, panellists pointed out that impact on something as big as the national curricula is not to be on the backs of the teachers that participate in professional development. Instead, changes in the curricula should come in a more top-down approach, with the institutions that are providing the teacher training programmes pushing for the updates on the national level. Furthermore, new topics should not be expected to be crammed next to the standard curriculum. Namely, panellists commented that teachers often complain about having too much to cover already, making it impossible to introduce a whole extra topic. Therefore, teacher training programmes need to help teachers learn how to connect new topics, new ideas, and new methods to the existing curricula.

The main conclusion from this study is that affective goals of teacher training programmes in general and, more specifically, at large research institutions, such as CERN, should not be disregarded as something less important. Indeed, affective goals are perceived by both researchers, in-practice teachers, and management representatives as more important than cognitive goals.

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