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Delphi Study on Learning Goals of Professional Development Programmes

Motivation

Advances in scientific and educational research are entering various national high-school curricula. Often, such curricular updates can overwhelm teachers (OECD, 2019). Therefore, diverse professional development programmes (PDPs) for teachers to expand their professional knowledge are crucial for successful implementation of curricular changes (Banilower et al., 2007; Borko, 2004; Greene et al., 2013; Hewson, 2007; Luft & Hewson, 2014; OECD, 2019; Pena-Lopez, 2009). Effective PDPs need to have clearly defined learning goals, that are considered important by all relevant stakeholder groups (Guskey, 2000; Loucks-Horsley et al., 2010; Villegas-Reimers, 2003). However, studies on learning goals of PDPs rarely include more than one stakeholder group.

Theory: Learning Goals of Professional Development Programmes

The great majority of studies on learning goals of PDPs includes teachers as the only stakeholder group (e.g. Park Rogers et al., 2010). Research scientists as facilitators of PDPs with no educational background are only included in a few studies (e.g. Gentsch, 1999). Furthermore, the opinions of educational researchers and government representatives are seldom included. Therefore, the views of educational researchers and government representatives can only be deduced from the recommendations in the literature in educational research (e.g. Borko, 2004) or national policies (e.g. Loeb et al., 2009), respectively. Previous research suggests that collaboration between different PDP stakeholders can lead to more effective PDPs (Kennedy, 2007; Park Rogers et al., 2007). Yet, studies sparsely include more than one group of stakeholders.

The learning goals of studies that include various stakeholder groups can be categorised into the three dimensions of professional knowledge: content knowledge (CK), pedagogical content knowledge (PCK), and pedagogical knowledge (PK). Here, it was found that the enhancement of CK was mentioned most often by all stakeholder groups as a learning goal (e.g. Borko, 2004; Gentsch, 1999; Park Rogers et al., 2010). Similarly, enhancement of PCK was also frequently mentioned by all stakeholder groups (e.g. Borko, 2004; Loeb et al., 2009; Park Rogers et al., 2010; Schuster & Carlsen, 2009). In contrast, the enhancement of PK was only included as a learning goal of PDPs in some studies with teachers (e.g. Park Rogers et al., 2010) and one study with educational researchers (Smith & Gillespie, 2007).

Research Questions

- Which learning goals and objectives of professional development programs (PDPs) for in-service high-school science teachers at science research institutions are perceived as the most important by the relevant stakeholders?
- What differences and similarities between the expectations of different groups of stakeholders regarding the learning goals and objectives of PDPs for in-service high-school science teachers at science research institutions can be identified?

Methodology

To answer the research questions, we conducted a conventional Delphi study. A conventional Delphi study is an iterative method to gather experts' judgements on a particular topic (Osborne et al., 2003). Our Delphi study was conducted in the context of PDPs at CERN, the European Organization for Nuclear Research.

The stakeholder groups in our study, shown in Table 1, included various experts with knowledge of CERN and its PDPs. The Delphi study framework allowed them to interact anonymously and everyone's ideas were valued equally. The stakeholders participated in three rounds of questionnaires. As the results of each round were the basis for subsequent rounds, we present the intermediate results together with the methodology of the first two rounds.

The Delphi study started with the first-round open-ended question: "What are the goals and objectives of professional development programs at CERN and similar large research institutions?". The stakeholders' answers were analysed using the inductive thematic analysis. Here, the majority of the themes emerged from the first 15 responses. The analysis concluded with seven themes. The initial inter-rater agreement of the analysis was 80% and rose to 100% after discussion. For completeness, one theme was added based on Enkrott et al. (2017). Hence, the first round concluded with a list of eight learning goals, shown in Figure 1.

In the second round, the stakeholders rated the learning goals from the first round on a 6-point Likert-type scale ranging from "(1) Very unimportant" to "(6) Very important". The analysis showed a significant ceiling effect, with more than 64% of stakeholders rating all learning goals as at least "(3) Slightly important". Additionally, two new learning goals emerged from the stakeholders' comments, as shown in Figure 1.

In the third round, the stakeholders ranked the ten learning goals from the second round from least important to most important. In the analysis, the learning goals were grouped into three ranking groups, namely the high, medium, and low importance groups. The grouping was based on the position of the median rank of the goal with respect to the interquartile range of the entire list, as shown in Figure 1. The distances between the adjacent ranking groups were tested using the Mann-Whitney test. The stakeholder agreement in the overall ranking was analysed using Kendall's coefficient of concordance. The agreement on the individual goal ranking was analysed using the Kruskal-Wallis test, followed by Dunn's test with the Bonferroni adjustment. Additionally, stakeholder's comments were thematically analysed.

Table 1. The number of stakeholders in each of the groups in the three rounds. The numbers changed due to adding new stakeholders (teachers) and different response rates.

Panel	**1st Round**	**2nd Round**	**3rd Round**
Physics Education Researchers	28	31	32
Country Delegates	16	11	12
Research scientists	18	14	11
Teachers	19	45	43
Total	81	101	98

Results

First, the Mann-Whitney test on the ranking groups showed statistically significant differences between both high and medium ($W = 38254$, $p << .001$), and medium and low importance groups ($W = 213384$, $p << .001$) with strong effect sizes ($r = 0.56$ and $r = 0.63$, respectively). Next, Kendall's coefficient of concordance showed a high level of agreement between all stakeholders ($W = 0.90$, $p < .01$). Furthermore, the Kruskal-Wallis test showed significantly

different rankings of the stakeholders only on one goal, namely the "Learn about connections between different fields of science" (X^2 = 12.8, p = .005). The difference has a medium effect size (E^2 = 0.132). The Dunn's test showed that teachers ranked this goal significantly higher than education researchers (Z = -3.49, p << .001; p = 0.003 with Bonferroni adjustment).
Last, the analysis of the stakeholders' comments required no additional learning goals to be added to the list. The only important theme emerging from the comments showed that the stakeholders found it difficult to rank the learning goals due to their similar importance.

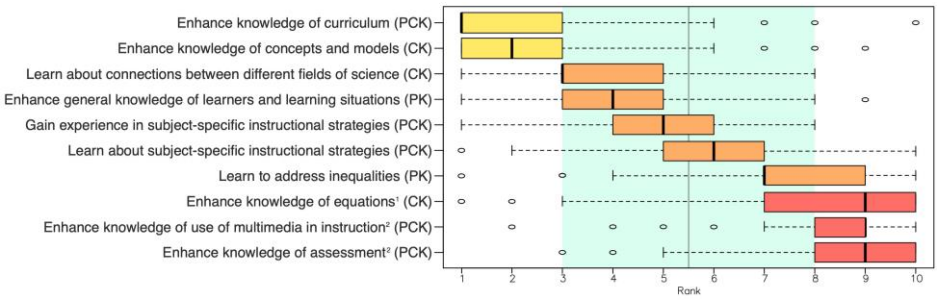

Figure 1: The boxplot shows the ranking of the learning goals. The green area represents the interquartile range of the whole list. The yellow bars indicate the high importance goals, orange bars indicate medium importance goals, and red bars indicate low importance goals. [1]The goal was added based on Enkrott et al. (2007) after the first round. [2]The goals were added from the stakeholders' comments after the second round.

Discussion, Conclusions and Outlook

The ranked list of learning goals of PDPs in Figure 1 shows the most important learning goals for PDPs at particle physics research institutions as perceived by the relevant stakeholders. This list of learning goals can be considered complete, as the stakeholders have not expressed the need to add any more learning goals after the last round of the study. Most learning goals on the list falls under either PCK or CK, with both being present also in the highest-ranked group. The PK goals are less prominent and lower-ranked, which is congruent with previous studies. Furthermore, the analysis of the comments in the last round of the questionnaire showed that the stakeholders believe PK should rather be addressed in institutions that are specialised in pedagogy. With the abundance of experts in content, research institutions should rather focus on enhancing teachers' CK. However, the prevalence of PCK calls for a stronger role of educational experts in the design and facilitation of PDPs at large research institutions.
Additionally, our study found that the stakeholder groups strongly agree on the learning goals of PDPs at large research institutions. Only the learning goal "Learn to connect the different fields of science" was ranked significantly higher by the teachers compared to the other stakeholder groups. Here, the teachers could find this more important as they are less familiar with the topic of particle physics and thus require more examples to learn how to make this relatively challenging topic more relevant for students. Further studies are needed to determine whether this difference would be reduced in a different context.
Our study marks the first step in closing the literature gap in the multi-stakeholder analysis of the learning goals of PDPs. The results of this study can be generalised to other research institutions in particle physics, as their stakeholder groups are likely the same. However, research in different fields of science is required before further generalisations can be made.
The outcomes of our study provide a good basis for the design and evaluation of PDPs at CERN and similar laboratories. Indeed, the hierarchy of the learning goals could influence the design of future PDPs at CERN and particle physics research institutions worldwide.

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