PREPARING TEACHER EDUCATORS FOR LANGUAGE-ORIENTED SCIENCE EDUCATION: DESIGN AND IMPACT OF A PROFESSIONAL DEVELOPMENT PROGRAM

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Abstract

Integrating language and science education is a potential way to strengthen science in primary education. To prepare both language as well as science teacher educators for teaching language oriented science education to their students, a professional development program (PDP) was developed. The PDP consisted of a blended learning program and was designed according to the principles of design based research. Design criteria concerned characteristics of effective professionalization, use of effective multimedia solutions and key components of language oriented science education. The impact of the PDP has been studied by using a mixed method design with a pre- and post-questionnaire (16 participants) and a multiple case study with interviews. The results indicated that teacher educators of both language and science became more aware of the relationship between language and science, they acknowledged the importance of integration of language and science and had acquired new knowledge about language-oriented science education. This latter result was reflected in their teaching; they integrated language and science in their lessons and even in some cases they taught their students how to enact language oriented science lessons at their internship schools.

Keywords: teacher education, language-oriented science education, blended professionalization.

1 INTRODUCTION

In the Netherlands it has been difficult to implement Science and Technology (S&T) in the primary education curriculum. The curriculum is overloaded and teachers have no background in this domain. So, in general teachers face a lack of knowledge in S&T, have limited pedagogical content knowledge, low self-efficacy in teaching S&T and ultimately face a lack of time [1, 2]. It has been advocated to combine language and science education to overcome the issues teachers face in teaching S&T [3]. Combining these two subjects is beneficial for learning language as well as science [4, 5, 6]. Science provides a meaningful context to language learning and language is of utmost importance in learning science, in reasoning about scientific phenomena [6]. In addition, teachers in primary education are generalists with often more affinity with language than science. Therefore integrating language education with science can be used as a vehicle to bring science into the classrooms [8, 9].

Given the potential of language-oriented science education in primary education, preservice teachers should be equipped to teach language-integrated science lessons. When preservice teachers develop a positive attitude towards integrated lessons, they can act as ambassadors of language-oriented science education and in such way help to strengthen science education in primary education. Therefore it is important that preservice teachers develop necessary knowledge and skills to combine language and science in their lessons. Van der Zee, Gijsel and Doppenberg [10] carried out a review study and cautiously concluded that an integrated curriculum at primary teacher education positively contributes to students' attitudes towards integration, content knowledge and skills. However, both the integration of subjects, i.e. science and language, and learning about integration are not commonplace at teacher training colleges. Therefore teacher educators likely need professionalization in this area.

Research on the professional development of teacher educators has been of little interest in the literature. In the Netherlands, Kools and collegues [11] carried out research in this area. They asked 268 teacher educators which areas and domains and what kind of learning activities they prefer when it comes to their professional development. They concluded that these differences depend on teacher educators' experiences. In general, teacher educators prefer reading literature, attending conferences, consulting colleagues and experimenting in their own classroom.

Because of the limited literature concerning professional development of teacher educators with respect to language-oriented science lessons, we carried out this study. To prepare both language as well as science teacher educators for teaching integrated language and science education to their students, we developed a professional development program (PDP), according to the procedure of design based research [12]. To investigate the impact, we used the model of Clarke and Hollingsworth [13]. They developed and validated a model to describe the non-linear, continuing process of learning. This model is depicted in Figure 1. Change occurs through processes of reflection and enactment in four distinct domains: the personal domain (teacher knowledge, beliefs and attitudes), the domain of practice (professional experimentation), the domain of consequence (salient outcomes), and the external domain (sources of information, support or stimulus). Professionalization is considered as a complex process described as growth path ways between these four domains. Changes in one domain can result in changes in another domain (change sequences and growth networks).

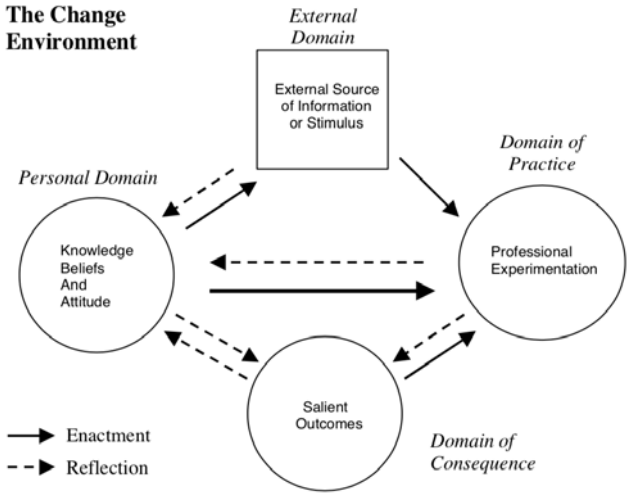

Figure 1. The interconnected model of professional growth according to Clarke and Hollingsworth [13] (p. 951).

2 METHODOLOGY

2.1 Research question

In this study, we aimed to answer the following research question: What is the impact of a blended professionalization in language-oriented science education for primary teacher educators?

2.2 Design

According to the principles of design based research [12], we developed a blended professional development course, including face-to-face meetings and an online learning environment. The design of the course was guided by 'The Carpe Diem approach', which is especially applicable to the design of blended and online courses [14]. The following design criteria have been applied:

1 Evidence-informed professionalization [15, 16] including: a) classroom practice, b) high quality input, based on proven concepts and models and c) active, collective inquiry-based learning;

2 Evidence-informed design of the modules, using the multimedia principles of Mayer [17];

3 Connection to our former professionalization study in which primary school teachers were scaffolded to develop and teach language oriented science lessons [18]. In those lessons, we focused on vocabulary and oral language skills to facilitate scientific reasoning. Primary school teachers learned to develop language-oriented science lessons in which hands-on science activities, reasoning steps and language skills were taught in an integrated fashion.

The PDP consists of eight online modules, one interactive webinar and two face-to-face meetings. Participants attended the modules individually and at their own pace during one year. The type of assignments was diverse, e.g. reading literature, watching a good practice video, interactive discussion,

curriculum analysis, practical assignments in their own classroom, and preparing a presentation about their own practice.

The design was systematically evaluated in a few rounds. The practical usability [19] (user-friendliness, time investment, effectiveness and innovative content) was subsequently evaluated by the design team, a language expert and the participants. Participants appreciated the user-friendliness and positively evaluated blended learning and assignments. They also positively assessed the link with their own classroom practice and appreciated active learning and interdisciplinary working in a network. The participants commented moderately positive on the innovative character of the content of the PDP course for both themselves and their university. After each evaluation, the design was optimised.

2.3 Impact study

2.3.1 Participants

In total 36 participants registered for the course (14 science teacher educators, 19 language teacher educators and 3 researchers). Sixteen participants (5 science teacher educators, 9 language teacher educators and 2 researchers) participated in both the pre- and post-test (44.4%). The participants came from 10 different organizations (including 1 university from Belgium). The low response rate is possibly due to the fact that 13 people did not participate or hardly participated in the course.

Three couples of teacher educators from three different institutes were selected for the multiple case study. They were selected according to the following criteria: as a couple they should represent both science as well as language and both should have actively participated in the course (at least 75% of the modules finished and 100% attendance at the meetings). Three couples met these criteria.

2.3.2 Questionnaire

The pre- and post-questionnaire consisted of 11 statements concerning educators' pedagogical knowledge of language-oriented science education, 5 statements concerning application of language-based science teaching in their own teaching practice, 6 (or 8 in case of science teacher educators) statements about instructing students how they can teach language-oriented science lessons and 6 statements concerning students applying integrated lessons in their internship. These categories are related to the domains described in the model of Clarke and Hollingsworth [13]. Responses to each statement followed a 4-point scale ranging from totally disagree to totally agree. Additionally, at the end of every category educators could give remarks and suggestions.

Table 1. Categories pre- and post-questionnaire.

	Domain Clarke & Hollingsworth	***Number of questions***
A. Knowledge of language-oriented science education	*Personal domain*	11
B. Application of language-oriented teaching in educators' educational practice	*Domain of practice*	5
C. Teaching of language-oriented science education to students	*Domain of practice*	6 (language educators), 8 (Science educators)
D. Application of language-oriented science education by students in their educational practice	*Domain of consequence*	6

2.3.3 Interview format

A semi-structured interview format was developed based on the results of the analysis of pre- and post-questionnaires. For each couple of educators, the results of the questionnaire were summarized per category and remarkable findings were verified in the interview. In addition to the categories of the questionnaire, as mentioned in Table 1, two additional questions were raised. One question addressed potential intentions for curriculum change. The other question addressed the interdisciplinary way of teaching and building a community.

2.3.4 Procedure

The pre-questionnaire was completed online before the start of the course. The post-questionnaire was completed after the course had ended.

Three couples of teacher educators were interviewed via the application Zoom and the duration of the interview was 45-60 minutes. The interviews were video-taped and transcribed verbatim.

2.3.5 Analysis

We applied a Wilcoxon signed rank test to determine whether scores on the post-questionnaire differed significantly from those on the pre-questionnaire. Also individual scores of the couples of teacher educators were analysed and for each category (A-D) a summary was described per couple. Subsequently, the individual scores and findings were verified during the interview. To analyse the interviews we used an analytical framework based upon the domains of Clarke and Hollingsworth [13]; i.e. the personal domain, domain of practice, domain of consequence and external domain. Three of these domains can be directly linked to the categories of the questionnaires, as mentioned in Table 1. In addition to utterances concerning students applying language-oriented science lessons also utterances with respect to intentions to curriculum change were linked to the domain of consequence. Results pointing towards working in a community and using literature will be linked to the external domain. In the transcripts of the interviews first all utterances belonging to one of the four categories were identified and coded by one researcher. Afterwards a second researcher coded these utterances. In case there were any differences, based upon mutual agreement a final code was decided upon. Ultimately the three cases have been compared and similarities and differences have been described.

3 RESULTS

First, we show the results of the quantitative analysis of the questionnaires. Second, we describe the results of the qualitative analysis of the multiple case study.

3.1 Analysis of the questionnaires

A Wilcoxon Signed Rank Test revealed that in categories A, B and C, scores on the posttest were significantly higher than on the pretest (category A, $z = 3.47$, $p = .001$ (two sided), category B, $z = 2.65$, $p = .008$ (two sided) and category C, $z = 2.31$, $p = .021$ (two sided). The mean scores (M) and standard deviation (SD) are indicated in Table 2.

Table 2. Results questionnaire (scale 1-5, N=16).

	Pretest M (SD)	***Posttest M (SD)***	***Significance***
A. Knowledge of language-oriented science education	3.10 (0.44)	3.66 (0.20)	.001
B. Application of language-oriented teaching in educators' educational practice	2.96 (0.52)	3.38 (0.36)	.008
C. Teaching of language-oriented science education to students	3.05 (.54)	3.30 (.74)	.021
D. Students' application of language-oriented science education in their educational practice	3.19 (.46)	3.17 (.43)	NS

3.2 Case study

3.2.1 Case 1: plans for curriculum development

Karin (science teacher educator, 14 years of teaching experience and Helen (language teacher educator, 6 years of teaching experience) are affiliated to the University of Applied sciences Zeeland. A central focus at their institute is the development of a thematic centred curriculum.

In the personal domain, several results were noted. Helen reported an increasing awareness of the differences in language skills amongst students. As a consequence, she argued that it is important that teacher educators teach in a more language-oriented manner. Karin has become more aware of the

relationship between language and science. At the beginning of the course, she didn't acknowledge this connection, now she would like to make language in the science lessons more explicit: '*you can offer much more guidance in students' language development. Students often say 'something is heavier' or 'something is lighter*', *which is scientifically not correct.*' Both teacher educators indicated that it is important to accomplish coherence in the curriculum. Karin stated: *'when teaching really together, you can't teach only your part without asking what this adds to the combined lesson*'.

In the domain of practice a few results were identified. To illustrate, Helen and Karin applied the acquired knowledge and specific online course materials to a teachers' workshop about language-oriented science education.

In the domain of consequence many results were identified. On a level of curriculum improvement both teachers showed several intentions to improve their teaching of language-oriented science education: they planned an analysis of their curriculum with respect to combining language and science, working together more frequently when it comes to thematic assignments, intended to pay more attention to students' language development in science lessons and extension of internship assignments. In addition, both teacher educators would like to address in team meetings with educators the importance of integration, scaffolding and unambiguous use of academic and subject-specific language. Consequences on the student level are not clear. Although Helen did teach her students to use science in a language oriented manner, she didn't visit the students in their internship yet, to evaluate their teaching practice.

In the external domain two clear results could be identified: the course had resulted in a new network and had provided useful materials like lesson plans and relevant literature. Karin stated: '*undoubtfully, the articles are helpful, but also the videos of teachers really contributed to my awareness of the relationship between language and science*'.

In summary, this case showed results in all four domains with a focus on the personal domain and domain of consequence: i.e. acquiring knowledge and making plans for curriculum development.

3.2.2 Case 2: teaching practice

Hetty (language teacher educator, over 10 years of teaching experience) and Hans (science teacher educator, over 10 years of teaching experience) are affiliated to the University of Applied sciences Ede. Both teachers already integrated language and science lessons in the second year of teacher education. They focused mainly on students' formulation of research questions and scientific vocabulary.

Most results could be linked to the personal domain. Hans acquired new knowledge about science and language teaching. After finishing the course, he considered it important to use academic language and subject-specific language by teacher educators but also by teachers at the internship schools. Hetty was already aware of the importance of language oriented teaching and was strengthened in this believe by following the course. Both teachers argued that co-teaching is important in order to increase the efforts in working together as a team and improve consistency in the teaching models. Immersing into each other's discipline resulted in new insights. Integration of language with other subjects provided, according to Hans, new possibilities to deepen science content knowledge. Participating in the course resulted for Hetty in increased confidence of other domain specific content and she discovered that integration of science deepens her own language content knowledge: *'the other subjects provide a meaningful context for language teaching'.*

Concrete changes in classroom practice could be linked to the domain of practice. They both used materials from the course, like auxiliary cards to design and teach language oriented lessons. Hans asked students to describe their observations and to formulate questions that encouraged higher order thinking. By modelling and scaffolding, Hetty learned her students which kind of questions promote reasoning.

With respect to the domain of consequence several results were identified. Both teachers reported the intention to implement language oriented education with scaffolding techniques into the curriculum.

Examples of results in the external domain were the introduction to new literature and more discussion between language and science teacher educators. Hans stated: '*we already taught duo lectures, but it was more like that slide is yours and that slide is mine. Now we together think it through more thoroughly combined with using literature, which results in better lectures'*.

In summary, results can be linked to all four domains. Focus seems to be in the personal domain and domain of practice: acquiring new knowledge and using this knowledge in classroom practice.

3.2.3 Case 3: intentions to renew the curriculum

Ellen (language teacher educators, 5 years of teaching experience) and Lies (science teacher educator, 10 years of teaching experience) are affiliated to the University of Applied sciences Thomas Moore (Belgium). In their curriculum, language and science were taught completely separately. Occasionally lesson consultation took place.

In the personal domain several results were identified. Lies acquired new knowledge with respect to terminology (academic language, subject specific language, reasoning steps), became aware of the importance of integration of language and science and the importance of reasoning steps to promote conceptual change. Also Ellen stressed the importance of reasoning steps: '*due to the fact that students themselves think about the reasoning steps, they better understand the concepts and as a consequence they can better transfer this knowledge to children*'. Ellen is now more aware of how valuable (and time consuming) language oriented teaching is and more aware of the important role of language in other subjects.

Several results could be linked to the domain of practice. Ellen showed examples of language-oriented science lessons in her classroom. Lies asked her students to formulate reasoning steps and stimulated the use of subject-specific language: *'Now I say explicitly: take care, this is daily language, you should use more subject-specific language. So I really make this explicit, before I never did'*. Also they carried out their plans for co-teaching of language-oriented science education.

In the domain of consequence, intentions for changes in the curriculum dominated. For example, both teachers have the intention to add language goals in the lesson preparation form that students use in their internship. They would like to teach students how to formulate language goals. Finally, they would also like to give in-service training about language oriented science education.

Results in the external domain focused on discussion with colleagues, extending their network and exchanging materials and expertise (both intern as well as with other institutes).

In summary, again we demonstrated results in all domains, with a slight focus on the domain of consequence and external domain.

3.2.4 Cross case comparison

In all cases results could be linked to all four domains. However, there were differences in focus (see Figure 2). In case study one the focus was on development of knowledge of the teacher educators themselves (personal domain) and intentions for changes in the curriculum (domain of consequence). In case study two development of knowledge (personal domain) and applying new knowledge in the classroom (domain of practice) were most dominant. In the third case study, there was a focus on network extension (external domain) and intentions to renew the curriculum (domain of consequence). These differences could be explained by the various contexts of the universities and various personal backgrounds and teaching experiences.

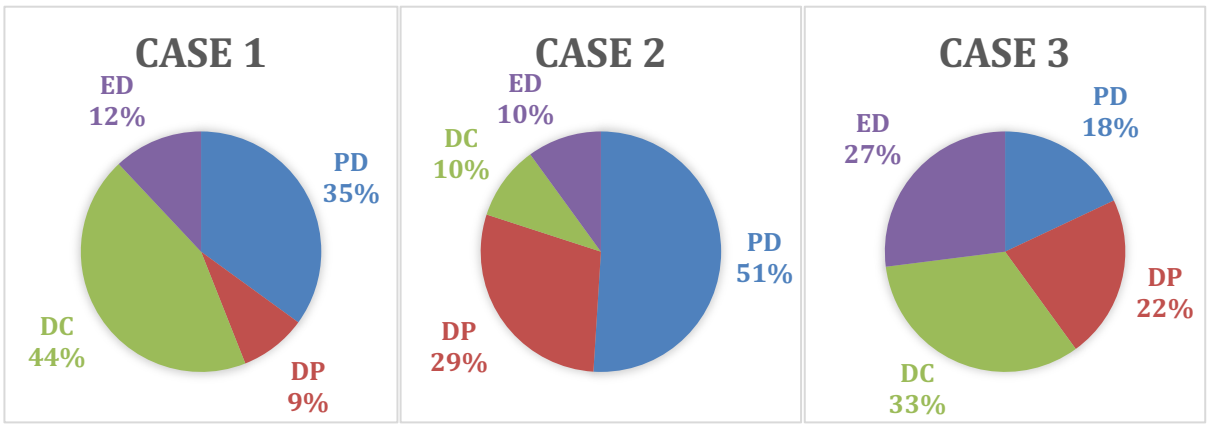

Figure 2. Comparison of cases 1, 2 and 3.

In the personal domain in all three cases similar results were mentioned such as acquiring more knowledge about language-oriented science education and awareness about the relationship between language and science. With respect to the domain of practice in all cases the educators used the

knowledge of the blended professionalization course in their teaching. The main results in the domain of consequence were intentions for curriculum change. Unfortunately hardly any results indicated in the direction of students implementing language-oriented science teaching at their internship schools. Finally, in all cases educators got to know relevant literature, worked more closely together at their university and had extended their network of educators. These results could all be linked to the external domain.

4 CONCLUSIONS

In this study, the impact of a professional development program (PDP) concerning language-oriented science education for primary teacher educators has been studied. The results of both questionnaires as well as a multiple case study indicated that the PDP resulted in an increased awareness of the relationship between language and science and more knowledge about language-oriented science teaching. Especially scaffolding students' language and the use of reasoning steps to promote scientific thinking were new aspects of the participating teacher educators. In Smit, Gijsel, Hotze & Bakker (2018) we elaborated on these concepts in more detail [18]. Teacher educators indicated that after finishing the PDP, their lessons were more language oriented and they also taught their students how they can teach language-oriented science lessons at their internship schools. Unfortunately, the results of the questionnaires did not yet indicate a positive impact on the students' level; there was no evidence of students enacting language-oriented science lessons at their internship schools. Likely the timeframe of the PDP was too short and the moment of our measurement too early to measure any impact on the level of the students. Nevertheless, many teacher educators indicated intentions to implement changes in their curriculum to strengthen language-oriented science education. So on the long run, a stronger effect at the level of students enacting language-oriented science lessons can be expected. Another important result of the PDP is the fact that the teacher educators had acquired access to new literature and got to know other teacher educators from other institutes to build a community. It would be interesting to carry out a follow-up study and investigate a few years later the progress of the teacher educators in teaching and implementing language oriented science at their institutes and examine whether students truly have become ambassadors of language-oriented science education.

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