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REVIEW ARTICLE

Identification of Science Teacher Profiles Based on Lesson Observation Data

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ABSTRACT

It is characteristic that besides other duties teacher competence management and development is becoming a part of school responsibilities. Still, school leaders lack the experience and instruments to accomplish these duties. From a teacher's perspective competence management and development can be seen as the process of identification and implementation of professional development (PD). An effective competence management approach that is widely used in business environments is the identification of required and actual competence profiles to judge which development is needed. Such a competence management approach isn't characteristic of school environments, still a promising perspective on how to solve challenges regarding teacher PD (TPD). TPD interventions are often criticized as being too general ("one size fits all" dominates); therefore, the search for practices on how to "tailor" PD initiatives to individual teacher needs is topical for TPD research. An effective way to personalize TPD could be the determination of TPD profiles and the design of the PD around these profiles. Person-centered approaches dominate in the identification of science teacher profiles, as surveys and tests are commonly used. Examples, of how the identification of science teacher profiles can be done using lesson observation data are missing. Science teaching is a complex process; to limit the complexity of this study, the authors focus on teaching that promotes student conceptual understanding (CU). A mixed method study was designed and conducted in a sample of 26 science teachers, who represented urban municipalities' science teacher population. The study included science teacher lesson observation and analysis, and determination of science teacher performance regarded teaching that promotes student CU. Science teacher performance data were used to identify teachers with similar performance across the selected criteria and to create science teacher profiles. A methodology for how lesson observation data can be used to identify teacher profiles in small teacher samples is described. Six various science teacher profiles in teaching that promote student understanding were identified, characterizing the variety of science TPD needs.

KEY WORDS: Conceptual understanding; teacher professional development; teacher profiles

INTRODUCTION

The rationale for large annual investments in science teacher professional development (STPD) is clear – effective STPD has a positive impact on student results (Sims et al., 2021). Still, not all professional development (PD) interventions positively impact all teachers, leading to an idea of "tailored" PD in opposite to "one size fits all" PD that dominates (Darling-Hammond et al., 2017; Tooley and Connally, 2016). There have been multiple studies that confirm that science teachers are scattered not only by their experience, education, and professional learning needs but also by challenges that they meet in their everyday practice (Zhang et al., 2017) and also by proposals to tailor the PD interventions according to these teacher related variables (Bae et al., 2020).

The authors of this study are following the idea, that teacher PD (TPD) interventions should be "tailored" according to individual TPD needs, based on the rationale that adults learn effectively when their needs are met (Meissel et al., 2016).

To limit the broadness of STPD needs, this research focuses on STPD needs regarding instruction that promotes student conceptual understanding (CU).

Deep CU of science concepts is a key learning outcome that occurs in most of 21st-century science curriculum documents across the world (Murphy et al., 2018). The development of CU in science education is important for students in today's world to become citizens who can make informed decisions about themselves and the world in which they live, and also to reach an understanding, of how knowledge of the concepts observable in nature is created (Holme et al., 2015). Science classroom instruction that promotes student CU should include recognition of student preconceptions, promotion of conceptual change, modeling, use of scientific language and various representations of a concept, and metacognition (Stern et al., 2017).

The author's country, Latvia, like other European countries, is experiencing educational reforms and curriculum change. The updated science subject curriculum is constructed around the fourteen big ideas of science education (Harlen, 2010) and student conceptual understanding of these ideas is one of the key goals of the reform (Skola 2030, 2017). The intention how implementing these changes is also similar to educational reforms across the world – STPD is seen as a way how science teachers will change their practice according to the reform. Author countries' educational reform also obligates new requirements for school leaders. Teacher competence management and linkage of TPD needs with appropriate solutions is now seen as school leadership teams' responsibility. Still, school leadership teams lack good practice and instruments to accomplish this task (Saleniece and Namsone, 2020).

The current study aims to conceptualize STPD needs to be regarded to the promotion of student conceptual understanding and cluster teachers with similar PD needs into clusters from the STPD developer perspective.

Accordingly, two research questions were stated:

1. RQ1 How do science teachers differ in their classroom instruction regarded to promotion of student conceptual understanding?
2. RQ2 What PD need profiles are characteristic of Latvian science teachers?

The study is part of a larger research project that is aimed at designing science teacher needs-based PD and confirming its positive impact on science teacher practice.

LITERATURE REVIEW

TPD Needs

Published development need classifications include "felt needs (what people say they need), expressed needs (expressed in action) normative needs (defined by experts), and comparative needs (group comparison). Other distinctions include individual versus organizational or group needs, clinical versus administrative needs, and subjective versus objectively measured needs" (Grant, 2002). In the case of TPD needs, these needs can be conceptualized in three various levels – individual teacher, organizational, and system – and also can be determined with at least two approaches– deficit (gaps between observed and needed practice) and growth (the support teachers need to make sense of information in ways that are personally meaningful to them) (Altschuld and Witkin, 1999).

In this study, the authors follow the learning need definition from the deficit perspective proposed by Grant (2002) and use the term "teacher professional development needs" to describe "the gaps between the observed and required teacher practice" that are conceptualized at the organizational (school) level.

Science Teacher Profiles

The idea of grouping individuals according to their competence expressed in their performance has emerged from competence management research in the business environment. The rationale for such grouping is clear – it is more effective to plan, organize, and conduct staff development for larger groups of individuals who share similar needs. From a business environment perspective, the competence profile is a set of required or acquired competencies, their titles, descriptions, and levels that describe the employee in the organization (Zandbergs et al., 2019). The competence profiles can be divided into actual and required competence (Różewski and Małachowski, 2012): Actual competence profiles – contain competencies that the employee has acquired and expresses in action; required competence profiles – contain competencies required by the organisation to be possessed by the employee. The business environment competence management approach is only emerging in teacher competence management (Holzberger and Schiepe-Tiska, 2021).

In the last decade, other approaches for teacher profile determination and analysis have emerged in teacher education research (Bae et al., 2020). To distinguish teacher subgroups based on a measurable set of characteristics, and to analyze how teacher profiles correlate with other variables and student outcomes, scholars use person-centered approaches and such statistical methods as latent profile analysis (Marsh et al., 2009). There are solid body of examples, of how teachers can be profiled based on variables characterizing their instructional practice, motivation, stress job satisfaction, and assessment practices (Bae et al., 2020). Regarding TPD, De Wal et al. determined four various teacher motivation profiles that were variously associated with engagement in PD activities (De Wal et al., 2014). In a more recent study, Bae et al. identified five different science teacher profiles, based on teacher pedagogical content knowledge and motivational beliefs (Bae et al., 2020). Still, no studies up to this date have attempted to identify profiles of science teachers who engage in PD.

Teaching That Promotes Student Conceptual Understanding

Concepts and principles are the basic building blocks of scientific knowledge and understanding of a concept is a precondition for making complex inferences or accomplishing any scientific work with it (Mi et al., 2020). Therefore, it is decisive for students to attain CU about the core ideas of science subjects and build this understanding coherently. Many scholars agree that students' CU can be elaborated when science lesson builds on the ideas that students bring to lessons and use various representations of the concept.

In a recent guidance report, Holman and Yeomans emphasize seven science teacher practices that promote student understanding of concepts: building on student ideas, metacognition, modeling, retrieval of knowledge, practical work, using the language of science and feedback (Holman and Yeomans, 2021). In the majority of cases, these practices are novel or partly understandable to science teachers, and effective TPD is seen as a pathway to meaningfully incorporate these practices in science teachers' everyday practice. Still, questions remain that the most effective way is how such STPD should be conducted (Hugerat et al., 2015).

METHODOLOGY

Context

The research was carried out in an urban municipality (9 schools, approx. 8300 students and 800 teachers). The researchers are collaborating with municipality and school leaders to evaluate teacher instruction quality and to develop tailored PD solutions. The author's country like other European countries is experiencing a curriculum change focusing on student conceptual understanding as a science learning outcome.

Participants

Twenty-six grade 7–12 science subjects (four physics, 11 biology, seven chemistry, and four geography) teachers formed the research sample. No information about the participant demographic was available to the authors.

Instruments

To create science teacher profiles, according to the business competence management approach, it is vital to select appropriate criteria that characterize the required competence. In this study, the authors used selected criteria from a previously developed and validated instrument – the framework of teacher performance assessment to support teaching 21st-century skills (Bērtule et al., 2019). The selected instrument is a category-criteria framework, consisting of 17 criteria that conceptualize teacher classroom practices that support the acquisition of 21st-century skills in the author's country's educational context. The 17 criteria are structured in six categories (i.e., student self-regulation, student cognitive activation) and three domains (planning, teaching, and classroom environment) derived from teachers' everyday practice. Teachers' performances according to all categories and criteria of the framework are described in five levels (scale 0–4): Expert, proficient, developing, beginner, and not observed. The performance level descriptors were validated by 145 lesson observations in 18 different subjects in grades from 1 to 12.

Research Design and Procedure

To answer the research questions, an exploratory mixed-method research design was chosen.

The authors analyzed and compared the seven recommendations for teaching to promote student conceptual understanding by Holman and Yeomans (2021) with the criteria from the category-criteria framework of teacher performance assessment to support teaching 21st-century skills (Table 1), to choose six criteria from four categories, that describe the required teacher competence to promote student conceptual understanding.

Second, the chosen categories were prioritized (Figure 1) according to the assumption, that the use of multiple representations of the curriculum is a cornerstone for conceptual understanding (priority) – cognitively active learning and metacognition are limited when only a few representations of the curriculum are available. The second cornerstone (second priority) is instruction – cognitively active learning and metacognition are also limited when the science lesson is poorly planned and managed. Student cognitive activation and metacognition were stated as the third and fourth priorities due to the reason that metacognition cannot be adequately developed when cognition is limited.

An example of teacher performance level descriptors for criteria 6.1. Representation of the curriculum is displayed in Table 2.

The authors stated the third-performance level in each of the selected criteria as the required performance level.

Third, all 26 teacher lessons were observed and transcribed by experienced and specially trained experts. The authors analyzed the transcriptions according to previously selected criteria and determined teacher performance levels in each criterion according to the performance level descriptors. For the first five teachers, the authors determined the performance levels from the transcriptions individually and then compared their decisions. An inter-rater agreement of 0.8 was reached, and the authors discussed and reached an agreement in the cases where determined performance levels differed. The performance levels for the remaining 21 teachers were determined by the first author. In the further study, authors followed the premise that profiles characterizing groups of individuals can be created by clustering individuals based on

Table 1: Comparison of recommendations for teaching to promote student conceptual understanding with criteria from the category-criteria framework of teacher performance assessment to support teaching 21st-century skills

Recommendations for teaching to promote student conceptual understanding (Holman and Yeomans, 2021)	Corresponding criteria from the category-criteria framework of teacher performance assessment to support teaching 21st-century skills (Bērtule et al., 2019)
1. Build on the ideas that pupils bring to lessons	5.1. Instructional design
	2.2. Classroom discourse
2. Help pupils direct their learning	1.2. Promotion of metacognitive strategies
3. Use models to support understanding	6.1. Representation of curriculum
4. Support pupils to retain and retrieve knowledge	5.1. Instructional design
	5.2. Classroom management
5. Use practical work purposefully	5.1. Instructional design
6. Develop scientific vocabulary	2.1. Tasks for cognitive activation
	2.2. Classroom discourse
7. Use structured feedback	5.1. Instructional design
	5.2. Classroom management

similarities in variables describing them (in this case by similar performance across the criteria).

The use of statistical methods (latent profile analysis, k-means clustering, and mean-shift clustering) to cluster teachers with similar performance across the selected criteria was considered, still, the small number of entries (n = 26) was a limitation to use these methods.

Lastly, to create TPD need profiles, authors used the developed prioritization of categories corresponding to teaching that promotes student conceptual understanding and tiled teachers in profiles according to their performance (Figure 2).

FINDINGS

Table 3 shows study sample teachers (n = 26) mean and median performance levels in the selected criteria and the minimal and maximal performance levels observed.

The identified TPD needs profiles and median performance levels characteristic to each profile are presented in Figure 3.

DISCUSSION AND CONCLUSION

The obtained results indicate that study samples science teachers' performance regarded to promotion of student conceptual understanding varies, leading to a conclusion that teachers are also scattered in their PD needs. No teacher reaches the required competence level in all of the selected criteria, still, teacher mean performance levels in basic instruction and curriculum representation are better than in student cognitive activation and promotion of metacognition. The criteria where teacher samples mean performance level is closest to the required level are basic instruction. Still, in each criterion, there is a teacher, who performs poorly. The practice of promotion of student metacognition stands out. Between study samples teachers there are only a few who include this practice in their science lessons.

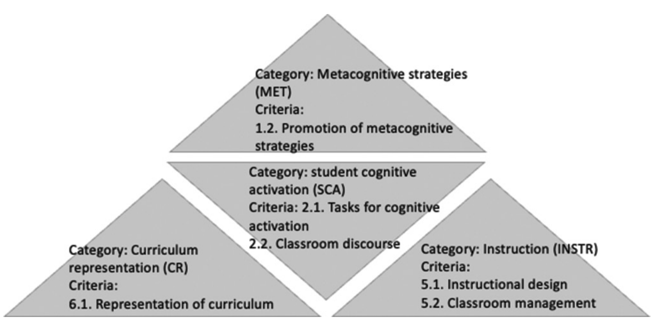

Figure 1: Prioritisation of selected criteria characterizing teaching that promotes student conceptual understanding

The results indicate five various STPD needs profiles, based on the observed instruction regarded to promotion of student conceptual understanding.

Most of the study sample teachers adhere to profile 1.2. Teachers of this profile perform one level below the required level in basic instruction; minimal efforts are made to cognitively activate students and to represent the curriculum in various ways, as profile teacher performance is in level 1.

Teachers of profile 2.2.1. are one level below required in basic instruction and curriculum representation, cognitively active learning is observed in performance level 1 in their lessons, still the promotion of metacognitive strategies isn't observed in their lessons. Teachers of profile 1.3. are balanced in their performance, except promotion of metacognitive strategies (performance regarded to MET isn't observed in their lessons). Still, their performance in all observed criteria is in the first level.

Teachers of profile 1.1. perform poorly in basic instruction, promotion of metacognitive strategies and cognitively active learning isn't observed in their lesson, still, some efforts are made to variously represent curriculum. Teachers of profile 2.1. use various curriculum representations and are close to level 2 in their performance in basic instruction, still, there are only some signs of student cognitive activation in their lessons, and no promotion of metacognitive strategies is observed. Teachers of profile 2.2.2. have the most comprehensive performance regarded to promotion of student conceptual understanding. Teachers of this profile have a solid performance in curriculum representation and instruction, and they are close to performance level 2 in student cognitive activation, also some efforts are made to promote metacognitive strategies.

The identified STPD needs profiles confirm the hypothesis, that science teachers are scattered across their needs regarding instruction that promotes student conceptual understanding. Some of the identified profiles converge with science teacher profiles identified by Bae et al. (2020). For example, the PD needs profile 2.1. is similar to the "conventional" profile from Bae's research and could represent science teachers, who are not motivated to promote reforms (in the case of this study,

Table 2: Performance level descriptors for criteria 6.1. Representation of curriculum

Level	0	1	2	3	4
Performance descriptor	The used curriculum representations aren't appropriate for students' age, development of misconceptions is observed.	Some (1–2) curriculum representations are used inappropriately to students' age (too complicated or too primitive).	Multiple representations of the curriculum are used appropriate to age, but the development of misconceptions is still observed.	Some (1–2) scientifically appropriate representations of the curriculum are used appropriately to student age.	Multiple, scientifically appropriate representations of the curriculum are used appropriately to student age.

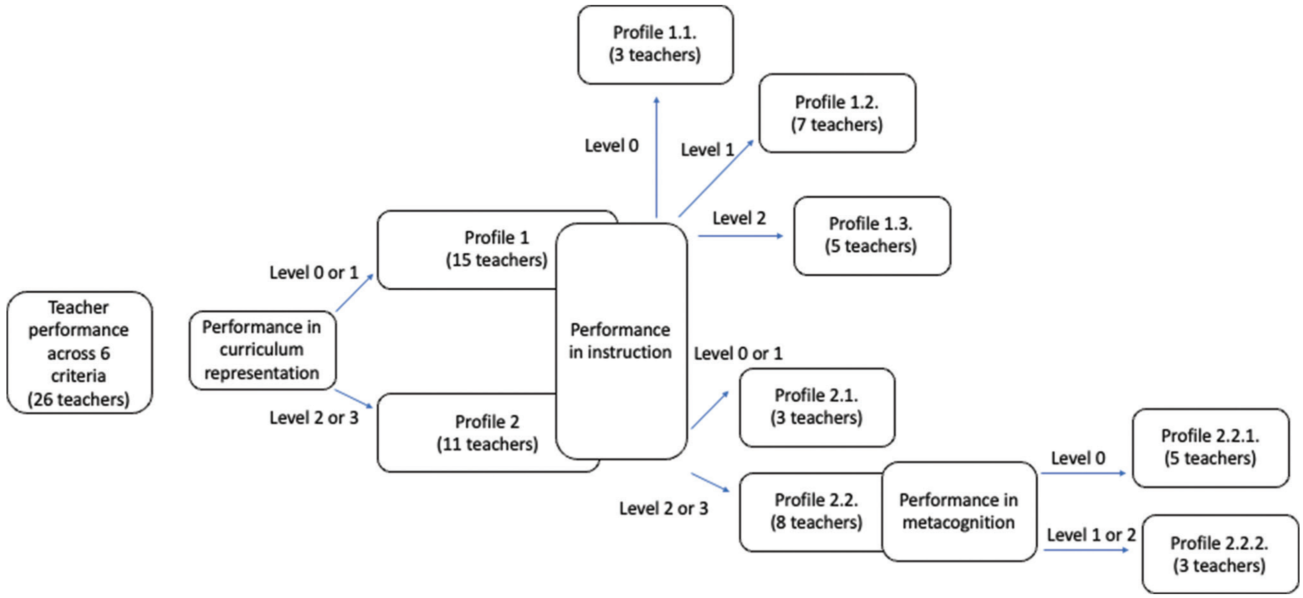

Figure 2: Decision tree for the identification of science teacher professional development needs profiles

Table 3: Study sample teachers' performance in selected criteria characterizing teaching that promotes student conceptual understanding

Categories	CR	INSTR		SCA		MET
Criteria/Results	**6.1.**	**5.1.**	**5.2.**	**2.1.**	**2.2.**	**1.2.**
1. The mean performance level of the study sample	1.42	1.69	1.54	0.69	0.92	0.19
2. The median performance level of the study sample	1	2	2	1	1	0
3. Minimal performance level of study sample (observations)	0 (n=4)	0 (n=1)	0 (n=2)	0 (n=10)	0 (n=5)	0 (n=22)
4. The maximal performance level of the study sample (observations)	3 (n=4)	3 (n=2)	3 (n=2)	2 (n=2)	2 (n=3)	2 (n=1)

don't use tasks for cognitive activation, and do not promote metacognition), still have PCK above average (in case of this study uses multiple representations of curricula). Furthermore, from our perspective, the teacher profile "confident with multiple goal approach" corresponds with teacher profile 2.2.2. from the present research, as these teachers show performance higher than average in performance, mastery, and PCK.

Furthermore, the identified science teacher profiles correspond with teacher profiles that can be identified through TALIS teacher survey data analysis. TALIS data analysis both in Turkey (Özdemir et al., 2023) and in South Korea (Jang et al., 2023) highlight four various teacher profiles (laissez-faire, typical, controlling, and versatile). The "controlling profile," identified in TALIS data, corresponds to teacher profile 2.2.1. identified in the present research – teacher of both profiles tends to emphasize higher levels of classroom management in comparison to student cognitive activation. Teacher profile 2.2.2. identified in the present research corresponds to the "versatile" teacher profile identified in TALIS data – teachers of both profiles tend to emphasize high levels of cognitive activation, classroom management, and clarity of instruction. Furthermore, the "typical" teacher profile corresponds with teacher profile 1.3. identified in our classroom observation data, as both profiles describe teachers with similar and mediocre performance in classroom management, clarity of instruction, and cognitive activation. Our data doesn't highlight the "Laissez-faire" profile from TALIS data (low performance in clarity of instruction, mediocre performance in clarity of instruction, and cognitive activation), instead, we identify profiles 1.1. and 1.2. where not only teacher performance in classroom management is lower than average, but also performance in cognitive activation and clarity of instruction is low.

The teacher profiles that can be identified in our research still do not appear in other international studies and can be explained within the context of the Latvian educational system. The acute lack of science teachers has caused a decrease in the qualification required for teaching, leading to two tendencies – other subject specialists are re-qualifying to teach science subjects and a lot of pre-service teachers are working in school full-time parallel to their studies (OECD, 2020).

We believe that the identified profiles can be used for differentiation of STPD, moving away from a "one-size-fits-all" approach to TPD (Poole and Li, 2023). We support the perspective, that each teacher should engage in PD, that meets his/her needs (McChesney and Cross, 2023) and the teacher profiles can be used as a starting point for the design

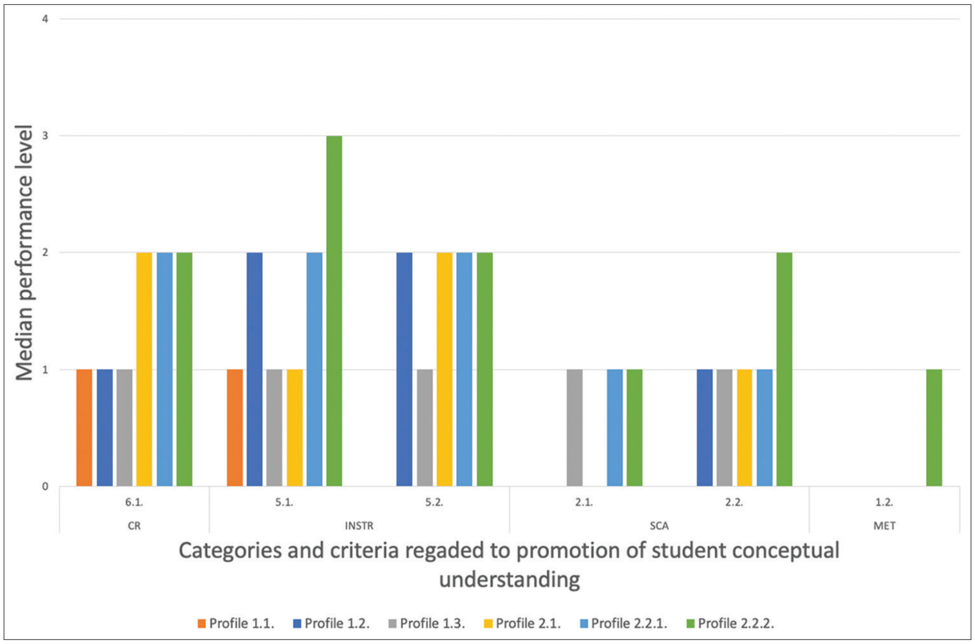

Figure 3: Median performance of identified science teacher professional development needs profile teacher in the selected criteria characterizing teaching that promotes student conceptual understanding

of such PD, as they describe the gaps between teacher actual and evidence-based effective teaching practices in prioritized order. We see particular TPD solutions that can be linked with the identified TPD profiles. For example, profile 1.1. teachers show low performance in classroom management and previous studies show, that coaching is one of the most effective PD forms to change classroom management (Wilkinson et al., 2020). Profile 1.1., 1.2. and 1.3. teachers show low levels in curriculum representation, indicating a need for these teachers to broaden their PCK in particular science subjects. We see guided professional learning communities as a possible solution for such needs (Dogan et al., 2016; Jones et al., 2013). Still, we believe that the described STPD need profiles should be used in tandem with data characterizing teacher quality and demographic information and should be used by school leaders as a basis for discussion with particular science teachers to decide on their PD.

The methodology described in this study can be used to conceptualize STPD needs and to identify STPD needs profiles when TPD needs are seen from a deficit perspective. The case of instruction regarded to promotion of student conceptual understanding proves that in small samples teacher profiles can be identified without statistical methods. Further research that confirms the validity and reliability of this methodology should be conducted.

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