Skills requirements among primary school science teachers

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Abstract

In the spring of 2018, the Danish coalition government (VLAK Government) announced a new national science strategy that expressed a desire for more capable teachers within the field of science. This article presents the key results from the mapping of knowledge and skills requirements among science teachers in primary schools that was carried out in collaboration between Rambøll Management Consulting and University College Copenhagen for the Danish Ministry of Education Based on a combination of quantitative and qualitative data taken from the perspective of the science teachers themselves, a general need and demand for subject-didactic skills development is highlighted. The study also indicates a relatively high demand for targeted upgrading of academic skills among natural science/technology teachers in preparatory classes.

Introduction

The VLAK government's national science strategy addresses a number of challenges facing the field of natural science, including the lack of motivation for science among many children and young people and the small number choosing to take up science courses (Danish Ministry of Education, 2018a). At the same time, the strategy focuses on how academic and subject-didactic skills among science teachers are important for creating education that benefits the curiosity, motivation and academic competence of children and young people. One of the focus areas of the science strategy is a desire for more capable teachers in natural science. As part of this focus area, the government sought the targeted and continuous academic improvement of science teachers in primary schools.

In order to better strengthen the knowledge base for funding this initiative, Rambøll Management Consulting and University College Copenhagen carried out a major mapping exercise of knowledge and skills requirements among science teachers in primary schools on behalf of the National Agency for Education and Quality (Rambøll & University College Copenhagen, 2019). This topical article presents the key results of the mapping exercise conducted between October 2018 and January 2019. The purpose of this article, therefore, is not to contribute supplementary independent analyses or discussions but, rather, to highlight the key results of the mapping exercise via an additional channel and thereby contribute to a qualified basis for further discussions on teacher skills – both now and in the future.

[1] Martin Foldager Hindsholm was employed by Rambøll Management Consulting between 2011 and 2019, during which time he led a project on the mapping of skills requirements among science teachers in primary schools. The project was a collaboration between Rambøll and University College Copenhagen and was carried out on behalf of the Danish Ministry of Education.

Priority has been given to communicating those results based on data close to practice – i.e. on questionnaire and interview data collected from teachers, school managers, science instructors and other key actors.
The article's authors, Alexander Secher and Martin Foldager Hindsholm, acted as the overall consultant and project manager respectively on the aforementioned mapping exercise.

It should be emphasised that the results presented below were not based on objective assessments of the teachers' skills. Rather, they should be seen as an expression of how science teachers perceive their own academic and subject-didactic skills. Consequently, the article paints a picture of whether and in which areas there is an actual need and demand for knowledge and skills development from the perspective of the science teachers themselves. The teacher perspective is supplemented by key insights from school managers and representatives from municipal government.

The article firstly presents the data basis and methodological choices underlying the key results highlighted here. Key results related to the existing academic knowledge and skills requirements among science teachers in primary schools are then shown, followed by the findings related to subject-didactic knowledge and skills requirements. Underlying both is an assessment of present knowledge and skills among science teachers as well as an assessment of the demand for knowledge and skills.

Method

The extensive mapping exercise of skills requirements among primary school science teachers carried out by Rambøll Management Consulting in collaboration with University College Copenhagen used a mixed-methods approach and was based on interviews with an expert and stakeholder panel, three questionnaires and interviews with science teachers, pupils, science instructors, school managers and science coordinators as well as a systematic knowledge mapping of effective skills development initiatives aimed at science teachers in primary schools (Rambøll & University College Copenhagen, 2019).

In view of the article's scope and in order to focus on those results most closely based on data close to practice, the article is primarily concerned with the quantitative questionnaire data and qualitative interview data[2]. These are described in more detail below.

Quantitative data

The basis for the quantitative data consists of data from three questionnaires conducted among science teachers, school managers and science coordinators or other municipal government representatives respectively. The table below shows both response rates and the number of respondents for each of the three questionnaires.

[2] Interviews with members of the expert and stakeholder panel are therefore not included, and the systematic knowledge mapping of effective skills development initiatives is included only to a limited extent and for perspectival purposes.

Table 1. *Overview of response rate*

Target group	Number invited	Number of responses	Response rate (%)
Municipal government representatives	**98**	**71**	**72**
School managers	**1,774***	**667**	**38**
Science teachers	**2,459 (3.7 per school)**	**1,108**	**45**

Note: *Six schools have been omitted from the questionnaire because they fall outside of the target group on account of being either tenth grade centres, business schools or international schools with no Danish speaking teachers.

The questionnaire conducted among municipal governments was all-inclusive in that every municipality in the country was invited to participate in the study. As the table indicates, representatives from 71 of the country's 98 municipalities participated, giving a response rate of 72%.

The questionnaires for the school managers and science teachers were conducted on an all-inclusive basis at school level, with all school managers in the folkeskole system as well as those at independent and private schools (0-9th grade) being invited to participate in the study. As the table indicates, 667 out of 1,774 school managers contacted participated in the study, giving a response rate of 38%.

Science teachers were invited to participate in the questionnaires by setting up a link distributed through their respective school managers. It is therefore not possible to calculate precisely how many science teachers actually received an invitation to participate in the questionnaire. The most realistic suggestion is that the number of managers who forwarded the invitation to science teachers at a maximum corresponds to the number of managers who chose to participate in the study themselves. Based on this, a total of 1,108 out of approximately 2,459 science teachers participated in the study, giving a response rate of 45%.

The relatively low response rate among school managers and science teachers means that generalisations regarding the remaining population of school managers and science teachers should be made with a degree of caution. Thus, it cannot be assumed that science teachers and managers in the sample group systematically differ from those science teachers and managers who did not participate in the study. For example, one could imagine that it is those very schools and science teachers who are particularly involved with the field of natural science who chose to participate in the questionnaire. However, this risk of systematic differences between science teachers is relatively limited, partly because a very large response base was established and partly because it was ensured that science teachers at the individual schools were selected at random as part of the distribution process. Furthermore, as part of the distribution process, we prioritised ensuring an even representation among the four science subjects in order that the analyses provide an overall picture of the knowledge and skills requirements among science teachers in primary schools across these four subjects. This is reflected in the

fact that of the participating science teachers, 44% teach biology, 42% teach physics/chemistry, 44% teach geography and 46% teach natural science/technology[3].

Qualitative data

In addition to the three questionnaires, the article is based on interviews with a number of key actors. Specifically, case study visits were carried out at seven schools, where interviews were conducted with either individuals or focus groups involving science teachers, pupils, science instructors, school managers and science coordinators from municipal government. The seven schools were chosen to ensure a variation based on school type (folkeskole/independent and private elementary school), municipality size and whether or not the school provided lower secondary education. The table below shows the number of schools where interviews were conducted with the various participants included in the study.

Table 2. *Overview of case study visits.*

	Number of focus groups/interviews	Number of participants/observations
Focus group or personal interview with science coordinator and/or school manager	**6**	**8**
Focus group of pupils at pre-school, primary and lower secondary level	**7**	**32**
Focus group of science teachers	**7**	**26**
Focus group of science instructors and other resource personnel	**3**	**4**
Observation of teaching	**4**	**4**

All interviews and focus groups were conducted on the basis of a semi-structured approach where the interviewees were given a number of identical questions but where there was also space to explore other perspectives of interest and relevance to the study (Harrits, Pedersen & Halkier, 2012: 150).

Analysis approach

The article uses methodical triangulation of quantitative and qualitative data (Halkier, 2002). The quantitative analyses consist mainly of simple frequency analyses, although statistical significance tests have been conducted on questions where it is particularly relevant to investigate any differences in current knowledge and skills requirements across the subject groups. Specifically, a significance test was conducted in which differences in responses between teachers in one specific science subject relative to the group of teachers who do not teach in that science subject were tested by means of a t-test[4].

[3] The four groups do not total 100% because a teacher can teach in more than one of the subjects mentioned.

[4] These statistical analyses are referred to throughout the article even though they are not presented in their own table. However, they can be obtained by sending a request to asec@ramboll.com.

The article presents only those figures obtained from the questionnaire distributed to science teachers as this respondent group is the main point of focus of the article. However, the body text also includes results from the questionnaires conducted among school managers and municipal representatives as these substantiate and nuance the highlighted results. The quantitative analyses are further supplemented with substantive insights, key perspectives and interesting nuances from the qualitative coverage when this is considered analytically relevant.

Academic skills

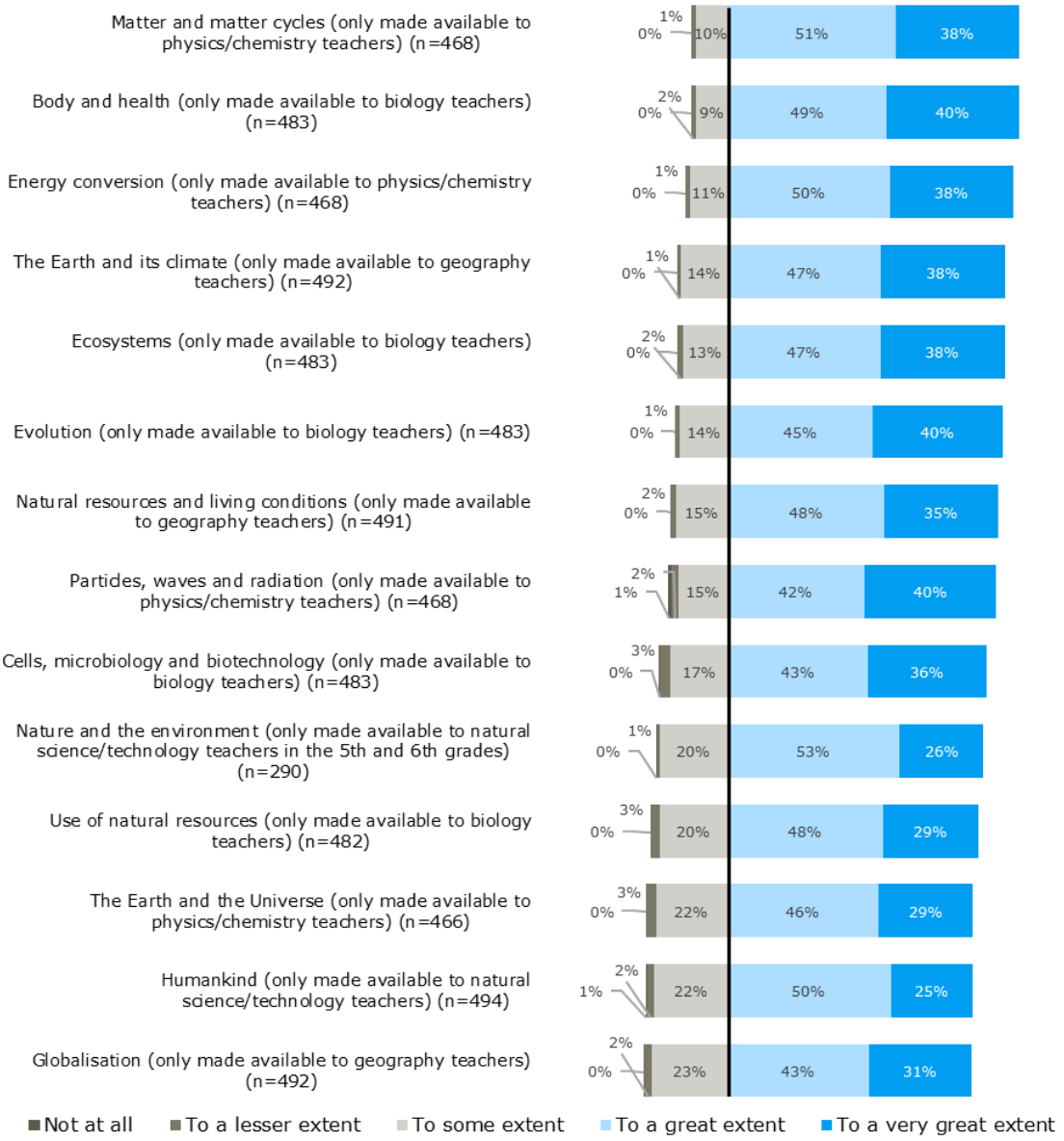
As part of the questionnaire, science teachers assessed the degree to which they feel adequately equipped to handle a number of different academic and subject-didactic teaching activities[5]. The main focus of this section is the science teachers' assessments of teaching activities with primarily academic aims.

Within the science subjects, differentiation is made between two types of academic knowledge and skills objectives. Thus, both science-related aims and subject-specific aims are addressed. The science-related aims describe the working methods and processes that are common for all of the science subjects. The subject-specific aims, on the other hand, describe the specific content of the individual science subject and are used in up to five skills and knowledge areas. The guidelines for the four science subjects emphasise that teaching should include content from both types of guideline objectives to enable the development of skills in an interaction between science-related and subject-specific aims (Danish Ministry of Education, 2018b). Against this background, Figure 1 below presents teachers' assessments of that segment of skills and knowledge areas they themselves feel best equipped to teach in.

The teachers have responded on a scale of 1 (not at all) to 5 (to a very great extent). The various skills and knowledge areas in the figures are ranked according to the proportion of teachers who, to a great or very great extent, feel equipped to teach their pupils in these skills and knowledge areas. The vertical line through the figure separates the "to some extent" and "to a great extent" response categories.

[5] In practice, although the vast majority of activities will call for both academic and subject-didactic skills, for analytical and communicative reasons connected to the data collection, the activities had already been divided according to whether the activities primarily called for academic or subject-didactic skills based on the immediate assessment of the involved parties. Furthermore, it can be argued that several of the activities, in addition to academic and subject-didactic skills, also call for general didactic skills. In order to maintain a strict analytical division, however, it was decided that only academic and subject-didactic skills should be differentiated.

Figure 1. *Skills and knowledge areas for which teachers feel best equipped*



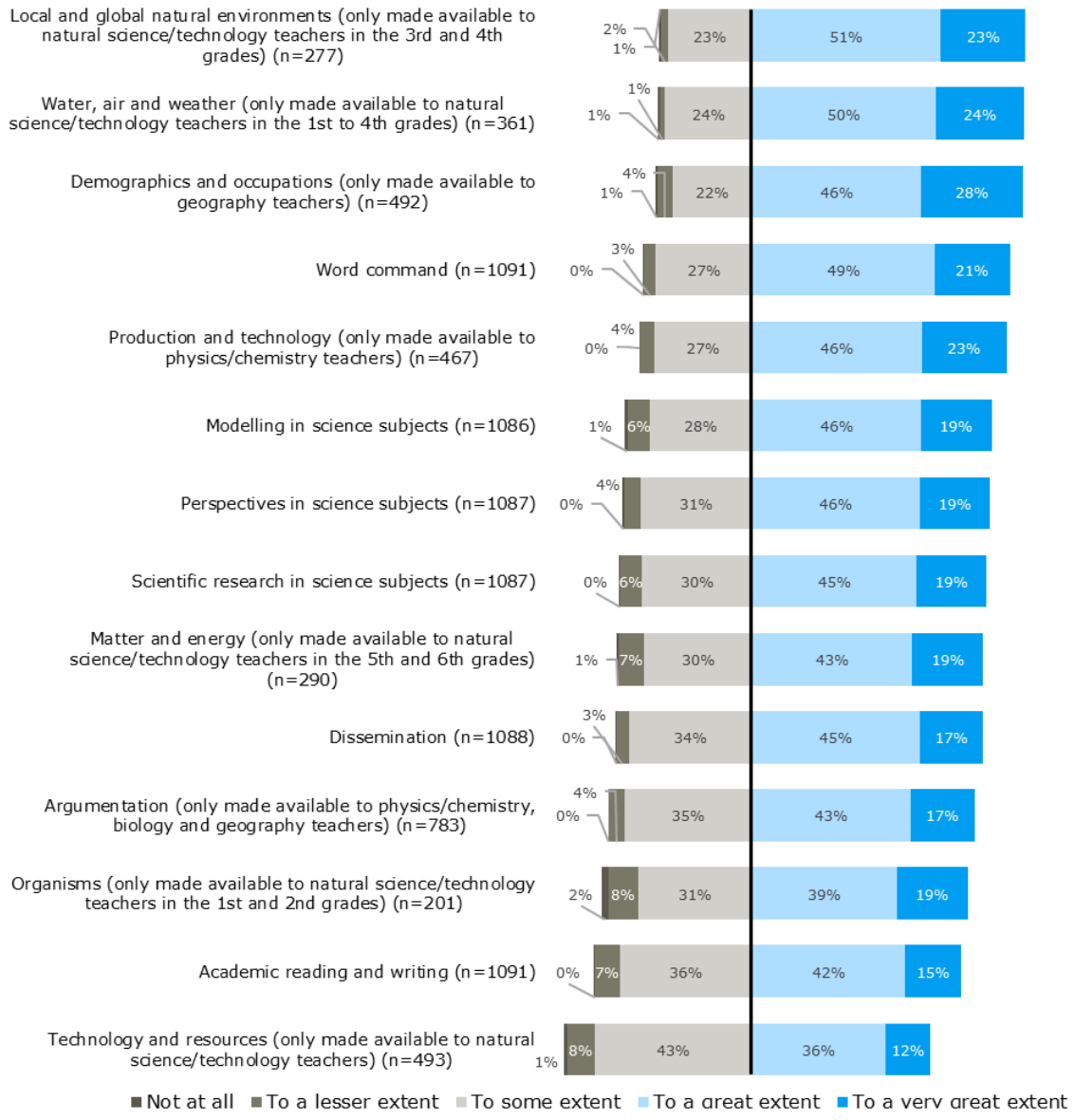
Note: The questions concern the teachers' academic skills. Question: To what extent do you feel adequately equipped for the following? 'Don't know' answers have been omitted from the analysis.

The figure shows that the majority of science teachers in lower secondary education in particular feel well-equipped to teach their pupils in the subject-specific skills and knowledge areas that characterise their particular science subject. For example, 89% of physics/chemistry teachers feel that they are equipped to a great or very great extent to teach their pupils about matter and matter cycles. This opinion on personal competency in the subject-specific skills and knowledge areas appears to apply across the science subjects at lower secondary level (physics/chemistry, biology and geography).

In contrast to the above, a different picture emerges when the focus is on teachers in natural science/technology as well as on more general science objectives. This is

illustrated in Figure 2 below, which presents the segment of skills and knowledge areas that teachers feel least equipped to teach in.

Figure 2. *Skills and knowledge areas for which teachers feel least equipped*



Note: The questions concern the teachers' academic skills. Question: To what extent do you feel adequately equipped for the following? 'Don't know' answers have been omitted from the analysis.

The figure shows that teachers in natural science/technology feel least well-equipped to teach their pupils in skills and knowledge areas in natural science/technology compared with science teachers in the three lower secondary-level science subjects. Across the skills and knowledge areas in natural science/technology generally, a relatively small proportion of teachers in natural science/technology feel well-equipped to teach their pupils in these subjects.

There seems to be a definite need therefore for upgrading academic skills among teachers in natural science/technology. This is also reflected in the national skills coverage report, which indicates the level of skills coverage in the four subjects, defined as the proportion of timetabled teaching hours covered by teachers with the skill levels "teaching competency" and "equivalent competency" relative to the total number of hours. It shows that during 2017/2018, skills coverage was 97.1% for physics/chemistry and 87.2% for biology, while the skills coverage was only 76.8% for geography and 68% for natural science/technology (Danish Ministry of Education, 2018c)[6]. There has been a rise in skills coverage across all four science subjects during the last six years. This is especially true in natural science/technology, where the skills coverage has increased by almost 17 percentage points since 2012/2013. However, as can be seen from both the current skills coverage and Figure 2 above, there is still a need for the further upgrading of academic skills among teachers in natural science/technology.

As part of the questionnaires and in relation to the above, school managers and municipal representatives also assessed which science subject(s) had the greatest need for skills development. The largest proportion of school managers (42%) as well as municipal representatives (37%) responded that the need for skills development was equal across the four science subjects. However, the second largest groups among school managers (30%) and municipal representatives (38%) responded that the need for skills development was greatest among teachers in natural science/technology, which is precisely the science subject in which skills coverage is lowest. During an interview, one manager elaborates on why the need for skills development is greatest among teachers in natural science/technology. At the same time, however, the manager emphasises that developing skills among teachers in natural science/technology must not be done in isolation, but needs to be followed up by equivalent skills upgrading among teachers at lower secondary level:

> "For a number of years, I've been of the opinion that it's teachers in natural science/technology that we need to develop, as this is where we lay the foundations. However, as pupils become more proficient at the science and technology level, lower secondary teachers also need to develop; otherwise, they are unable to follow and adapt the teaching. Investment in natural science/technology teachers should be supported, but we should not forget that it needs to be in the context of a lower secondary education." (School manager, 2018)

Aside from the need for skills development in natural science/technology, Figure 2 also identifies a tendency among science teachers to feel less equipped for teaching pupils in general science objectives compared to subject-specific ones. For example, only 57% of science teachers feel to a great or very great extent that they are adequately equipped to teach academic reading and writing; similarly, 62% of teachers answer that they feel to a great or very great extent that they are adequately equipped to teach the topic of dissemination. Finally, less than two thirds of science teachers state that they feel to a great or very great extent that they are adequately equipped to teach their pupils in

[6] As part of the mapping exercise, teachers also indicated in which of the science subjects they had teaching or equivalent skills. Here, 95% of teachers in physics/chemistry and 82% of teachers in biology answered that they had teaching skills in their specific subject, while 66% of teachers in geography and 60% of teachers in natural science/technology answered that they had teaching or equivalent skills in their subject.

scientific investigation or perspectives respectively. By extension, the statistical analyses show that the group of teachers in natural science/technology feels significantly less well-equipped to teach their pupils these more general scientific objectives compared to the group of science teachers who do not teach natural science/technology. This substantiates the fact that there is a particular need for developing the academic skills of teachers in natural science/technology.

General science skills is one of the most prevalent topics of the focus group interviews conducted among science teachers and school managers. However, in similar fashion to the results in Figure 2, it is primarily inquiry-based and dissemination teaching skills that are mentioned as being challenging, the latter being linked to the training of pupils in academic discussion and argumentation.

Focus group interviews with science teachers suggest that inquiry-based teaching is especially challenging for those who have been teaching for a number of years. As one younger teacher puts it:

> "We had decided upon a course in IBSE (Inquiry Based Science Education) etc. A number of people would have benefitted from it. This is something we've been taught and have experienced for ourselves, though some will find it challenging, for sure." (Science teacher, 2018)

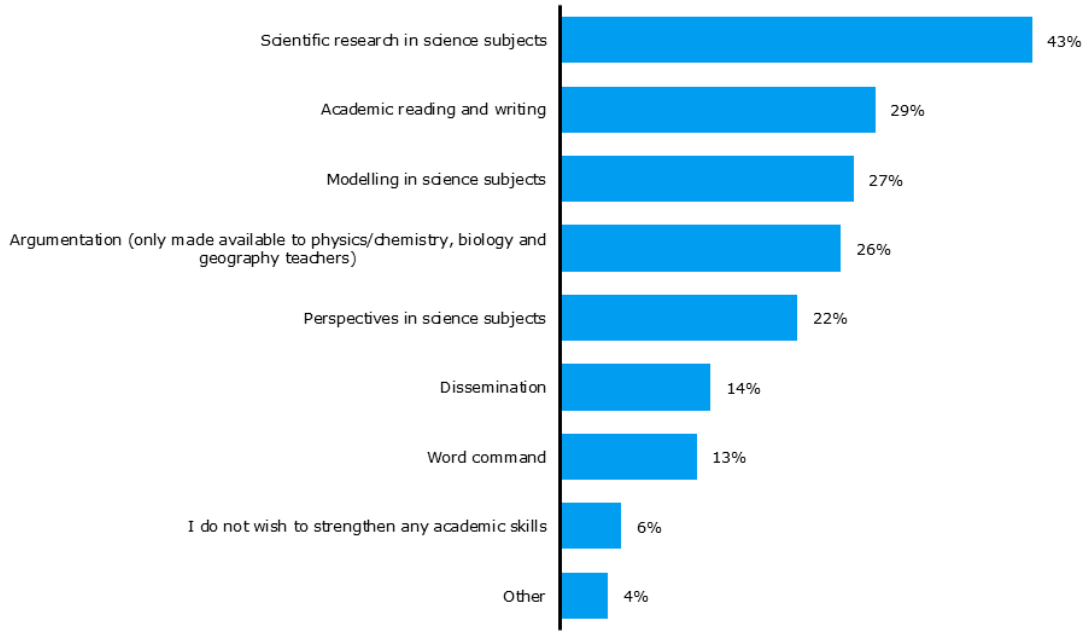
During an interview, one manager also explains their experience of how the "newer" teaching methods challenge teachers. The manager describes such methods as "chaos teaching", making reference to some of the teachers' experiences. A particularly challenging aspect of inquiry-based teaching, according to the teachers, can be that this teaching approach demands a certain type of courage from the teacher, who must step out of the classical teaching role where the teacher always holds the answers. While this can be daunting for the teachers, they also find that the rewards can be great:

> "There were times when I nearly couldn't breathe because it was too chaotic. But all of a sudden a common thread appears and everything starts to make sense, and then you notice how [the pupils] really take something from it and suddenly begin to attach subject terminology." (Science teacher, 2018)

One manager elaborates on how part of the challenge lies within the teacher's self-understanding. According to the manager, teachers must step into a new, more facilitative role. All in all, the above suggests that science teachers in general feel less well-equipped for teaching their pupils more general science objectives, with inquiry-based skills in particular challenging those teachers surveyed.

Figure 3 presents the skills development aspirations of teachers in relation to the more general science objectives. Each bar indicates the percentage of teachers who wish to develop a specific skill. The teachers had the opportunity to state all of the skills they wished to strengthen.

Figure 3. *Teachers' skills development aspirations in relation to the science objectives*



Note: Multiple choice question. N=1095. Question: Which academic skills do you most want to strengthen?

Only six percent of all of the science teachers indicate that they do not wish to strengthen any academic skills. Generally speaking, therefore, the demand for developing academic skills appears to be relatively high. In this context, it is worth noting that a significantly lower proportion of teachers in natural science/technology have no desire to strengthen any academic skills compared to the group of science teachers who do not teach natural science/technology. In other words, teachers in natural science/technology express a general desire to upgrade their academic skills.

43% of science teachers respond that they wish to raise their skills level when it comes to the skills and knowledge area of scientific research. Thus, by some considerable margin, this is the academic skill that most of the teachers wish to strengthen.

There is also considerable demand among school managers and municipal representatives for developing skills in teachers within the four science competencies. 21% of school managers and 42% of municipal representatives state that there is a particular need for enhancing skills among science teachers for instructing pupils in inquiry-based skills. Similarly, 20% of school managers and 42% of municipal representatives indicate a particular need for enhancing skills in science teachers for instructing pupils in modelling competency.

Science teachers have also indicated which academic skills they wish to develop within the individual science subjects. Here, 41% of teachers in natural science/technology wish to enhance their skills relating to the technology and resources skills and knowledge area. Among physics/chemistry teachers, the majority (26%) would like to develop their skills in production and technology, while the majority (25%) of biology teachers wish to enhance their skills in the skills and knowledge area of cells,

microbiology and biotechnology. Among geography teachers, there is a similarly high demand (17%) for skills development in demographics, business and globalisation.

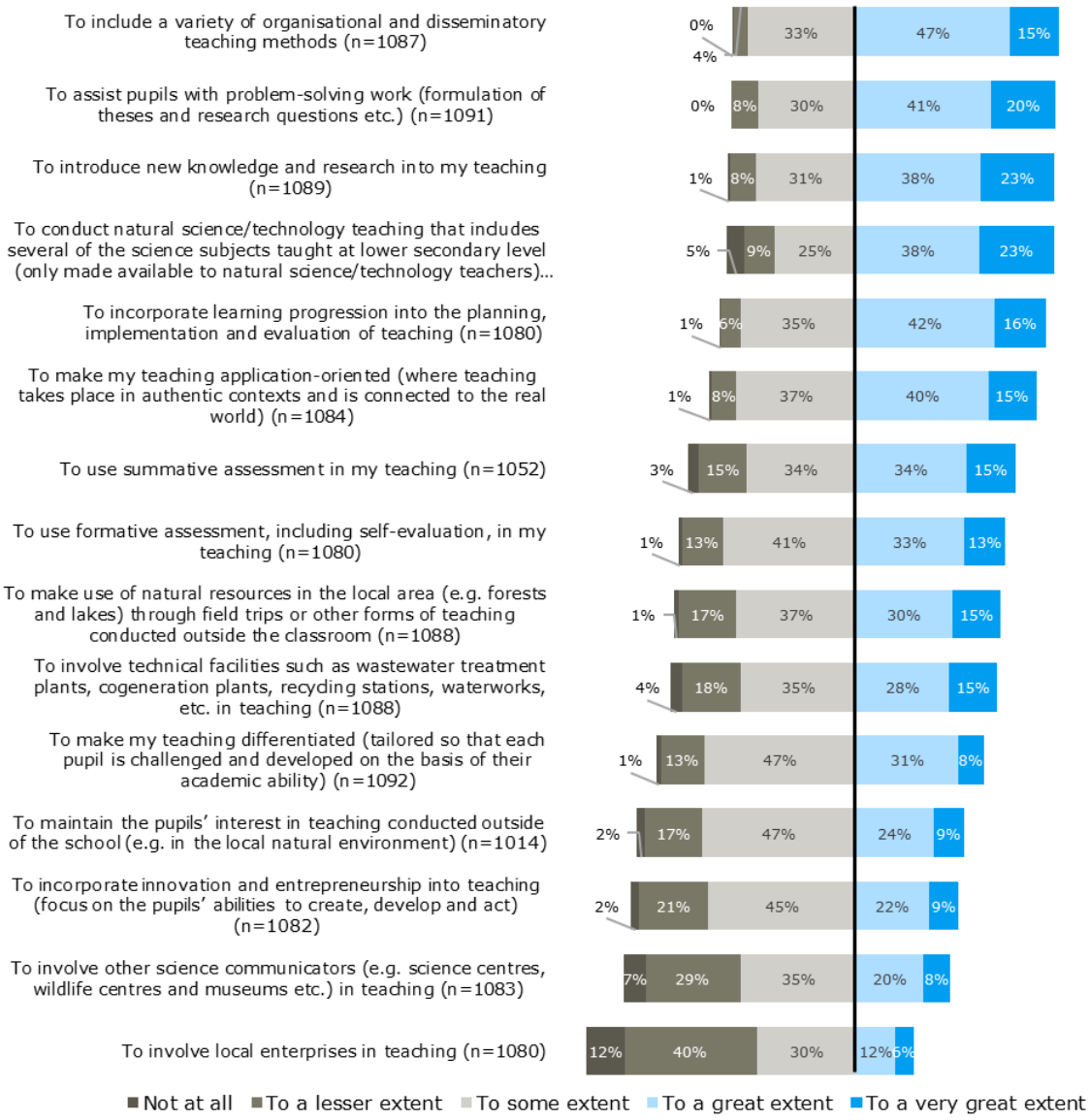
The above analyses, in summary, point to two main conclusions regarding the current need and demand for academically motivated knowledge and skills development. Firstly, there seems to be a pronounced need for upgrading academic skills among teachers in natural science/technology. Secondly, there seems to be both a need and demand for developing skills for teaching the four science competencies, with inquiry-based skills in particular being highlighted in both the quantitative and qualitative data sets.

The section below focuses on the current need and demand for developing knowledge and skills of a more subject-didactic nature.

Subject-didactic skills

It should be emphasised at the outset that, across all of the teaching activities investigated, there seems to be a need for skills development of some kind or other that is primarily subject-didactic in nature. A range of between 22% to 82% of science teachers say that they feel not at all or only to a lesser or to some extent adequately equipped for the activities. This section therefore focuses solely on the segment of investigated activities for which science teachers feel least well-equipped.
The figure below presents those teaching activities of a primarily subject-didactic nature where, on the basis of the questionnaires conducted among science teachers, there seems to be the greatest need for skills upgrading.

Figure 4. *Subject-didactic activities for which teachers feel least well-equipped*



Note: The questions concern the teachers' subject-didactic skills. Question: To what extent do you feel adequately equipped for the following? 'Don't know' answers have been omitted from the analysis.

The figure shows first and foremost that science teachers generally feel ill-equipped for involving external actors in their teaching. Thus, only 18% of science teachers feel to a great or very great extent that they are adequately equipped for involving local enterprises in their teaching. The same applies in terms of teachers involving other science communicators (e.g. wildlife centres and museums) in their teaching, with only 28% of science teachers indicating that they feel to a great or very great extent adequately equipped for this. However, the statistical analyses indicate that the groups of biology and geography teachers respectively feel significantly better equipped for involving enterprises in their teaching compared to the group of science teachers who teach neither biology nor geography.

Furthermore, only 31% of teachers indicate that they feel to a great or very great extent equipped to incorporate innovation and entrepreneurship into their teaching – in spite of these being highlighted as key learning objectives in the curricula of all four science subjects. Lastly, less than half of science teachers answered that they feel to a great or very great extent adequately equipped to use summative assessment (49%) or formative assessment (46%) in their teaching. Consequently, there seem to be definite subject-didactic knowledge and skills requirements concerning the use of assessment in teaching. Previous studies also emphasise a need to develop evaluation skills in science teachers, since high-quality formative assessment in particular can be a motivator for increased learning among pupils (Nielsen, 2017).

In contrast to the above, science teachers generally feel more positive in the assessment of their own competency to conduct activities within the multidisciplinary and joint subject field. 76% of science teachers involved in secondary level education state that they feel to a great or very great extent adequately equipped to conduct joint academic courses[7].

Even though the questionnaires among science teachers indicate that teachers generally feel well-equipped in multidisciplinary and joint subject fields, the interview data gives a different, more nuanced, impression. The qualitative data indicates that it is primarily during the joint courses and, in particular, the supervision process leading up to the joint examination in physics/chemistry, biology and geography that some science teachers can feel challenged:

> "I feel really challenged during collaborative science work [joint courses]. I don't feel that this collaboration produces newly energised pupils. My impression is that they sometimes get more confused. This method is a big challenge." (Science teacher, 2018)

One manager agrees with the above and says that the school has spent a lot of time supporting teachers in being able to carry out multidisciplinary work. It is also generally true in the quantitative data that school managers give relatively high priority to developing skills among science teachers working in multidisciplinary and joint subject fields. In relation to the supervisory process leading up to the joint examination in physics/chemistry, biology and geography, working with problems can in itself pose a challenge to teachers, but it is the art of guiding pupils in multidisciplinary problems in particular that science teachers experience as posing a significant challenge. This is how one teacher describes the experience of being asked a question relating to another subject:

> "I cover both biology and physics/chemistry, but when [the pupils] ask questions about geography, I completely panic. So I ask [name of colleague]. I'd really like to be better equipped for guiding and supervising [pupils] in geography." (Science teacher, 2018)

In a similar fashion to the above example, several teachers describe how they often feel obliged to refer their pupils to another science teacher. This delays the supervision process and frustrates both pupils and teachers. Another teacher describes the period leading up to the joint examination as "hell" because a number of teachers lack the

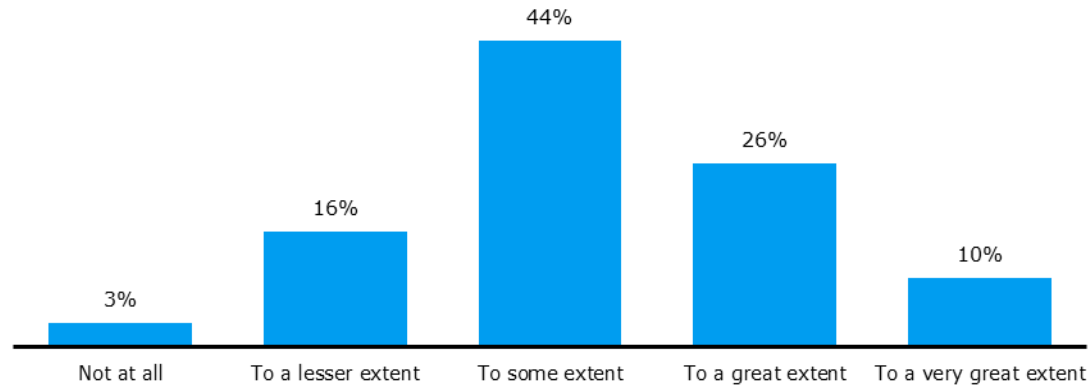
[7] These results are not shown in the figure because, as mentioned, it presents only those teaching activities of a subject-didactic nature where there seems to be the greatest need for the upgrading of skills.

necessary skills, thereby causing the remaining teachers to take on the larger share of the supervisory task.

Equally challenging, and compounding the above situation, is the fact that both the joint examination and joint courses are relatively new exercises. According to the teachers, this places greater demands on their preparation work, partly because the availability of customised courses and tools is still limited. At the same time, science teachers do not have the opportunity to develop material themselves, either individually or with colleagues, and the planning duties connected with the joint courses are often placed on a single teacher because there is no opportunity for teachers to conduct joint planning.

Science teachers have also been asked about the extent to which they feel their knowledge of scientific research is up to date. The results are presented in the figure below.

Figure 5. *Teachers' experience of feeling up to date with the latest research*



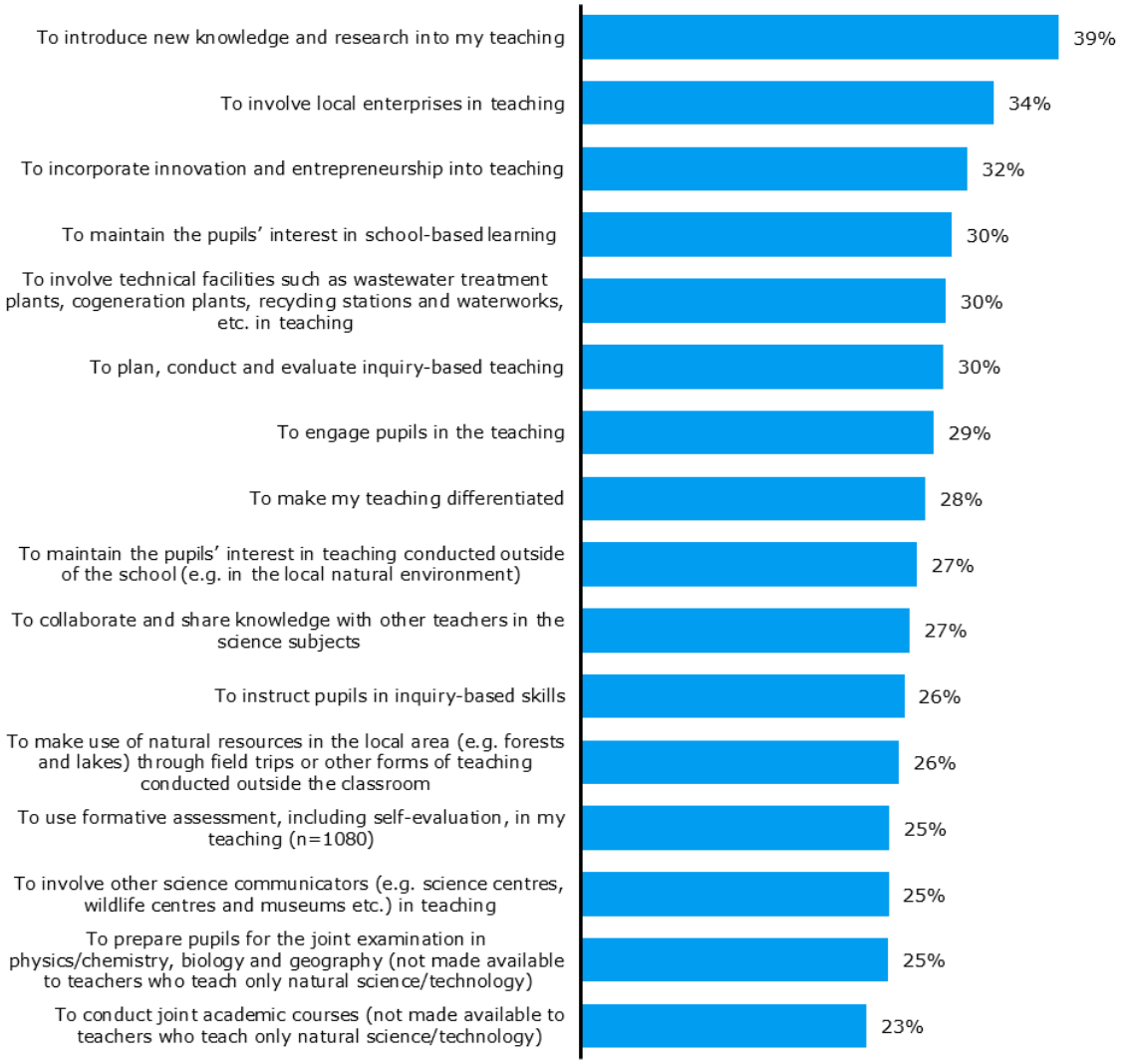
Note: N=1083. Question: To what extent do you feel that your knowledge is up to date in terms of the latest

Slightly more than one third of science teachers (36%) say that they feel their knowledge is to a great or very great extent up to date in terms of the latest scientific research, while just under one in five teachers (19%) feel that their knowledge is not at all or to a lesser extent up to date. The statistical analyses show, in addition, that the group of teachers in natural science/technology feels significantly less up to date compared to the group of science teachers not teaching natural science/technology.

In an extension of the above question, science teachers were given the opportunity to note if there were any specific research areas they would like to keep abreast of. Although the teachers mention a broad range of research areas, there appear to be some key repetitions. A comparatively large number of teachers mention research areas such as climate, sustainability, biotechnology, robotics, astronomy, genetics, radiation and programming.

Lastly, the science teachers indicated which subject-didactic skills they wish to strengthen. The results are shown in the figure below, which illustrates the segment of subject-didactic skills that most teachers want to develop.

Figure 6. *Percentage of teachers wishing to enhance their subject-didactic skills*



Note: Multiple choice question. N=1095. Question: Which subject-didactic skills do you most want to strengthen?

The subject-didactic skill that most teachers want to enhance, by a considerable margin, is the ability to introduce new knowledge and research into their teaching. 39% of science teachers indicate a desire to strengthen this skill. Correspondingly, the ability to introduce new knowledge and research into science teaching is the subject-didactic skill, which, according to the majority of school managers (32%) and municipal representatives (49%), needs the most improvement.

In this regard, the systematic mapping of knowledge and skills development among science teachers in primary school highlights two core elements that are especially conducive to helping science teachers introduce new knowledge and research into their teaching (Rambøll & University College Copenhagen, 2019). Firstly, collaboration in local communities of practice can help to create a space for dialogue and reflection among science teachers on the latest knowledge pertaining to their field. Secondly, formalised collaboration with universities or university colleges creates the opportunity for science teachers to update their knowledge on the latest scientific research, just as

these partnership programmes give science teachers insight into university-level science, which can increase their academic knowledge and subject-didactic skills (Andersen et al., 2017; Ufnar et al., 2017).

In addition, roughly one third of science teachers say that they wish to enhance their subject-didactic skills in order to incorporate innovation and entrepreneurship (34% of teachers) into and include local enterprises (32% of teachers) in their teaching. At the same time, these relate to two of the skills in which science teachers say they feel least well-equipped (cf. Figure 4 results). As with the science teachers, there is also a considerable demand among school managers (30%) and municipal representatives (49%) to strengthen science teachers' skills in relation to them incorporating innovation and entrepreneurship into teaching.

Existing literature shows that there are tangible skills development benefits for teachers through a formalised collaboration with local enterprises and other authentic learning environments (Ufnar et al., 2017; Daubjerg & Pedersen, 2018). As a starting point, therefore, it would seem productive to satisfy the desire expressed by science teachers to enhance their ability to include local enterprises in their teaching. However, the benefits of this school-enterprise collaboration are conditional on creating a common language and laying a didactic stepping stone between the school and the enterprise in order to link the authentic learning environment to the science teaching and vice versa (Daubjerg & Pedersen, 2018).

Lastly, the results indicate that science teachers wish to strengthen their subject-didactic skills in order to make their teaching more inquiry-based (30%), differentiated (28%) and, to a lesser extent, application-oriented (21%). These skills development aspirations are shared both by science teachers and school managers. Previous studies show that inquiry-based teaching can help to enhance pupils' learning, just as application-oriented teaching, where academic learning is applied to a practical field, appears to support pupils to a large extent in their scientific learning (Nielsen, 2017).

In summary, and if one focuses on the quantitative questionnaire data, it can be concluded that there seems to be a greater need and demand for developing subject-didactic skills than for upgrading academic skills. This is also reflected in the interviews, with teachers feeling most challenged in relation to subject-didactic skills, on account of the fact that outstanding academic skills cannot stand alone:

> "You may have good academic skills, but if your communication skills let you down, it's hard. My academic level may be high, but if all I see is them completely losing their interest, I would rather have gaps in my academic skills than in my communication skills." (Science teacher, 2018)

According to the teachers, the academic and the subject didactic are mutually dependent if the desired outcome is good teaching. However, the general emphasis is that both academic and subject-didactic skills are important.

Summing up and perspective

This article has identified both the academic and subject-didactic knowledge and skills requirements among science teachers in primary schools and has thrown light on the existing demand for skills development in science teachers as perceived by teachers themselves, school managers and municipal representatives. Based on the above analyses, this article points to three key findings:

- **Skills development requirements in natural science/technology:** Physics/chemistry, geography and biology teachers generally feel well-equipped to teach pupils in subject-specific skills and knowledge areas. However, the study indicates there is a need for upgrading the academic skills of teachers in natural science/technology.
- **The four science competencies:** Science teachers feel relatively ill-equipped to teach their pupils in the overall science objectives, such as scientific investigation and perspectives. The considerable demand for skills development in relation to inquiry-based skills is shared simultaneously by science teachers, school managers and municipal representatives.
- **Subject-didactic skills development:** There is a general need and demand for developing subject-didactic skills. This is relevant to e.g. a teacher's ability to introduce new knowledge and research into their teaching and to incorporate innovation and entrepreneurship. School managers in particular express an additional need for skills development in the multidisciplinary and joint academic subject field.

In addition to the above, it should ultimately be pointed out that 49% of science teachers respond that the existing opportunities for skills development are either not at all satisfactory or are satisfactory to a lesser extent. A strikingly large percentage indicate that current practices in skills development do not sufficiently enable teachers to acquire the knowledge and develop the skills needed to support the national objectives relating to pupils' interest, motivation and learning in the science subjects. This raises the question of what actually characterises a good skills development course.

The mapping exercise carried out by Rambøll Management Consulting in collaboration with University College Copenhagen suggests that the organisation, length and follow-up of the skills development course largely determine whether it will improve the quality of teaching (Rambøll & University College Copenhagen, 2019). Teachers and school managers highlight two informal initiatives – joint skills development among science teams and the observation of colleagues' teaching – as being particularly effective in raising the quality of science teaching. Both of these skills development initiatives are centred around academic fellowship and collegial collaboration, which, according to science teachers, have a beneficial effect on the quality of their teaching.

In line with this, previous studies show that when developing the skills of science teachers, positive results can be achieved by conducting skills development activities in local communities of practice. Structured collaboration with academic colleagues within the individual subject or in combined science groups is especially in demand among

science teachers (Andersen et al., 2017). This type of collaboration in communities of practice can enhance academic skills among science teachers, as academic communities provide space for dialogue about the latest knowledge in the field. But communities of practice are also conducive to developing teachers' subject-didactic skills, since practical exchange and reflection provide an opportunity to share good teaching experiences and allow teachers to support each other, which can reduce preparation time and uncertainty when applying new methods in teaching. Other studies point out that there are also benefits to be gained from engaging in online learning communities, which offer an opportunity for digital academic exchange and knowledge sharing among individual science teachers (Knowles, 2017). The interview data from both science teachers and school managers also emphasises the fact that joint skills development and collegial exchange are considered effective and are generally in demand by schools. In practice, however, other everyday concerns, such as insufficient time for collegial networking and substitute teaching, are barriers to implementing these kinds of skills development initiatives.

Finally, the mapping exercise indicates there is a need for more targeted skills development courses (Rambøll & University College Copenhagen, 2019). If the initiative is to be effective, skills development must focus on very specific themes and actual tools that science teachers can apply directly to their teaching practice. In line with this, previous studies have illustrated that the targeted and subject-specific upgrading of skills, when used as part of an intensive skills development course, has a positive impact on science teachers' academic knowledge (Clary et al., 2018) and confidence in their own abilities (Ensign, 2017; Dailey et al., 2018). However, ongoing academic exchange and follow-up in the wake of skills development courses are required if science teachers are to maintain their academic gains over time (Clary et al., 2018; Dailey et al., 2018; Knowles, 2017).

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