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Abstract

For years, the need for inquiry- and problem-based learning (PBL) in primary and lower secondary education, within science and mathematics, has been addressed worldwide and requires support from a range of pedagogical sources. One important basis for such support is continuing teacher education. The present research builds upon data from a nationwide qualitative investigation (Hesselholt Henne Hansen et al., 2019), conducted as part of a feasibility study aimed at initiating a new STEM (science, technology, engineering, mathematics) graduate teacher programme in Denmark, leading to a Master of Science (MSc) in STEM teaching. The investigation identified continuing education needs of science and mathematics teachers and student teachers. We looked into the results of the qualitative portion of the feasibility study and investigated whether and how problem-based learning was being emphasized as comprising desirable content areas for continuing teacher education. Data were collected from 35 group interviews with 66 respondents: teachers from public and private schools, and teacher students. The results showed that PBL stands out as a desirable focus area. Other student teachers expressed an interest in including didactic-based topics that are related to PBL, e.g. differentiated teaching, engineering design, technology, and information communication technology [ICT] within STEM education. Furthermore, respondents expressed their desire for collaboration with other subjects (e.g. Danish and social sciences) in interdisciplinary teaching and, as well, the opportunity to immerse themselves in academic topics such as education for sustainability, climate education, technology, and including specific experiences with applied science, mathematics and recent research. Without being able to make a quantitative statement, it must also be mentioned that some teachers expressed no need or desire for further education.

Keywords: teacher continuing education, problem-based learning, K–9 STEM education, interdisciplinary,

Type of contribution: PBL research paper

1 Introduction

Throughout the world, the importance of science and mathematics teachers' continued professional development is increasingly acknowledged (Dillon, Osborne, Fairbrother & Kurina, 2000). In a Danish context, various studies (e.g. Rambøll, 2019; Undervisningsministeriet, 2018) have shown the need for capacity- building for science teachers. Nielsen (2012, p. 10) noted 'a need for science-specific teacher development in Denmark', but concluded that we know 'very little about the precise challenges and needs'. A report from Rambøll Management Consulting (Rambøll, 2019) noted, among others, the need for science teachers to receive capacity-building in their professional development. While 95% of physics and chemistry teachers and 88% of biology teachers have teaching competence in their subject, it only applies to 66% of geography and 60% of science and technology teachers (Rambøll, 2019).

For an international audience, it is important to say that the Danish teacher training for K–9 (primary and lower secondary school) is organized as a four-year programme at university colleges (UC). The Danish teacher education programme has four specialisations in the natural sciences: science/technology (Grades 1–6); biology (Grades 7–9), physics/chemistry (Grades 7–9); and geography (Grades 7–9); and two specialisations in mathematics: one in primary education (Grades 1–6) and one in lower secondary school (Grades 4–10). The teacher students normally specialise in three subject areas; Danish or mathematics must be one of these three. In a European context, this designates the teacher training programme as producing specialised teachers of education (European Commission, 2011a; European Commission, 2011b). The more teacher education has a strong relationship to practice (e.g. 16 weeks of practicum in various periods and forms) and teaching in the required subject areas (e.g. mathematics, Danish) integrates subject content with pedagogical content (Uddannelses- og Forskningsministeriet, 2020). Within the last few years, a new science teacher specialisation has arisen wherein teachers specialise in mathematics and three natural science subjects. This focus addresses interdisciplinary science teaching yet still does not contain additional subject matter (Petersen, Ahrenkiel, & Krossá, 2020).

Several years ago, the Danish Ministry of Education launched a National Science Strategy (Undervisningsministeriet, 2018), articulating the need for further continuing education of teachers in the natural sciences and, as well, the development of stronger professional didactic environments in educational institutions. This strategy has two national objectives: (1) encourage children and young people to take an interest in the natural sciences during primary and lower secondary school and to choose the natural sciences in upper secondary and vocational STEM programmes and (2) ensure that more children and young people achieve a high level of proficiency in science and vocational STEM programmes (p. 7). As part of this strategy, a new master's level educational programme for science and mathematics teachers was launched. As described in Nielsen et al. (2018), a consortium of five Danish universities and six Danish university colleges have applied for funding for preliminary research (feasibility study), development, and start-up of a K-9 STEM- related master's programme. The programme will start in autumn 2020.

Internationally, PBL has increasingly been adopted by K–12 teachers (Hmelo-Silver, 2004) – including within Danish science education – e.g. through introduction of problem-oriented engineering design in K–9 classrooms (Auener et al., 2018), and through an interdisciplinary science examination in 9th grade covering biology, physics/chemistry, and geography. In the aforementioned feasibility study, the qualitative part (Hesselholt Henne Hansen et al., 2019), we looked into the results of this effort and investigate if and how problem-based learning is being identified as desirable didactic and content areas for continuing teacher education by the teachers themselves. In this article, we specifically examine to what extent the teachers' answers reflect the need for further education in PBL and how it connects to a PBL approach, descripted in section 2.

2 Theoretical approach

2.1 Why PBL?

PBL indicates a process by which, according to Edwards and Hammer, (2006), increased students' motivation to learn and to focus their learning are present. Strobel and Barneveld (2009) point out that PBL is more effective, compared to traditional lecture based instruction, in relationship to long-term retention of knowledge and skills development. PBL also supports active, self-directed learning, students' experience of meaningful learning (Kolmos, Du, Holgaard, & Jensen, 2008), and students' motivation (Ertmer & Simons, 2014).

2.2 PBL approach: What is PBL in a lower secondary school context?

Barge (2010) delineates six principles in problem-based learning (PBL): *problem orientation*, *participant direction*, *project organisation*; *integration of theory and practice*; *team-based approach*, and *collaboration and feedback* (p. 9). *Problem orientation* means that a problem or challenge serves as the point of departure for learning (see also Holgaard et al., 2017). Barge (2010, p. 9) elaborates *participant direction* as 'students defining the problem and making key decisions relevant to the successful completion of their project work' (p. 9); *integration of theory and practice* enables 'students [..]. to see how theories and empirical/practical knowledge interrelate' (p. 9). A *team-based approach* means that students work together in project groups and use collaboration and *feedback* that, according to Barge (2010), allows not only the exchange of ideas but also assessments and critiques from both peers and, supervisors and thus an improvement in their learning result. Thus, 'the skills of collaboration, feedback and reflection are an important outcome' (p. 10) of the learning process. In our new study, based on data from the analysis of teachers' need for capacity building (Hesselholt Henne Hansen et al., 2019) we evaluate the degree to which it falls within these six principles of PBL.

In a systematic literature review, Merritt et al. (2017) found that there is 'no consistent definition of PBL' (p. 1). They define PBL as an instructional method (p. 4) and identify the following theoretical concepts from the relevant literature on K–8 mathematics and science education: (a) clinical-medicine education definition (learning by doing, students get presented to problems before instruction); (b) functional or curriculum design definitions (focus on implementing PBL in classroom with detailed steps); (c) constructivism or project- based definitions (learning through project work with real-life problems); and (d) conceptual-change definitions (inquiry-oriented science learning for early learners with focus on cognitive scaffolding) (pp. 4–7). Past research identifies the need for science teachers to master interdisciplinary approaches across STEM subjects (Bybee, 2013). By extension, the ability to handle such interdisciplinarity requires, amongst other attributes, teaching competencies in PBL. The relationship between PBL and differentiated teaching and interdisciplinarity is underscored by the following quote from Savin-Baden (2000):

> Problem-based learning is thus an approach to learning that is characterized by flexibility and diversity in the sense that it can be implemented in a variety of ways in and across different subjects and disciplines in diverse contexts. As such it can therefore look very different to different people at different moments in time depending on the staff and students involved in the programmes utilizing it. However what will be similar will be the focus of learning around problem scenarios rather than discrete subjects (p. 3).

3 Methodology

The qualitative data obtained in the current study is based on summaries of 35 focus group interviews with 66 respondents. The respondents were selected so as to represent the potential target groups of the STEM Teacher Master's Programme: K–9 public schools, private schools, and the Danish efterskole teachers, as well as teacher students (Hesselholt Henne Hansen et al., 2019). We conducted twenty-one interviews at K–9 public schools, six interviews with teachers from private schools and the Danish efterskoles (boarding schools), and eight interviews with teacher students (LS) – all respondents with a geographical spread across the country. The qualitative data were collected in connection with a feasibility study concerning the Master's Programme in 2019. In this paper, the data are interpreted with a focus on PBL supplemented with additional comments and observations.

A semi-structured design, based on two interview frameworks targeted at teachers and teacher students, were used. Researchers from Aalborg University, UC Absalon, UCL University College Lillebælt, University College Copenhagen (KP), University College North Jutland, and VIA University College interviewed the respondents. The interview frameworks were designed to inquire about teachers' needs for further training that would enable them to effectuate STEM-based learning units. The interview guide contained questions about professional background and possible content of the study. The interview formats were based on a table with possible content elements concerning science and subject-didactics elements, one of them concerning PBL. However, the respondents were free to bring up their own areas of interest and personal experiences. As described in Hesselholt Henne Hansen et al. (2019), every interview was audio recorded. After each interview, the interviewer prepared a written summary based on a template with professional background (education, subjects, and

> Danish efterskole: In Denmark there is a long-standing tradition with boarding schools for grades 8–10. This tradition mainly originates within the ideas and initiatives of the clergyman, poet and politician, N.F.S. Grundtvig (1783–1872), and the teacher, Christen Kold (1816–1870). Based on their ideas about 'a school for life based on the living word', the first 'folk high school' for adults was founded in 1844 and the first 'free school' (private independent school) for children in 1852. Later in 1879, the first boarding school ('efterskole' in Danish) based on Grundtvig and Kold's ideas was established.

number of years of teaching experience) and possible content elements, mentioned by the respondents. These summaries were subsequently compiled for analysis; they were coded in Nvivo 12.0. Then, the summaries were analysed across school settings (i.e. lower secondary, private, or efterskole, or teacher students) relative to the coding category 'potential content of the graduate program'. The answers from the Danish respondents were translated into English by the authors.

4 Findings

Based on the data obtained, six content areas (A–F) were identified that reflect the respondents' input regarding optimal content for PBL-related continuing education. At the end of each content area, the authors related each element to the six PBL principles (described in Section 2).

*Content Area A. Engineering – PBL and investigative competence***:** Respondents highlighted engineering and PBL as important methods to achieve interdisciplinarity, differentiated instruction, and increased pupil engagement. '[We could use] engineering, problem-based learning, because we can see that the students benefit from it' (Teacher 1, Hesselholt Henne Hansen et al., 2019, p. 8). Moreover, engineering and PBL are important for the development of inquiry competences. Respondents also mentioned modelling as a multidisciplinary way of working that can qualify an approach as PBL-based. The science teachers, on the other hand, were not so concerned with interdisciplinarity or PBL; they did, however, mention modelling as something that could improve instruction. Some science teachers expressed great interest in qualifying for teaching PBL-related curricula because of the project-organised interdisciplinary science examination in the 9th grade (Børne- og Undervisningsministeriet, 2019) covering the subjects physics/chemistry/biology/geography). Two teachers' (Teachers´ 2, 3, School A) even expressed the desire to in '[...] try project- oriented working methods – as a student'. Thy elaborated this statement and made the following proposal to the structure of the programme: They want to divide the study into subject areas that could be taught together when working with a subject/problem and simultaneously awareness of that particular topic. The teachers described a large common area of study, with inclusion of outside guest teachers and cooperation with other teachers on a given thesis in the Master's programme, as well as the possibility of sitting for an exam in a manner similar to their students. They highlighted issues from the real world as something they need to work on, see below. *Authors: The needs in this section can be reflected in problem orientation and project organisation.*

Content Area B. Interdisciplinary integration: The need for *interdisciplinary* integration between the different subjects in science and mathematics as emphasized as important but challenging. Only a minority of the teachers are educated in all three science subjects; therefore, there was a strong wish expressed by the respondents to gain knowledge of the other subjects and connect them to their own field of expertise. Moreover, the respondents expressed a desire for more relevant and realistic interdisciplinarity with separate subjects integrated within the various topics. The first spotlight is a quote from a teacher: 'The desire for the interdisciplinary field to grow, so that the education must deal with, just as the professional field regarding sustainability and engineering' (Teacher 4, School B). Respondents mentioned that interdisciplinarity with social studies could be relevant in relation to sustainability and climate education, especially for teachers who did not teach geography. The focus on integrating science subjects in an interdisciplinary way is pronounced. Here is a second excerpt from one of the dialogues:
Interviewer: 'Will such a master's programme make you say that now we have some teachers who can come out and teach a unified natural science?' Teacher 5 (School C): 'Yes. I hope so. Otherwise I really

just think you should discard the idea' (comment: provide the education).

Only teachers instructing in both mathematics and science have implemented an interdisciplinary focus. Several respondents saw inclusion of mathematics teachers in the science team as desirable but difficult to achieve – which, in turn, points back to their desire to focus on developing collegial collaborative formats and learning communities. 'We have a lot of kids who are scared of math ... when they see a graph, they panic ...there's also something like scaling. There is not the same "transfer" from mathematics to science as I could imagine' (Teacher 6, School D). Cooperation between the subjects Danish and science was also mentioned by many respondents. A wish for communities of practice between Danish teachers and science teachers was highlighted. Such cooperation was regarded as potentially strengthening pupils' competencies for source criticism and improving the reading skills needed to learn science. *Authors: The needs in this section can be reflected in problem orientation, participant direction, team-based approach, and collaboration and feedback.*

Content Area C. Authentic problems and external learning environments: These were highlighted as important with respect to their potential for producing high motivation among pupils and differentiating of teaching in the classroom between pupils with different level of knowledge. These are areas with a large demand for planning in order to be implemented in practice. There is both interest in and need for this area to be included in the Master's curriculum. Here, an explanation from the interviews is available (Teacher 6, School D): 'Authentic issues are something that motivate students. Therefore, it must be part of the education and how to transform scientific knowledge into teaching knowledge'. Another teacher (Teacher 7, School C) emphasized the contribution of authentic learning: 'There is a need to explore the possibilities for collaboration between school, business and other surrounding communities under the auspices of the open school concept from the Folkeskoleloven (Education Act) 2014 in order to present students with so-called authentic issues'. Teachers (8, 9, School E) express the importance of contact with universities and companies for authentic issues that they can apply in primary and lower secondary school. They point out an overall lack of practice in school education and insufficient possibilities for receiving instruction related to and tried in practice. Therefore, practice-relation and opportunities for teachers to make suggestions and then try then in their own teaching is an important issue in the programme. *Authors: The needs in this section can be reflected in problem orientation, participant direction, project organisation, integration of theory and practice.*

Content Area D. Differentiated teaching: One of the elements noted by the interviewees is the establishment of learning communities among pupils. According to the responses, the programme has to handle the various prerequisites and competencies that the teachers need. The teachers experience a considerable challenge in differentiating and formulating learning outcomes for all pupils, especially in relation to the format of the new exam and student inquiry. Furthermore, it is challenging for both teachers and pupils to work within interdisciplinary focus areas; the competence goals for science are especially challenging for pupils who, by and large, are not interested in or motivated by science. 'We have offers for the dyslexic students, but not for the students who feel "science-blind". How can you approach this in a professional way?' (Teacher 10; Hesselholt Henne Hansen et al., 2019). *Authors: The needs in this section reflects on problem orientation, participant direction, project organisation, team-based approach and collaboration and feedback.*

Content Area E. Development of own practice: The respondents mentioned action-based learning, communities of practice with colleagues, specific experience regarding applied science and mathematics and, as well, using newer research in teaching. An example from the extensive data illustrates these content elements: '(...) need for empirical research methods – more than what teacher education has provided – even in the bachelor modules. How to collect data in educational projects?' Teachers from School A felt it was important that highly project-oriented teaching in the Master's programme could be transferred into own practice. In continuation of the mentioned project-organisation, the lower secondary school teachers, especially at Grades 8 and 9, focused on interdisciplinarity as a focal point. This, again, was related to the joint natural science examination. However, there was no consensus on how to tackle the issue. Some teachers felt the focus should be on the professional qualification in relation to their subjects (School H), others emphasized a combination between professional qualification and didactics (School C and School I). According to some teachers, the focus should be on didactics and motivation. Additionally, time must be devoted to project-oriented working methods and experimental and problem-based learning. Furthermore, there must also be time for reflection. As the students have different focus areas (comment: as teacher in biology, mathematics, physics/chemistry and/or geography), time to complement each other is essential. That could be the focal point of education rather than focusing too much on didactic theorists. According to the teachers from School E, instead of theory, the focus is on increasing the ability to translate learning into something that is interesting and situated in real-life problems. Teachers from the private School F support the importance of theory-practice interrelation in the Master's programme, with experiments in their own school teaching practice, combined with project-oriented working methods. In this programme, they felt, it was quite important to be specific with respect to subject area and didactics (so that such curricula could readily be transferred to school science instruction. They highlighted the need to know where to look for kay research in their field, in order to continuously be updated on the latest research. This is supported by teachers from School G. According to development of their own practice, many respondents mentioned ICT (Information and communications technology), technology and understanding technology as important. For a large number of respondents, with the exception of for mathematics, using technology in a science context is challenging. *Authors: The needs in this section reflect problem orientation, participant direction, project organisation, integration of theory and practice, and team-based approach and collaboration and feedback.*

Content Area F. Opportunity for professional immersion: Respondents highlighted the opportunity for professional immersion. They particularly emphasized obtaining a higher level of professional mastery within the sciences – not only in their own subjects, but also in the other subjects included in interdisciplinary teaching. Besides, the respondents sought inspiration for effective source criticism and focused on how to apply materials related to recent research and expand the material from the digital platforms – often highlighted as superficial and deficient. *Authors: The needs in this section reflect problem orientation, participant direction, integration of theory and practice, team-based approach and collaboration and feedback.*

5 Discussion

Even though PBL was not often mentioned specifically, we saw a great variety in problem-based related issues. As shown in Section 4, content areas A– F reflect on the six *PBL principles* in different ways. However, in the discussion, we will take a closer look into these PBL principles: 'problem-orientation, participant direction, project organisation; integration of theory and practice; team-based approach, and collaboration and feedback' (Barge, 2010, p 9).

Problem orientation and project organisation

Regarding problem-orientation, many respondents mentioned the need for authentic problems. These can be brought into action by integration of external learning environments in STEM teaching. One of the reasons to do so is to support pupils' interest in STEM education (see, for example, Grunwald, 2016, 2019). Moreover, some of the interviewees directly mentioned PBL as an important part of the programme in relation to engineering. This fits with the developed engineering didactic for lower secondary schools (Auener et al., 2018), which requires further continuing education to support and develop investigative and inquiry-based competences. Still, the overall challenge of how concrete to make problem-based learning (Kolmos et al., 2008) in school science is not decidedly visible in the data. On the other hand, the need to develop teacher competences in scaffolding the pupils' learning process was brought up in the teacher interviews (see Auener et al., 2018, for further explanation). The question, however, is: to what extent is the understanding of problem orientation possibly connected to *project organisation* (another PBL principle) within the teacher's mind? Supporting student learning in a PBL project also requires the teacher's assistance in formulating the problem they want to solve. In this regard, differentiated teaching – a demand of some teachers – can be carried out but still requires additional pedagogical skills to practice in the classroom.

Integration of theory and practice

Additionally, the request for authentic problems, as expressed by the teachers and teacher students, reflects on the demanding challenge in STEM education to connect theory with practice in school teaching (see Grunwald, 2019, 2020). This is a third PBL principle. Another meaning with this connotation – and this is the prevailing view – is the need for a Master's programme with a coherent link between theory and practice. Teachers want to use theories or new research in the sciences in relation to their teaching. Some respondents expressed that they want a programme reflecting the teaching they need to practice in their own classroom. Competencies gained from the programme should be used in close connection with practice and vice versa. The outcome will be more motivated and skilled teachers and higher-quality instruction in the STEM topics.

Participant direction

The need for differentiated teaching is mentioned before, see problem orientation, to catch pupils' difference in interest, professional level (Nielsen, 2017). This calls for a project-organised form of teaching. Grant & Hill (2006, pp. 3–4) describe five factors in participant directed pedagogy that have influence on teachers adoption in the classroom: (1) recognition and acceptance of new roles and responsibilities; (2) comfort level in a more dynamic (physical) learning environment; (3) tolerance for ambiguity and flexibility in managing this new learning environment; (4) confidence in integrating tools, technology and networks into the curriculum and teachers' daily work within the new learning environment; and (5) integration of the new pedagogy to which with everyday life beyond the classroom. The extent to which this is a need and can be transformed for further education has to be elaborated.

The two last PBL principles, *collaboration and feedback* and a *team-based approach,* are only peripherally visible in the data. Here, further research is needed to provide knowledge of teachers' challenges.

Interdisciplinarity

At least interdisciplinarity is not a PBL principle, but important according to Savin-Baden (2000), see section 2. Respondents point out interdisciplinarity as an important topic, both in terms of integration with science subjects and cooperation with other school subjects as mathematics and Danish; mathematics, because it is obvious, and should be more frequently considered together with science subjects, and Danish because of the language issue and the fact that Danish, at least in primary classes, has most teaching hours (Rambøll, 2019). Interdisciplinarity is a precondition, as observed by different teachers, when working with authentic problems and important issues like sustainability and climate change. The results indicate that some teachers may feel challenged by interdisciplinary subjects and courses, and especially during the facilitating process in the run-up to the interdisciplinary exam in 9th class (Børne- og Undervisningsministeriet, 2019). In short, facilitating in a PBL context is linked to 'the overall concept for the teacher's role and function' (Kolmos et al., 2009, p. 10) with the teacher as a process-guide (ibid., p. 10) for pupils' learning. Nevertheless, results from the Rambøll report (2019) show that natural science teachers generally feel well prepared for interdisciplinary and common subject field activities. This is based on the fact that teachers in physics/chemistry, geography, and biology feel well equipped to teach subject-specific skills and knowledge areas in the classroom. This applies to those teachers who specialise in one or more different science subject areas, though not all are (see introduction). Nevertheless, the Rambøll report (2019, p.8) points out that 'there seems to be a greater need for professional qualification of teachers in science, just as science teachers in general feel less adept at teaching students the more general sciences skills and knowledge goals'. 'The four joint natural science competencies: investigation, modelling, perspectivation and communication) are central to students' learning throughout the school process.' (Rambøll, 2019, p. 86). The questions of how modelling can support a PBL approach in teaching and vice versa (Nielsen, 2017) need further investigation.

To get back to problem orientation as an essential PBL principle, this requires a different type of teaching from presenting 'pre-defined content' in a book chapter (Ertmer & Simons, 2005, p. 5). These authors point out teachers' need for new tools and strategies that can support the implementation of PBL principles like the facilitating of student inquiry and ongoing formative feedback in the classroom. In another article the authors distinguish between different efforts for the scaffolding teacher (Ertmer & Simons, 2014). They propose the following three efforts: (a) PBL planning, (b) PBL implementation, and (c) PBL assessment. In this context (a) involves the identification of the 'driving questions', the location of resources, and the creation of student ownership in the problem, (b) includes the creation of a collaborative classroom culture, the support of students' engagement, and (c) encompasses both the development of assessment methods/instruments and students' self-assessment skills. Nevertheless, these requirements are further challenged by the demand for developing an interdisciplinary didactic, where STEM education has to cooperate. Such a didactical STEM approach lacks development (Bybee, 2013). PBL can be a pedagogical or didactical frame to support this professional and didactical development.

6 Conclusion

The need for the integration of engineering and PBL was highlighted, as well as the integration of mathematics. However, it is also important as qualifiers for sustainability and climate education. However, we noticed that there are teachers in the study who believe that they do not need continuing education. In these instances, it could be interesting to investigate what professional and didactic challenges they face and what assistance they may need in order to improve their teaching practice.

It should also be mentioned that the research method has some limitations due to the different researchers involved in writing the summaries of the recorded interviews. This has probably resulted in different focal points, depending on the interviewer's professional background and interest.

At the content level, the K-9 schools science and mathematics teachers and student teachers who were interviewed expressed a need for interdisciplinary integration, because integration of the different subjects of science and mathematics is challenging. Focus for the teachers has been the interdisciplinary exams in science. Moreover, they expressed a wish to work with authentic problems and to experience more cooperation with the surrounding society regarding the problems. The argument for that is more motivated students and a need under the auspices of the open school concept. Engineering, PBL, and investigative competences are directly mentioned as possible content; engineering because it is important in relation to interdisciplinarity, differentiated teaching, and the motivation of the students. With the introduction of engineering in Danish lower secondary schools, there is a demand for PBL and thereby a need for a competence boost for the teachers. However, to support the teacher's continuing education for developing an interdisciplinary STEM didactic, new didactic approaches, including PBL, are needed to help teachers with planning, implementation, and assessment of teaching.

7 References

Auener, S., Daugbjerg, P. S., Nielsen, K., & Sillasen, M. K. 2018. *Engineering i skolen – hvad, hvordan, hvorfor?*
[Engineering in school - what, how, why]. Aarhus: VIA University College.

Barge, S. 2010. *Principles of Problem and Project Based Learning - The Aalborg PBL Model*. Aalborg: Aalborg University.

Barrows, H. S. 2002. Is it Truly Possible to Have Such a Thing as dPBL? *Distance Education*, **23**(1), 119–122.

Bybee, R. 2013. *The Case for STEM: Challenges and Opportunities.* National Science Teachers Association.

Børne- og Undervisningsministeriet [Danish Ministry of Children and Education]. 2019. *Vejledning til folkeskolens prøver i den fælles prøve i fysik/kemi, biologi og geografi – 9. klasse*. [Guide to lower secondary school exams in the interdisciplinary exam in physics / chemistry, biology and geography - 9th grade].

Dillon, J., Osborne, J., Fairbrother, R., & Kurina, L. 2000. *A Study into the Professional Views and Needs of Science Teachers in Primary and Secondary Schools in England*. London: King's College.

Ertmer, P. A., & Simons, K.D. 2005. Scaffolding Teachers' Effort to Implement Problem-Based Learning. *International Journal on E-Learning*, **12**(4), 2005, 319–328.

Ertmer, P. A., & Simons, K. D. 2006. Jumping the PBL Implementation Hurdle: Supporting the Efforts of K–12 Teachers. *Interdisciplinary Journal of Problem-Based Learning*, **1**(1).

Ertmer, P. A., & Simons, K. D. 2014. *Scaffolding Teachers' Efforts to Implement Problem-Based Learning*.

West Lafayette: Purdue University.

European Commision, 2011a. *Mathematics education in Europe: Common challenges and national policies.* Brussels: EU. Retrieved from http://eacea.ec.europa.eu/education/eurydice

European Commision, 2011b. *Science education in Europe: National policies, practices and research.* (). Brussels: EU. Retrieved from http://eacea.ec.europa.eu/education/eurydice

Grant, M.M., & Hill, J.R. 2006. Weighing the rewards with the risks? Implementing student-centered pedagogy within high-stakes testing. In R. Lambert & C. McCarthy (Eds.) *Understanding teacher stress in the age of accountability* (pp. 19–42). Greenwich, CT: Information Age Publishing.

Grunwald, A. 2016. *Naturfagenes og ingeniøruddannelsernes attraktivitet – set fra et inter-organisatorisk læringsperspektiv.* [Attractiveness of science and engineering seen from an inter-organizational co-operation learning approach]. Doctoral thesis. Aalborg: Aalborg Universitetsforlag.

Grunwald, A. 2019. *Samarbejdet om den åbne skole: Veje til fornyelse af undervisning i naturfag, teknologi og engineering.* [Cooperation in the open school – ways to innovate the teaching of science, technology and engineering]. Frederiksberg: Samfundslitteratur.

Grunwald, A. 2020. Innovating problem-based learning in lower secondary school by means of a systematic theory-practice interchange in STEM education. (unpublished)

Hesselholt Henne Hansen, M. H., Routhe, H. W., Krabbe Sillasen, M., & Grunwald, A. 2019. *STEM-lærer kandidatuddannelse: Lærernes stemme: Kortlægning af læreres og lærerstuderendes behov for en STEM-lærer kandidatuddannelse*. [STEM Teacher Master's Program: Teacher's Voice: Mapping Teachers 'and Teacher's Students' Needs for a STEM Teacher's Master's Program]. Århus: VIA University College.

Hmelo-Silver, C. E. 2004. Problem-based learning: What and how do students learn? *Educational Psychology Review*, **16**, 235-266.

Holgaard, J. E., Guerra, A., Kolmos, A., & Petersen, L. S. 2017. Getting a hold on the problem in a problem- based learning environment. *International Journal of Engineering Education*, **33**, 1070–1085.

Kolmos, A. Xiangyun, D., Holgaard, J.E., & Jensen, L.P. 2008. *Facilitation in a PBL environment*. Online publication. Aalborg University. UNESCO Chair in Problem Based Learning in Engineering Education.

Merritt, J., Lee, M., Rillero, P., & Kinach, B. M. 2017. Problem-Based Learning in K–8 Mathematics and Science Education: A Literature Review. *Interdisciplinary Journal of Problem-Based Learning*, **11**(2).

Nielsen, B.L. 2012. *Science teachers' meaning-making of teaching practice, collaboration and professional development*. Doctoral thesis. Aarhus: Aarhus University.

Nielsen, J. A. (eds). 2017. *Litteraturstudium til arbejdet med en national Naturvidenskabsstrategi* [Literature review for the work on a National strategy for National Sciences]. København: Institut for Naturfagenes Didaktik.

Nielsen, J. A., Dyreborg Andersen, T., Bonderup Dohn, N., Elmose, S., Grunwald, A., Hansen, R., Petersen, M. R., Sillasen, M., Michelsen, C. 2018. *Kandidatuddannelse i naturfags- og matematikdidaktik – Projektbeskrivelse.* [Master's program in science and mathematics didactics - Project description]. København: Institut for Naturfagenes Didaktik.

Petersen, M. R., Ahrenkiel, L., & Krossá, H. K. 2020. *Evaluering af og udviklingsmuligheder i naturfaglige profillinjer - slutrapport for kortlægning, oplevede effekter og fremtidsperspektiver.* [Evaluation and possibilities for development of science education study profiles – final report on mapping, experienced effects, and perspectives for the future]. Odense: UCL Erhvervsakademi og Professionshøjskole.

Rambøll Management. 2019. *Undersøgelse af kompetencebehov blandt naturfagslærere i grundskolen* [Investigation of competency needs among science teachers in primary/lower secondary school]. Retrieved February 25, 2020, from https://www.uvm.dk/publikationer/2019/191106-undersoogelse-af-kompetencebvehov-blandt-naturfagslaerere-i-grundskolen

Savin-Baden, M. 2000. *Problem-based learning in higher education: Untold stories*. Buckingham: Open University Press/SHRE.

Uddannelses- og Forskningsministeriet [Ministry of Higher Education and Science]. 2020. About the University Colleges. Retrieved from https://ufm.dk/en/education/higher-education/university-colleges

Undervisningsministeriet [Danish Ministry of Education]. 2018. *National Naturvidenskabsstrategi* [National Strategy for Natural Sciences]. Retrieved February17, 2020, from file://plan.aau.dk/Users/grunwald/Downloads/180313-National-naturvidenskabsstrategi-web%20(5).pdf