7-2012

Investigating engineers' needs as a part of designing a professional development program for engineers who are to become mathematics teachers

Ragnhild Johanne Rensaa

Follow this and additional works at: <https://scholarworks.umt.edu/tme>

Part of the [Mathematics Commons](#)

Let us know how access to this document benefits you.

Recommended Citation

Rensaa, Ragnhild Johanne (2012) "Investigating engineers' needs as a part of designing a professional development program for engineers who are to become mathematics teachers," *The Mathematics Enthusiast*: Vol. 9 : No. 3 , Article 5.

DOI: <https://doi.org/10.54870/1551-3440.1248>

Available at: <https://scholarworks.umt.edu/tme/vol9/iss3/5>

This Article is brought to you for free and open access by ScholarWorks at University of Montana. It has been accepted for inclusion in The Mathematics Enthusiast by an authorized editor of ScholarWorks at University of Montana. For more information, please contact scholarworks@mso.umt.edu.

Investigating engineers' needs as a part of designing a professional development program for engineers who are to become mathematics teachers

Ragnhild Johanne Rensaa¹

1. Introduction

The average age for teachers in mathematics and physics in Norway is about 60 (Sørensen, 2003) and few students taking a masters degree in a science subject choose a career as a teacher (KD, 2006). This implies that there may be a critical lack of science teachers in schools in the near future (Næss, 2002). At the same time, rather many graduated engineers – who have worked as engineers sometimes several years – want to contribute to the educational setting by taking part time jobs as teachers; lector-II (Vassnes, 2008). To combine this supply and demand for qualified teachers in mathematics, a professional development program in mathematics for engineers is planned. Focusing on this education, a research project is planned. It shall be a design research which initially will include a design of the tailored program in cooperation with the practitioners. This will be followed by an investigation of the engineers who take part in the program: How their mathematical knowledge develops as a result of completing the education.

¹ Narvik University College
P.O.Box 385
N-8505 Narvik
Norway
Phone: +47 76 96 63 04 (office) +47 76 96 60 00 (s.b.)
Fax: +47 76 96 68 21
Email: rjr@hin.no

The present paper has three aims: First, to outline the theoretical perspectives on which the planned design research project is based, along with general components to be considered when the engineers taking part in the program act as objectives. Second, to present the data collected to find out more about experiences and needs that engineers may have in a mathematics teaching position. Third, to discuss how findings in the incoming data material may influence the plans for the complementing studies.

The research question formulated is: What are the opinions, advantages and needs of an engineer in order to become a mathematics teacher, and how may these be implemented in a design research of a professional development program?

2. The design and theoretical framework

The theoretical framework of the planned main study is by Koenen Gravemeijer called developmental research (1994). He goes back to Freudenthal (1988), who meant that thought experiments are important in educational development. The developer envisions the teaching and learning process and after carrying it out tries to find evidence to see if the expectations he had were right or wrong. Based on practical experience, new thought experiments create an iteration of development and research. Gravemeijer claims that this cyclic process is at the centre of Freudenthal's concept of developmental research (1994, p. 449). Developmental research is similar to what is alternatively called design research. Eric Wittman is one researcher who sees advantages by regarding mathematics education as a design science (1995). He emphasizes that an important element is building theory related to the design and then making the empirical investigations.

In our main study, researchers and practitioners will work closely together to develop the courses to be offered in the program. The design of the courses tailored for engineers is an important part, see Figure 1.

Figure 1: Phases in the design research

The cooperation between researchers and practitioners is intended to be a composition of Wagner's clinical partnership and co-learning agreement (Wagner, 1997), and is guided by the particular type of students involved. The reason for this adjusted framework is an earlier experienced difficulty with collecting realistic data among engineers (Rensaa, in preparation). The close cooperation between researchers and practitioners in the design research may contribute to building a bridge between the research and the teaching practice (Czarnocha & Prabhu, 2004).

It is not relevant to mix the engineers with other students at our university. This is both because the designed courses need to be tailored to the particular setting that the engineers are in, and because earlier experience with such a mix has been somewhat diversified (Rensaa, 2009a; 2009b). The tool for analysis of data – both in the preliminary investigations of the present paper and in the main study – will be mathematical competencies (Niss, 2003b). As a main task they have to consider and answer the question ‘What does it mean to master mathematics?’ To do this, a competency based approach is adopted, defined in the following way:

Mathematical competence then means the ability to understand, judge, do, and use mathematics in a variety of intra- and extra-mathematical contexts and situations in which mathematics plays or could play a role (Niss, 2003b, p. 7).

Altogether eight competencies are defined, in which the first group focuses on the ability to ask and answer questions in mathematics: Competencies in thinking mathematically, posing and solving problems, modelling and reasoning mathematically. The second group of competencies is about the

ability to deal with mathematical language and tools: Representing entities, handling symbols and formalism, communicating and aids/tools. In our analysis of the engineers building of new knowledge in mathematics, all these competencies will be relevant. The competencies are, in themselves, behavioral with focus on what to *do*. In some of the data collection this will also include what the engineers are expected to do.

The engineers to be attending the planned development program will typically be expected to have valuable experiences from their work as engineers in how mathematics is used in practical settings. In the present research, an investigation is generated in order to put light on which experiences some engineers themselves emphasize as their advantages. These experiences are advantages that should be utilized in a teaching position. They represent the benefits of being a teacher as an engineer, thus they need to be encouraged in the professional development program.

The program will encourage the participants partly to continue their work as engineers and partly to work as teachers after completing the studies. Thus, the professional experiences and practical illustrations may be updated and referred to contemporary with the teaching.

However, the transition from working as an engineer to being a teacher in mathematics is not straight forward. Many engineers have a 'workman approach' to mathematics (Kümmerer, 2001). They view mathematics as a set of procedures to be used, without seeing the necessity of deeper understanding, to produce the right answer. This implies a need of complementing studies that take into consideration the particular background of the engineers, utilize the experiences they have and expand their knowledge of mathematical topics, but at the same time aim at changing apprehensions that do not hold when a subject is to be taught. The transition from knowing mathematics for use to knowing mathematics for teaching is rather difficult and needs to be problematized. It is an example of *didactic divide* between disciplinary and pedagogical knowledge (Ball & Bass, 2000; Bergsten & Grevholm, 2004). Additionally, there are didactical and pedagogical aspects about being a teacher that a development program needs to take into consideration. The Danish KOM project (Niss,

2003b) lists six mathematics teacher specific competencies, all being relevant to an engineer in a teaching position: Curriculum competency, teaching competency, uncovering of learning competency, assessment competency, professional development competency and collaboration competency. The first four competencies are expected to be rather ‘new’ to an engineer, but depending on work content they may be part of experiences acquired by the engineers. Professional development competency is one that may evolve throughout the tailored educational program, while collaboration competency may very well be familiar to engineers.

In a study of engineers’ progress throughout the complementing studies, their previous knowledge will influence their study. It is important that this aspect is included in the design of the program because meaningful learning as defined by Ausubel (1968) is learning that connects to what is already known. New knowledge needs to be assimilated within the existing knowledge structure to implement modification of prior knowledge and thereby meaningful learning. Thus, it is relevant to carry out some preliminary studies to identify aspects about engineers’ experiences that are relevant for inclusion in the design of the program. Results from such preliminary studies may also help in preparing to the manner in which to collect data about previous knowledge of the engineers that will take part in the main study. Adler et al. states in their survey of research in mathematics teacher education (Adler, Ball, Krainer, Lin, & Novotna, 2005) that one of a number of fields that are underrepresented in this research, is teachers’ learning to directly address inequalities and diversities in the teaching with respect to mathematical background. Engineers will probably connect their mathematical knowledge and competencies to applications differently from students within the basic mathematics teacher education. Closer investigation of this is interesting.

3. Data and analysis

The data of the present study was collected by interviewing four engineers. The aim was to investigate more closely which needs engineers may have in order to become mathematics teachers.

The interviews were done to get input to the design of the professional development program, and are by no means claimed to provide general results. However, experiences and needs brought to bear during this study represent most certainly not isolated cases.

Criteria for selecting the interviewees were:

- Completed bachelor engineering education at least 5 years ago; so as to have a distance from the subjects.
- Work experience as an engineer; to have knowledge about practice.
- Some type of relation to teaching; in order to express opinions about the theme.
- Both sexes represented.

Based on this, two bachelor engineers and two master's engineers were chosen with help from teachers that have educated engineers for many years and are familiar with students' careers afterwards. However, since the development program in its overall form is to be designed to meet the bachelor engineers' needs – with an adjusted scheme for master engineers to join the program at a certain stage – the main part of the analysis and discussion deals with the bachelor engineers' responses. Some interesting statements and comments of the master engineers are however included. In the discussion to follow, all interviewees are made anonymous by given fictitious names and vague descriptions of their professional activity. I did not introduce the plans for the professional development education or any teaching themes to the engineers ahead of each interview, so as not to influence the answers. I wanted to grasp the engineers' immediate reactions and thereby their unaffected point of views. Concepts used in the questions were not explained or defined, just referred to and meant to be understood in everyday, social terms. Particularly, the word 'kompetanse' was used in more than one question. The public understanding of this word is more likely to be translated to 'skill', not the strictly defined word 'competency'. Thus, with a few exceptions, I will refer to it as skill.

The interviews were semi-structured with a planned schedule, but allowing other questions and comments to be brought about. However, I followed a main framework of themes for each of the four interviews:

- Initially about taking a part-time mathematics teacher position and asking if they regard themselves as being qualified for this - at the moment.
- Advantages of an engineer as teacher in mathematics.
- Views about mathematics, both own skills and what students in schools should learn. This involved two multiple choice questions listing alternatives like ‘understanding of mathematical relations and logical structures’, ‘interest’, ‘understanding of how mathematics is used in work and daily life’, ‘calculation skills’, ‘ability to use the correct formulas and methods’, ‘ability to translate practical problems to mathematics and solve them’, and finally the alternative ‘other abilities’ where the interviewee could give his or her own description.
- Which skills in mathematics and didactics the engineers think they lack.
- Teacher specific competencies. This was given as a table where each competency was listed and was to be graded as large, good, some or no own possession of, in addition no opinion. When referring to this particular table in the interviews to follow, ‘kompetanse’ is exceptionally translated to ‘competency’. This is since the categories of the table are based directly on the ones given by Niss (2003a). As referred to earlier, he presents six teacher specific competencies, but only five are referred to in the table. Development of professional competency is left out as only one of the interviewees is attending a teacher education program.

Each interview was ended by a question about interest in attending a complementing study to obtain the number of study points in mathematics that is required in a teaching position in school.

Interview with Sophie; a bachelor engineer.

Sophie has long experience as bachelor engineer but has not taken any steps towards teaching practice. She knows a lot about the profession from members in her family. The first question she is asked is if she presently would consider taking a part-time mathematics teaching position and if she regards herself as being qualified for this:

No, I haven't enough knowledge in the subject to do so. I've seen what it takes, and by that I bring with me big demands as to what a teacher in mathematics needs to know. This is also why I don't regard myself as qualified for such a job.

This is a reflective answer, showing that Sophie really has thought about the demands that rest upon a teacher's shoulder. She emphasizes lack of knowledge in the subject itself as a factor that makes it problematic for her to take a teaching position. This is elaborated further when she is asked about which mathematical skills she believes she lacks:

My theoretical background is too sparse, it dates from so many years back that I have forgotten about it. I need to brush up on it. Additionally, I have seen from helping my son in upper primary school with his homework that the mathematics has changed. They learn the subject differently from how I did at that age. Things are in a way inverted.

This last statement is most interesting. Sophie has probably grasped the problem oriented approach – that is rather usual in schools today – as an ‘inverted’ way of learning mathematics. NCTM defines this as “engaging in a task for which the solution method is not known in advance” (2000, p. 51). By starting with a problem and seeking ways to solve it, relevant mathematical arguments are introduced. This may surely be apprehended as a reversed order compared to how mathematics topics often were presented some thirty years ago. Back then theory and methods were introduced first and used in practical setting as a conclusion. Being aware of the changes, Sophie indicates that she has reflected on problem solving abilities which is an important mathematics didactics perspective. It is, however, notable that this feels somewhat unfamiliar to Sophie. Engineers are usually dealing with open, practical problems in their work, problems for which they seek solution

methods. Sophie does not directly relate this experience to the problem solving strategies in school subjects. And she does not stress this experience as a resource that an engineer has in a mathematics teaching position. Her answer to the questions about which advantages and contributions an engineer brings into the classroom, is that: “One can relate the subject to reality, tell about the usefulness and practical use of mathematics and put the subject into another professional connection”. The last statement indicates that Sophie regards the mathematics teaching situation as one where concepts can be brought into the practical world to illustrate how they may be used. The transition from a real world problem to a mathematical problem – which is the task for an engineer – seems not to be included. A conclusion to this is that Sophie somewhat separates her engineering experiences from what she reflects upon as being relevant in a teaching position. The connection is not as tight as her underlining of practical use known to an engineer, indicates. This is an aspect that needs to be taken into consideration in the professional development program. The interplay between the real world and the mathematical world needs to be emphasized to make engineers conscious about the back and forth transition and engineers’ advantages in this respect. Particularly, with reference to Sophie’s answer, the performance of active modelling as mathematising practical engineering problems needs to be problematized. This is an important part of the modelling competency (Niss, 2003a)

Sophie’s answer to the multiple choice question about own skills in mathematics underlines her own view about having practical experiences. She has chosen ‘understanding of how mathematic is used in working and daily life’ and ‘being able to translate practical problems to mathematics and solve them’ as her two most important skills. However, only the last option about being able to translate is chosen when she is to select the two most important skills that a student in school should hold. Additionally to this translation knowledge, Sophie emphasizes ‘understanding of mathematical relations and logical structures’ as important to students. This shows that she regards herself as one who possesses only by parts the competencies that are important for a student to

have. Her earlier statement referring to the lack of theoretical background and her background being dated, explains this. With respect to Sophie's comment on the earlier question about mathematics in schools today being inverted, her marks in the multiple choice question indicate that she actually has some knowledge about 'inverted situations'. This is in the meaning of inverted situations as situations where one has a (practical) problem and seeks to solve it by referring to mathematical arguments. Earlier, she expressed a lack of knowledge about this, but in the multiple choice question she actually indicates possession of this, all the same. She probably does not see the connection between engineering competencies and mathematical competencies. A professional development program need to make engineers like Sophie conscious about how engineering competencies may be translated to be used in a mathematics teaching situation.

In the table where Sophie is to grade her teacher specific competencies, a rather realistic view is revealed. The only competency she grades as having good possession of is cooperation. This competency she has probably gained through her work as engineer. Her teaching competency is marked out as 'some', while she has checked off both teaching and uncovering of learning competencies with a cross on the border line between 'some' and 'no' possession of. As she has not completed any type of teacher preparation programs, this is most pragmatic. It is probably due to her own rather rigorous interpretation of what it means to have a competency in each of the teacher specific abilities. As the word 'competency' not was defined ahead of the interview, Sophie was free to put whatever requirements she wanted into the word. But obviously she has rather high demands. The reason for this is probably what she has observed through her family members working as teachers.

Interview with Robert; a bachelor engineer

Robert is the second bachelor engineer under interview. His experience as an engineer is not as long as Sophie's, but he completed his education more than 5 years ago and has worked as an engineer

since then. Recently, he started a new job and parts of this job involve supervision of students when doing experiments in a laboratory. Thus, he is somewhat engaged in teaching.

Initially he claims, however, not to have considered taking a mathematics teacher position at any moment. The reason he gives for this, is that he has experienced on a number of occasions, how unmotivated children in primary and secondary schools can be. Still, he classifies himself as being qualified for such a position, with enough knowledge in mathematics to teach and ability to explain mathematical topics to teenagers. Some youths among his acquaintances, he explains, have told him that he is good in explaining mathematics to them. Robert gives an example of this:

A girl complained to me about not understanding her teacher's way of solving of a second order equation. The teacher had moved a number 4 from the left side of the equal sign to the right hand side, and then suddenly changed the sign of the 4. The girl could not understand *why*. I showed her how the teacher actually had subtracted 4 on both sides of the equal sign, and the result came out as minus 4 on the right hand side. This girl did suddenly understand what it was all about!

The statement is given to deepen his answer 'yes' to the question about being qualified to teach mathematics in school. He continues this argumentation when explaining which advantages an engineer has in a teaching situation: "We have learned a lot of mathematics. We have seen how important the subject is, and in how many places one needs to use mathematics". In general terms, Robert highlights experiences from practical use as the main advantage of an engineer as teacher, and he signalizes that he has knowledge within the subject. To him, this is enough to be a qualified teacher. In the multiple choice question regarding his views about mathematics, his emphasis of practical use is enhanced by his selection of 'knowledge of how mathematics is used in working and daily life' and 'knowledge of how to translate practical problems to mathematics and solve them' as the two most important mathematical skills that he holds. To Robert, however, these abilities seem to be the vital ones also in a learning situation. When I ask him to mark the two most important

approaches to mathematics that students need in school in order to learn the subject, he chose similar alternatives; how mathematics is used in working life, and translation from text problems to mathematics problems. Both alternatives – repeated twice in Roberts answers – may be recognized within the competency of mathematical modelling that is given by Niss (2003a) as “being able to analyze and build mathematical models concerning other areas” (p. 183). However, Robert seems to be rather tool oriented in his approach to the problems since he has not chosen the first alternative about understanding of mathematical relations and logical structures neither as a skill that he possesses himself nor as one of the two most important skills that a student needs to have. To Robert, understanding the ‘why’ is less important than understanding of the ‘how’. Robert is not the only engineer asserting this view (Kümmerer, 2001; Bergqvist, 2006), and this needs to be problematized most sincerely in the professional development program.

In the final part of the interview, dealing with didactical skills needed for a mathematics teacher, Robert continues in a self confident manner. When I ask him which skills – both mathematically and didactically – he thinks that he lacks in order to teach, his answer is “In the subject; none. In didactics; probably some”. In the table where he is to grade his curriculum, teaching, uncovering of learning, assessment and cooperation competencies, all but the first are classified as ‘good’. Curriculum competency is marked out as having some possession of. When returning the marked table to me, he explains that through his children’s school attendance – where he has taken part in a number of Parents Committees – and by having apprentices during his engineering profession, he has gained experience within most of the competencies. This is continued with a detailed story about how he on several occasions has had to motivate and encourage apprentices to do a better job. Once again, Robert’s self-confidence is brought to bear. He believes he possesses most teacher specific competencies to a good degree, despite never having practiced as an ordinary teacher or having completed any teacher preparation programs. Similar to Sophie’s case, this may be explained by Robert’s interpretation of the word ‘competency’. In lay terms it may be both vague

and inaccurate. And in contradiction to Sophie's interpretation, Robert has obviously no strict definition in mind. Thus, his grading of his own competency as 'good' to Robert may just mean that he knows about it and has personal experiences of it. He does for instance probably not regard uncovering of learning of mathematics as difficult, despite research saying something else. This competency includes interpretation and analysis of students' learning, their notions, beliefs and attitudes in addition to identifying each student's development (Niss, 2003a). This is surely not a competency that is picked up by taking part in Parents Committees. When instructing apprentices at an industrial establishment, some experiences in uncovering learning and development may be gained, but these are not with respect to mathematics. They are probably of a more practical nature.

The two masters' engineers

The two masters' engineers, Lisa and Paul, are both experienced engineers but with somewhat different priorities. Paul has earlier been teaching at an engineering education for a decade but has, in addition, several years of experience from the engineering profession – which he has returned to lately. Lisa on the other hand, started off her career by working as an engineer, but has changed her professional life to teaching both at secondary and tertiary levels. She teaches both mathematics and science subjects. Recently she has started a teacher credential program which in minor parts includes studies in mathematics didactics. Lisa claims not to have any inadequacy when it comes to skills in mathematics, and Paul claims to see himself as highly qualified to teach the subject at a tertiary level, but they have somewhat different views about what it takes actually to *be* a teacher in school. Lisa has reflected on this part rather carefully:

I have come to realize that there is a great challenge in knowing how to explain things and what one actually needs to explain. Things that seem so obvious to me that they are indisputable are stated in the mathematics didactics literature to be difficult. For instance, the calculation of integrals is to me a routine matter, often just easy and evident when you have the experience. But then, when I have to explain *why* we do it in this way and what the arguments are behind

using integrals to calculate areas, then it becomes difficult. Thus, I have come to realize that in teaching it is not enough to know the pure mathematics which I do, there is also the challenge in the aspect for the need of explanation.

Paul – on the other hand – emphasizes that he as part of his education has completed so many mathematics subjects or math related subjects that he is well qualified to teach at the secondary level. However, when I ask him which skills he believes he lacks, he does admit that since his own education is dates so many years back, some of the modern mathematics subjects are missing. This he has experienced through helping his children with their homework:

But it is an easy subject to teach, we have group works very often at home. I probably have some shortages when it comes to didactical skills, but as I see it the most important thing is to be *engaged* in your teaching.

The two rather different views about teaching of mathematics put forward by Lisa and Paul show the importance of the engineers' own experiences when it comes to realizing which needs they have in a teaching position. While Lisa is attaining a teacher credential program that requires her to think through difficult problems within teaching, Paul has his practical experiences from the domestic arena and during teaching of special subjects in an engineering education. At least in his formal teaching, it is most likely that if he has referred to mathematics it has been to readymade tools or equations that often are used to solve specific practical problems. Thus, his comprehension of what is required when teaching mathematics is probably to have a tool oriented approach.

4. Discussions and implications for the main study

The shortage of teaching professionals in mathematics and physics in schools may partly be solved by recruiting teachers from other science and engineering fields. Engineers as teachers is an example of this. They may be included in what literature defines as STEM (Science, Technology, Engineering and Mathematics) career changers, even if they only take part-time positions as

teachers in schools. All the interviewees and the literature points out that career changers bring a wealth of experiences, both personally and professionally, to the classroom (Grier & Johnston, 2009). Chamber (2002) lists a number of additional positive contributions from this type of teachers: Collegial support, good communicational skills, management of multiple projects, strong work ethic, more tolerance to diversity and more willingness to adopt student-centered methodologies. But as the present study suggests, the engineers could benefit from completing a professional development program in mathematics before starting teaching. At least two challenges have crystallized through the answers in the interviews, challenges that to our earlier experiences from engineering education most certainly are not outstanding for the engineers interviewed. These challenges need to be taken into consideration when designing the program:

- The engineers' apprehension of their own abilities and what it takes to teach, both in mathematical and didactical terms.
- The engineers' apprehension of how to connect mathematics and practical use outside schools.

The two bachelors engineers, Sophie and Robert, represent in a way two extremes when it comes to apprehension of own skills and what is required to be a mathematics teacher. While Sophie signalizes having fairly little confidence about her own knowledge – both lacking theoretical foundation and most teacher specific competencies – Robert gives the opposite impression. His self-confidence may in a classroom situation make him not hesitate to praise the usefulness of mathematics in engineering and provide the students with lots of examples. This may motivate students in schools. However, the drawback with having self-confidence like Roberts' is that he may not become conscious of his own limitations. Most engineers do unmotivated realize that they lack of didactical competencies, since this is absent from their education. Some knowledge may be gained through their work as engineers, and the experience in collaborative work may be rather extensive, but engineers do see the need for didactical training. The challenge is, however, to make these engineers also to realize their limitations when it comes to competencies in and

comprehension of, mathematics. Engineers have a rather broad knowledge of mathematical topics with reference to the list of themes that are dealt with – sometimes rather superficially – in mathematics courses in their own education. Thus, if they just look at the content of the mathematics subjects in schools, they will recognize most topics and thereby may be misled to believe that they are very qualified in the subject. Robert clearly has this opinion, and both masters' engineers also express this. Paul admits that he lacks some of the modern mathematics courses, but he does not see this or his limited didactics education as a problem. Lisa says that she has no shortfalls in mathematics in order to teach, but she is aware of the didactical needs. None of the four engineers do, however, seems to regard their own comprehensions of the mathematics *subject* as a challenge. Kümmerer (2001) states that many engineers have a workman approach to the subject, where following a receipt of rules produce the right answer to a problem. Bergqvist (2006) has revealed what she calls a tradition within the engineering education when interviewing a senior lecturer in a master engineering program: These students are prepared to learn a lot of algorithms in mathematics without much time for reflection. But a tool oriented approach is not enough in a teaching position. Problem solving, logical reasoning and concept understanding are all abilities of great importance. Among the interviewees, only one has marked off 'understanding of mathematical relations and logical structures' as an ability that she possesses herself; the masters engineer Lisa. The other three have not regarded this as one of the two most important skills that they hold. Thus, both Robert and Paul are examples of engineers who regard themselves as being qualified to teach mathematics even if they have gaps in their understanding of mathematics relations and logical structures. This is a major challenge that occurs ahead of the running of the complementing studies, and may result in the non-attendance of the program by some engineers. They do not realize themselves that they are in need of developing their mathematical competencies. A way to meet this challenge is use of publicity; getting professional journals to write about what is required. In this publicity it is important to emphasize the advantages that

engineer as a mathematics teacher can bring to the classroom in order to promote career change, but at the same time focus on additional mathematical competencies that an engineer lacks in order to become a qualified mathematics teacher.

In contrast particularly to Robert, Sophie has far less confidence in her own abilities to start teaching mathematics in primary or secondary school. She has – through observing family members' work – seen that it takes more than her 'engineering mathematics competence' to teach in schools and in this way she appears far more realistic in her answers. Too realistic, in a way. For professionals like Sophie it may be a problem that their expectations as to what is needed to be prepared for teaching in mathematics, are so vast that they hesitate in entering both complementing studies and a teaching position.

Many engineers do, however, have confidence in their own abilities that are not as extreme as Robert's or Sophie's, but lies somewhere in between. The masters' engineers Lisa and Paul, are examples of this. Indeed they both regard themselves as possessing mathematical skills enough to be teachers in schools, but they do also realize that they have some shortfalls. Lisa sees the need for learning mathematics didactics while Paul lacks some of the modern mathematics subjects. Both have confidence in their own skills, but see the need for learning more. Grier and Johnston (2009) writes about STEM career changers that "Their maturity brings confidence in their abilities to manage a classroom, understand student learning in the context of school culture, and to access content knowledge" (2009, p. 57). The professional development program needs to challenge these beliefs about own abilities and make the engineers conscious that they need to further develop their knowledge in mathematics and also with respect to didactics. This may both be done by introducing mathematics courses that usually are new to an engineer and by challenging the engineers within the topics in which they regard themselves to have knowledge in. For instance, a number theory course could initially be offered. This is a subject that engineers with a degree from some years back have not studied, and it appears to be an easy subject that in reality is both challenging and

demanding. Moreover, it is a subject that a teacher needs to have knowledge in. In calculus – which an engineer may think she is sufficiently qualified in just by looking at the themes – a challenge would for instance be to let him or her introduce the derivative to a group of students. The concept may very well be motivated by practical illustrations, but is not easy in theoretical terms: Students have problems understanding the meaning and definition of the derivative (Orton, 1983).

Both Sophie and Robert emphasize knowledge of practical use of mathematics as a main advantage an engineer has when teaching the subject and this is supported by statements from Lisa and Paul. But Lisa is the only one that refers to an example that may illustrate this usefulness. She mentions that when introducing the derivative to students, an engineer may easily come up with practical examples of areas where it is used. This is the only example referred to during all four interviews. In light of the setting, this is not surprising. The engineers were not given any time to prepare themselves for the questions and almost no information was given ahead of the interview. They were just asked there and then to answer some questions about mathematics and teaching of mathematics. The intention was to get immediate reactions reflecting the current situation. To the questions about advantages that an engineer has, the answers have consequently become more of a general nature. Still, since only one of the interviewed engineers is working as a mathematics teacher – and the other more distant to the mathematics content in school subjects – a prepared interview would perhaps not have given concrete suggestions anyway. Nevertheless, the answers do indicate that practicing engineers may not have immediate suggestions of illustrations and examples from their work. The professional development program needs to encourage this part rather profoundly. Even if engineers often and in different connections use mathematics as part of their work, it is not immediately given that they are able to identify this use. Thus, it becomes important to provide them with means for recognizing this. This is an aim of mathematical archaeology; “to make explicit the actual use of mathematics hidden in social structures and routines” (Skovsmose,

1994, p. 95). Engineers can be made aware of the use of mathematics through examples, but perhaps even more importantly through group work discussions about their own work.

Sophie's remark about an engineer's ability to place mathematics into another professional connection is noteworthy. The 'traditional' way of relating mathematics to the life outside schools is to conclude the teaching of a theme or a concept by illustrating how it may come to be of use in a practical situation. In a problem solving situation, the opposite way of thinking is initiated. One starts with a practical, often open-ended problem, and seeks ways to solve it. The necessity of deriving mathematical methods to solve the problem is then enforced. For experienced engineers who finished their education a number of years back, a problem solving aspect may be 'new' with reference to mathematics teaching. In an engineering job, however, this way of working – starting with a problem and searching for ways to solve it – is most certainly the usual approach. Thus, engineers need to be made aware of how to translate their experiences from problem solving as engineers to the classroom situation. Lecturers in the professional development program need to take into consideration that engineers may not directly see how their professional working methods are useful in a teaching situation. Their references to practical examples are important, but additionally their experiences from methods of their work as engineers are relevant. Students in schools can organize their work with the subject in a similar manner in the classroom. Sophie's statement indicates that she has not thought about this as an advantage, and she is most certainly not alone in this respect. If the main reference to how things are done in the classroom is from own schooling, one may have rather limited teaching aspects in mind. The complementing studies need to 'open the eyes' of some engineers.

To the last question in the interview about whether the engineers are interested in attending complementing studies in mathematics, they all answers 'yes'. This answer is somewhat inconsistent at least with Robert's and Paul's earlier statements saying that they regard themselves as qualified for a mathematics position in school. Their answers may just be given to please me as

the interviewer. But it may also be that the engineers – throughout the interview – have come to realize that they could benefit from completing a professional development program before starting to teach. The challenge is to reach other engineers with the same message, but still emphasize their valuable professional traits to motivate a career change.

References

- Adler, J., Ball, D., Krainer, K., Lin, F.-L., & Novotna, J. (2005). Reflections on an emerging field: Researching mathematics teacher education *Educational Studies in Mathematics*, 60, 359-381.
- Ausubel, D. P. (1968). *Educational psychology: A cognitive view*. New York: Holt, Rinehart and Winston.
- Ball, D., & Bass, H. (2000). Interweaving content and pedagogy in teaching and learning to teach: Knowing and using mathematics. In J. Boaler (Ed.), *Multiple perspectives on mathematics teaching and learning* (pp. 83-104). London: Ablex.
- Bergqvist, E. (2006). *Mathematics and mathematics education; Two sides of the same coin*. [Doctoral Thesis]. Department of Mathematics and Mathematical Statistics, Doctor of Philosophy. Umeå University, Umeå.
- Bergsten, C., & Grevholm, B. (2004). The didactic divide and the education of teachers of mathematics in Sweden. *Nordic Studies in Mathematics Education*, 9(2), 123-144.
- Chambers, D. (2002). The real world and the classroom: Second career teachers. *The Clearinghouse*, 75(4), 212-217.
- Czarnocha, B., & Prabhu, V. (2004). Teaching-research and design experiment – Two methodologies of integrating research and classroom practice. *International Conference to Review Research on Science, Technology and Mathematics Education*. Goa, India

- Freudenthal, H. (1988). Ontwikkelingsonderzoek [Developmental research]. In K. Gravemeijer & K. Koster (Eds.), *Onderzoek, ontwikkeling en ontwikkelingsonderzoek* (pp. 49-54). Utrecht, The Netherlands: OW en OC.
- Gravemeijer, K. (1994). Educational development and developmental research in mathematics education. *Journal for Research in Mathematics Education*, 25(5), 443-471.
- Grier, J. M., & Johnston, C. C. (2009). An inquiry into the development of teacher identities in STEM career changers. *Journal of Science Teacher Education*, 20(1), 57-75.
- KD. (2006). *Et felles løft for realfagene. Strategi for styrking av realfagene 2006-2009*: Kunnskapsdepartementet.
- Kümmerer, B. (2001). Trying the impossible: Teaching mathematics to physicists and engineers. In D. Holton (Ed.), *The teaching and learning of mathematics at university level: an ICMI study* (pp. 321-334). Dordrecht ; Boston: Kluwer Academic Publishers.
- NCTM. (2000). *Principles and Standards for School Mathematics*.
- Niss, M. (2003a). The Danish "KOM" project and possible consequences for teacher education. In R. Strässer, G. Brandell & B. Grevholm (Eds.), *Educating for the future. Proceedings of an international symposium on mathematics teacher education* (pp. 179-190).
- Niss, M. (2003b). Mathematical competencies and the learning of mathematics: The Danish KOM project. In A. Gagatsis & S. Papastavridis (Eds.), *Proceedings of the 3rd Mediterranean Conference on Mathematical Education* (pp. 115-124). Athens, Greece.
- Næss, T. (2002). *Realfagslærere i skolen. Rekruttering, beholdning og avgang*: NIFU skriftserie nr. 5.
- Orton, A. (1983). Students' understanding of differentiation. *Educational Studies in Mathematics*, 14, 235-250.

- Rensaa, R. J. (2009a). Can student teachers and prospective engineers profit from studying mathematics together? In C. Winsløw (Ed.), *Proceedings of the NORMA08* (pp. 73-80). Copenhagen, Denmark.
- Rensaa, R. J. (2009b). Some experiences with integrating student teachers and engineering students in the same class. *Problems, Resources, and Issues in Mathematics Undergraduate Studies, PRIMUS*, 19(5), 473-490.
- Skovsmose, O. (1994). *Towards a philosophy of critical mathematics education*. Dordrecht: Kluwer Academic Publishers.
- Sørensen, R. (2003). Varsellampene er mer enn røde. *Forskerforum*, 2008, from http://www.forskerforum.no/module_info/index2_forskerforum.php?level=2&xid=1759
- Vassnes, H. B. (2008). På vei inn i skolen. *TeknaMagasinet*, 1, <http://viewer.zmags.com/showmag.php?mid=srdhw&pageid=6#/page6/>.
- Wagner, J. (1997). The unavoidable intervention of educational research: A framework for reconsidering researcher-practitioner cooperation. *Educational Researcher*, 26(7), 13-22.
- Wittmann, E. C. (1995). Mathematics education as a 'design science'. . In A. Sierpinska & J. Kilpatrick (Eds.), *Mathematics education as a research domain: A search for identity* (Vol. 4, pp. 87-103): Kluwer Academic Publisher.