The SEFI Maths Working Group – Current Offerings and Future Tasks

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Abstract

In this discussion paper we firstly summarise the current offering of the SEFI Mathematics Working Group with regard to orientation for those who are interested in the mathematical education of engineers. Based on this summary we identify directions for further work. Finally, we present some ideas of how progress might be made in these directions.

Introduction

For over 30 years the Mathematics Working Group (MWG) of the European Society for Engineering Education (SEFI) has provided a forum for the exchange of views and ideas amongst those interested in engineering mathematics and has created several documents to capture the state of the art in learning, teaching, assessment and curriculum development regarding the mathematical education of engineers. In this paper we firstly give a brief overview of the current offerings of the MWG which are freely available on the group's website (http://sefi.htw-aalen.de). Then, we specify those topics which in our view will be of great importance in the near future. This includes a better understanding of the competence concept and ways to acquire and assess competencies as well as possible reactions to changes in the learning environment and the learning behaviour and technology use of incoming students. Finally, we outline potential further activities of the MWG in order to address these issues.

Current Offerings

In the last ten years the Working Group has held five seminars in Vienna, Kongsberg, Loughborough, Wismar and Salamanca. Contributions to these seminars and discussion sessions were concerned with questions such as

- What are the essential issues regarding the mathematical education of engineers?
- What is the role of technology?
- Which forms of assessment exist in Europe and are they adequate?
- How can we activate students?
- How can we achieve higher-level learning goals like mathematical understanding?
- How can we improve the attitude of engineering students towards the mathematical part of their education?
- What is the impact of the Bologna agreement on the mathematical education of engineers?

All the seminar contributions and reports from the discussion sessions are available from the group's web page at http://sefi.htw-aalen.de. These documents provide valuable experience from many European countries without claiming to offer a comprehensive and systematic overview of developments in Europe. Discussions at the seminars indicate that there is broad agreement on the importance of the topics and questions listed above but there are clear differences regarding the answers. This was particularly evident in discussions on the role of technology.

The second main means (in addition to the two-yearly seminars) for providing orientation is the core curriculum document. The third edition of this document was issued in September 2013, called "A Framework for Mathematics Curricula in Engineering Education" (Alpers et al. 2013). This document adopts the concept of mathematical competence, from the Danish KOM-project (Niss & Højgaard 2011) as the major goal of mathematics education. Higher-level learning goals that have been a topic of many discussions in the seminars are captured by this concept which is specified in more detail by identifying eight so-called competencies. The curriculum document is to be understood as a framework document, not as a specific one-size-fits-all curriculum. For a concrete curriculum for a specific type of engineering study course, the competencies need to be specified in more detail. The KOM-project provided three dimensions in relation to each competency (degree of coverage, radius of action, technical level). The third edition of the core curriculum document retains the lists of content-related learning outcomes from the second edition (Mustoe & Lawson 2002), although some have been slightly modified. Again, for specifying a concrete curriculum, one has to choose from these lists (and possibly make a few additions if necessary). The latest edition of the core curriculum document also contains chapters on learning and teaching arrangements and on assessment which take into account appropriate contributions and discussions at the seminars and also other relevant literature. Therefore, the document could equally be seen as a "framework" for the important questions listed above. It gives an overview and points the reader to further relevant literature.

There is also a special curriculum for a practice-oriented study course in mechanical engineering written within the framework (Alpers 2014). There, the competencies have been specified in more detail based on the experience of the author. This document should be seen as a first attempt to specify such a curriculum and it is likely that several iteration cycles will be required to improve this document. Nonetheless, the document can act as an example and inspire other people to write a similar curriculum for their type of study course.

The dissemination of the MWG's outputs outlined above occurs via different routes:

- the MWG's mailing list
- the national contact persons who are encouraged to disseminate the information to national, regional and local bodies and individuals interested in the mathematical education of engineers
- presentation at conferences (like the SEFI Annual Conference or national conferences)

- contacts with other bodies (e.g. ASEE Mathematics Division).

Important topics for future work

The development of the framework document is by no means the “end of history” in the mathematical education of engineers but rather an organizing scheme for further activities. One major area of future work is the concept of mathematical competence itself. A more precise competence description for different types of engineering education is required (i.e. an identification of those aspects of the eight competencies which are important). This could be done with respect to

- specific mathematical topics in context (for example, Laplace transforms, Dirac delta function, convolution) in order to recognize which kind of mathematical understanding is required to use a certain mathematical concept for solving certain kinds of application problems (usually this will be different from the kind of mathematical understanding a mathematician needs to understand and further develop mathematical theory)
- specific application subjects treated more generally, for example, which aspects of the competencies are important for machine element dimensioning (including the usage of tools like a machine element dimensioning program)
- workplace activities (also including the usage of tools available at engineering workplaces).

The first two points are dealt with in the German KoM@ING project (see http://www.kom-at-ing.de/ where an English description is available; see also Schreiber & Hochmuth 2013). For mechanical engineering and electrical engineering, the usage of mathematics in textbooks, lecture notes and assignments has been investigated, using qualitative research methods, to identify the required competence components. Since such a project must be restricted to a small sample of topics within the set of relevant applications subjects in a study course, further studies of this nature would be beneficial in order to build up a broader understanding. This could lead to the development of a sound knowledge base of competence components for different types of engineering study courses. This could be the basis for setting up additional curricula or for improving and enhancing the existing curriculum for a practice-oriented study course in mechanical engineering.

The crucial goal of mathematics education in engineering study courses is to enable graduates to use mathematics to solve problems in their daily work. In order to capture the competence aspects that are important for this goal with respect to a range of jobs, workplace studies are necessary. One might argue that if students are successful in their application subjects then this is a good indicator for success in their later jobs. But it is by no means certain that lecturers in application subjects really capture the competencies necessary for successful usage of application concepts in engineering jobs. Therefore, workplace studies are necessary but also very time-consuming to pursue (Alpers 2010).

In order to really have an impact on the capabilities of graduates, one has to find suitable learning scenarios for competence acquisition. For this, having a pool of competence related example tasks (assignments, problems, projects) with corresponding learning environments would be helpful. Such example tasks are also needed for convincing colleagues that the competence approach is helpful. When a colleague thinks that the tasks are interesting and important and that his/her students should be able to tackle such example tasks, then he/she is more likely to seriously consider the competence concept as a means for understanding and promoting student development.

Having a pool of competence-related example tasks also helps to assess competence since such tasks could be used not just for competence acquisition but also for assessment. But this is certainly not sufficient to address the assessment topic. Given the sometimes large number of students in classes, one also has to think about assessing aspects of competencies in smaller tasks performed in written exams. In the ICTMA community there is already a substantial amount of work on assessing the modelling competency which should be taken into account (see http://www.ictma.net).

The mathematical education of engineers cannot be considered in complete isolation from the other educational elements of engineering students' education. In recent years, there has been a rise in new approaches to teaching engineers. Pedagogies such as CDIO (see http://www.cdio.org/), Problem-based learning and Project-based learning (Graham, 2010) are becoming increasingly widely used. There is a need to consider if the mathematical education of engineers should be integrated into these methodologies and, if so, how this can be achieved. A common characteristic of these pedagogies is their motivation of students to engage in active learning by presenting them with tasks which require them to use fundamental engineering principles, some of which they may not have met before. These approaches offer potential for development of some of the mathematical competencies outlined in the framework document provided tasks with suitable mathematical content can be developed. One area where the MWG might address future activity is in exploring ways of integrating mathematics education more closely with other elements of engineering education.

Another open question is how we react to changes in the learning environment. Incoming students have access to a wealth of sources of software and hardware to supplement face-to-face teaching. Smartphones, laptops and tablets are commonplace and enable students to access information which their lecturer may have hosted on their VLE, but also provide access to computer algebra systems, MOOCs, lecture material from other universities, revision material and, increasingly, Mathematical Apps. Moreover social networking is enabling students to share information and work together in a way not dreamed of even 10 years ago. Many experience such technologies at school and they expect continued usage at University. An area for future work could be to address how best to teach and encourage conceptual understanding and active learning in this new environment. Perhaps also we could address how to take advantage of social media and other advances in technology to share resources/exchange ideas, etc. and, as a community of educators, we could also benefit.

It is important that not only do undergraduate engineers acquire mathematical competencies whilst at university but that they maintain these competencies throughout their working lives and this long-term “sustainability” of the competencies is a crucial element of engineering education in developing engineers to meet the expected future challenges of society (see Come et at 2013). Graduate engineers will need professional competencies to reflect all society changes, including not only engineering knowledge, problem analysis, investigation and applied research, solution design, project development and use of various high-tech tools, but also ethics, communications, social behaviour, project management and open capacities to use resources for life-long learning. Changing modes of knowledge production, dissemination and application are creating increased demand for skills in the inter-disciplinary team-working, the use of ICT and the ability to learn for oneself and from peers. Transformation of engineering education is necessary in order to provide environments and curricula facilitating such high demands on future engineers. Future challenges of the SEFI Mathematics Working Group might therefore also be focused on finding innovative teaching strategies that might lead to both a deeper mathematical conceptual understanding and enjoyment of solving mathematically based applied engineering problems, thus strengthening basic professional characteristics and mathematical competencies of engineers ready to work in the competitive environment of the future decades.

Potential future activities of the Mathematics Working Group

There are several ways to achieve results in relation to the directions stated above:

- We should monitor respective developments in other projects like KoM@ING and ask them to give presentations at the group’s seminars to make the results better known.
- We should encourage the SEFI MWG community to specifically work on the above topics by formulating seminar calls for papers accordingly.
- We should provide a framework for organizing contributions and putting them into perspective such that accumulation, progress and remaining deficiencies become evident and inspire future work. This could happen in the following ways:
    - By regularly updating the curriculum document to include new contributions
    - By keeping a (hopefully growing) set of curricula for special types of study courses
    - By developing databases of competence-related tasks (assignments, projects) for competence acquisition and for competence assessment (such as the MAPS server for mathematical application projects (Alpers, 2003) and the question bank for electronic voting systems (Robinson 2010)).

By following the directions stated above, the SEFI Maths Working Group should retain and extend its role as a valuable source of information and an interesting place for exchanging views on the mathematical education of engineers.

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