# Formulation Of The FIRIS-P Professional Core-Competency Framework For Flexible Academic Curricula: The Biomedical Engineering Program

Jan R. BUITENWEG

*University of Twente, Netherlands, The*, j.r.buitenweg@utwente.nl

# FORMULATION OF THE FIRIS-P PROFESSIONAL CORE-COMPETENCY FRAMEWORK FOR FLEXIBLE ACADEMIC CURRICULA: THE BIOMEDICAL ENGINEERING PROGRAM (PRACTICE)

**J.R. Buitenweg** [1]
University of Twente
Enschede, The Netherlands
ORCID 0000-0002-2531-3981

***Conference Key Areas****: Curriculum Development, Innovative Teaching and Learning Methods*
***Keywords****: Competency Framework, Curriculum Mapping, Constructive Alignment, Self Directed Learning, Flexible Study Paths*

## ABSTRACT

Introduction – How to formulate the goals of an academic educational program in such a way that they reflect the identity of the profession, but at the same time allow the flexibility required for self-responsible and self-directed individual study paths that can initiate lifelong learning and successful interdisciplinary collaboration after graduation? Here, we present a novel competency framework that (1) reflects the identity and academic level of the interdisciplinary Biomedical Engineering (BME) profession, (2) permits the alignment of program intended learning outcomes that accommodate the content of the different specialisation tracks of the BME program and (3) guides students and staff by improved curriculum mapping and optimization.
Methods – We collected input from teaching staff members who are actively practicing their BME profession in the interdisciplinary ecosystem around our university. Using their feedback, we iteratively formulated a set of core competencies that characterize the work and role of the BME professional. We obtained preliminary face-validity by performing curriculum mappings from several courses from BME-

---

[1] *Corresponding Author (All in Arial, 10 pt, single space)*

*J.R. Buitenweg*

*j.r.buitenweg@utwente.nl*

tracks and by asking feedback from students. Results – The iterations resulted in the FIRIS-P competency framework including five successive core professional competencies of which specified subcompetencies carry the BME identity: (1) Fundamental competencies, (2) Instrumental competencies, (3) Reasoning competencies, (4) Interventional competencies, and (5) Societal competencies. These core professional competencies are completed and supported by transferable Personal competencies. Discussion: Preliminary validation indicates that the FIRIS-P framework carries all three characteristics mentioned above, warranting future evaluation of its merits for education of lifelong learning BME professionals.

# 1 INTRODUCTION

In our rapidly changing society, facing complex challenges, we need lifelong learning academic professionals who continuously adapt to new circumstances and who can collaborate and contribute in an interdisciplinary context. Our educational programs should respond to that need by providing our students from ‘day one’ with meaningful guidance and training to take control of their self-directed individual development pathway. A main challenge we face here, is to offer a continuously optimized and flexible educational content that enables our students to gain professional mass and direction on this pathway, but at the same time sufficiently preserves the identity of the profession to ensure the value of the diploma.

## 1.1 Local Context: Our Biomedical Engineering program

During the last decades, Biomedical Engineering (BME) has evolved from a collection of mono-disciplinary professions with their own specialization towards their application in the medical field, to a fully interdisciplinary profession in its own right. Our Biomedical Engineering educational master program includes four specialisation tracks that are aligned to the research domains of our TechMed institute:

- Biorobotics (BRB) – focusing on the use of mechatronic systems for improved surgical interventions or rehabilitation.
- Imaging and in-vitro diagnostics (IVD) – focusing on visualising the human body and detecting abnormalities in cells and tissues in order to detect diseases and monitor health.
- Physiological signals and Systems (PSS) – focusing on the observation and modulation of human body systems (e.g. sensory, motor and endocrine), which can be dysfunctional due to trauma or disease.
- Bioengineering Technologies (BET) – focusing on technologies that mimic or restore the function of diseased organs and damaged tissues, such as organs-on-chips or tumours-on-chips and targeted (nano)medicine.

As the Body of Knowledge and Skills (BoKS) differs largely between the tracks, each track has a tailored program content to prepare students for their final Masters assignment in one of the track related research groups. Our Techmed researchers – operating in the entrepreneurial ecosystem of our university - are also core teachers of many courses and actively participate in shaping the BME curriculum.

## 1.2 Problem statement and objectives

For the formulation of program goals and design of curricula, numerous competency frameworks have been developed, mostly to ensure that educational programs meet accreditation standards. Many frameworks show a clustering of (sub)competencies in competency areas or core-competencies, e.g. constructed from accreditation standards (Lu et al. 2019) or, the other way around, based on results from competence research (May and Terkowsky 2014) and subsequently validated using accreditation standards.

The Dutch accreditation system has adopted the Meijer's criteria for academic bachelor's and master's curricula (Meijers et al. 2005) as assessment criteria for the accreditation of engineering programs. These criteria are also formulated as a framework of competencies that university graduates should have at the start of their professional career (see textbox 1 for their clustering in core-competencies). In our Biomedical Engineering program we have aligned the final program goals to the Meijer's criteria. Although this approach supports guarding of the academic level of training within the program, the identity and core competencies of the BME profession are only implicitly reflected in the clustering and generic formulations of the Meijer's based competencies. This makes it more difficult to identify how available or required courses in the different specialization tracks contribute to the program goals, which in turn hampers both the optimization of the program content by staff and the targeted and flexible use of the program content by students. Not surprisingly, we observe that our program goals primarily play a prominent role in the accredication cycle of programs and are less actively used in curriculum design or for guiding self-directed learning by students.

**Textbox 1: The Meijers Criteria for Academic Bachelor's and Master's Curricula [1]:**

A university graduate

1. is competent in one or more scientific disciplines
2. is competent in doing research
3. is competent in designing
4. has a scientific approach
5. possesses basic intellectual skills
6. is competent in co-operating and communicating
7. takes account of the temporal and the social context.

On the other hand, (Degré and Castilo-Colaux 2016) argued that competency frameworks can be a powerful tool for academic staff to collaboratively design their courses as a coherent part of the curriculum, for students to be more involved in their education and to choose their studypath and for the dialog with the professional field. Indeed, if we expect students to prepare for self-directed lifelong learning by deriving a BME-specific dot on their horizon and by determining their own study path, we need clearly formulated program intended learning outcomes that (1) are aligned with an instructive competency framework that explicitly reflects the identity of the BME profession well beyond graduation, instead of focusing on entry competencies, and (2) can accommodate the BoKS and content of courses in the different specialisation tracks of the BME program in a straightforward way. In our opinion, to fulfill the cohesive, instructive and communicative roles as proposed by Degré and Castilo-Colaux, a competency framework should not only adequately accommodate the 'what' of all competencies, but also should feature a clustering into competency areas that coherently reflects the 'how' of successful academic professional contributions to society: It should facilitate teachers to share the narratives of the successes (and failures) in their professional practices and shape both the content and the pedagogical approach in their education. It should also facilitate students to recognize the combined functionality of these core competences in the work of professionals (inside and outside academia), to choose role models and to develop the narrative of their own career. In our experience, the Meijers criteria and many other competency frameworks insufficiently fulfill this requirement, which made us initiate the development of a framework with a more functional clustering.

# 2 METHODOLOGY

## 2.1 Formulation of the competency framework

We collected input from teaching staff members who are actively practicing their BME profession in the interdisciplinary ecosystem around our university. We took the consensus on our mission as biomedical engineers, as posted on our educational website at that time (textbox 2) as a starting point and we reflected on how we as biomedical engineers use fundamental scientific knowledge to develop technology and apply this technology to create products that solve healthcare problems. By focussing on the activities (verbs) mentioned in the mission statement and connecting these to the content of our very different biomedical engineering practices, we then discussed how we could use this narrative to present the BME identity more explicitly and instructively in a clustering of competencies that can comprehensively accommodate the content of the BME specialisation tracks.

> **Textbox 2: Our BME mission statement**
> Biomedical Engineering is an interdisciplinary field, combining engineering disciplines and natural and life sciences. By integrating scientific and engineering concepts and methodology the Biomedical Engineer works to increase scientific knowledge and solve health care problems, by:
> 1) acquiring new knowledge of living systems through continuous innovation and substantive application of experimental, analytical, and design techniques.
> 2) design and development of new devices, algorithms, processes and systems to advance Medical Technology in health care.
> 3) solving health care problems through purposeful context-driven problem solving;
> 4) implementing solutions using excellent cross-disciplinary communication and collaboration.

## 2.2 Program intended learning outcomes and curriculum mapping

We tested if the new competency framework permits alignment of program goals that clearly describe the abilities of the student at graduation, in terms of the content of the BME specialisation tracks. At each component of the framework, we formulated track specific intended learning outcomes (TILOs) for each track. Subsequently, we tested if the new framework permits mapping of the content of courses in the BME program offer to the components of the framework.

### 2.3 Student responses

To get a first impression of the instructional value of the new competency framework and the merits for self-directed learning, the competency framework was provided and explained to students (N=60: 12 BET, 13 PSS, 12 IVD, 23 BRB) of the compulsory MSc-BME startercourse ‘Technology for Health’. Subsequenly, the students were asked to recognize these competences in the work of TechMed researchers. As an individual assignment, each student was asked to report the result of self-reflection, based on the following questions:

- Expertise: Which of the BME subcompetencies do you like or consider as one of your strengths? Answer options: Strong, somewhat, not my expertise.
- Ambition: Which of the BME subcompetencies do you want to acquire before you graduate? Answer options: Need this, done this, not for me.
- Importance: Which of the BME subcompetencies are important in the professional field you envision yourself working? Answer options: Important, moderately important, not important.
- Program offer: Which of the BME subcompetencies are in your opinion poorly or not represented in your educational program or courses offered at our university? Answer options: Need more, sufficient, too much.

Besides obtaining these nominal reponses, students were asked to briefly motivate their ratings or provide examples (data not reported here).

## 3 RESULTS

### 3.1 The FIRIS-P Competency framework

Our reflective discussions and iterations resulted in the FIRIS-P competency framework including five interconnected core academic professional competencies of which specified subcompetencies carry the BME identity (see also Fig. 1). Subsequently, these core professional competencies were completed by adding transferable Personal competencies. Also an explanation to students was formulated (not presented here).

### 3.2 Program intended learning outcomes and curriculum mapping

In Fig. 2, the use of FIRIS-P for program intented learning outcomes and curriculum mapping is depicted. For all subcompetencies, track specific intended learning outcomes (TILOs) can be formulated that specify the BoKS that should be mastered at graduation. By formulating different TILOs for different specialization tracks (see Textbox 3 for an example), the contribution of track content to the BME identity carrying competencies can be specified, despite differences between the tracks. Subsequently, the mapping of (desired) course content contributing to the attainment of TILOs becomes straightforward.

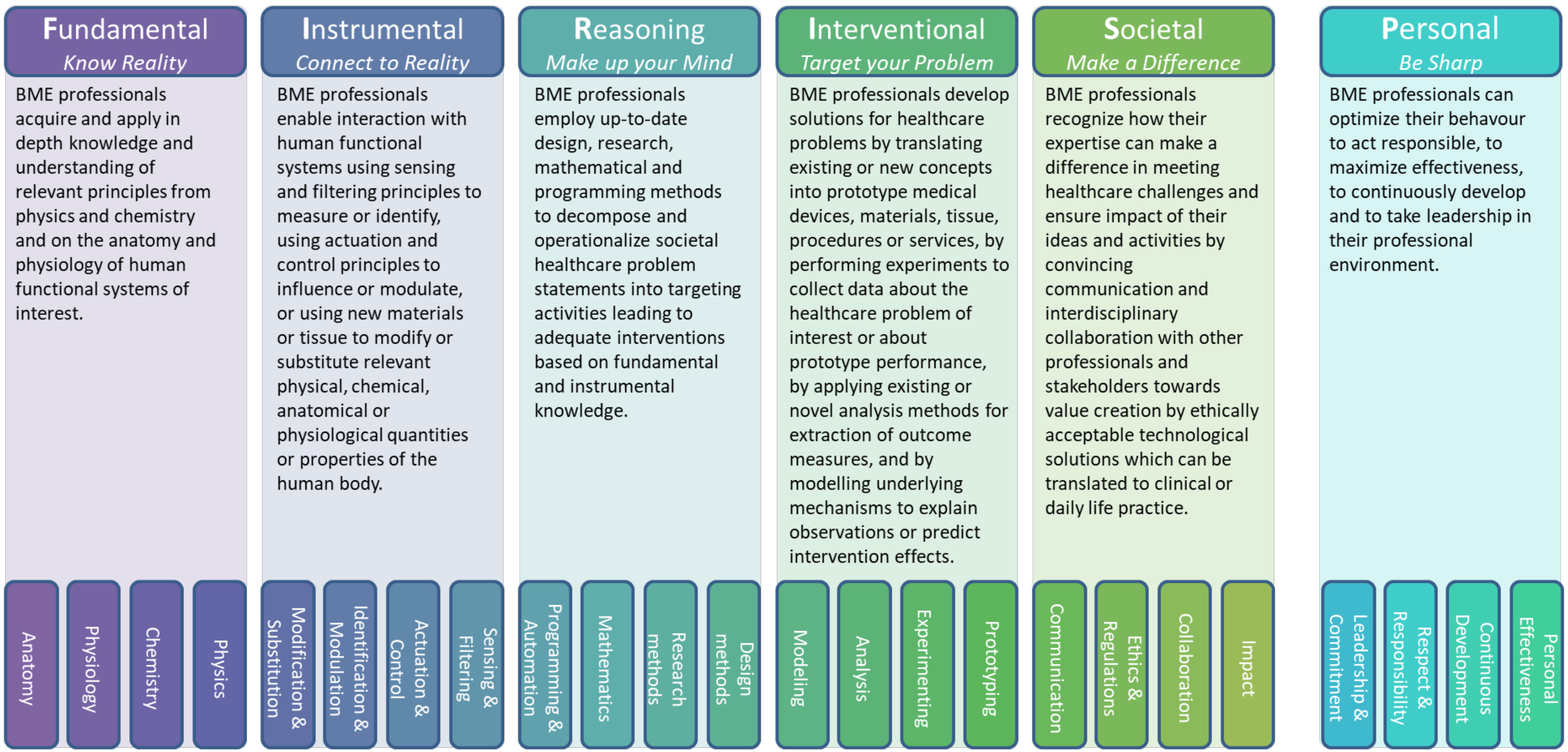


*Fig. 1. The FIRIS-P competency framework, in which the identity of the BME profession is made explicit in five core professional competencies (FIRIS), representing the way engineers impact society by interventional activities in which they thoughtfully employ fundamental and instrumental knowledge and skills. At each core competency, BME specific subcompetencies are formulated, linking the BME identity to relevant BoKS content. The FIRIS part is completed by Personal competencies, describing transferable knowledge, skills and attitudes needed for sustained effectiveness as a professional.*

**Textbox 3: Example of track specific program intended learning outcomes, connecting concrete BoKS to the FIRIS-P subcompetency Sensing & Filtering (Instrumental competencies)**

*Biorobotics* - The student can employ physical and chemical principles to obtain analog and digital signals which are sensitive to relevant quantities of human body and/or robotic systems of interest and can employ analog and digital signal processing methods to increase the specificity of these signals towards the human and robotic system behavior of interest.

*Physiological signals and systems* - The student can employ physical and chemical principles to obtain analog and digital signals which are sensitive to relevant quantities of human body systems of interest and can employ analog and digital signal processing methods to increase the specificity of these signals towards the human system behavior of interest.

*Bioengineering technologies* - The student can employ biophysical, optical and molecular biological techniques to study the function of human cells and tissues in healthy and diseased states.

*Imaging and in-vitro diagnostics* - The student can employ physical and chemical principles to obtain spatiotemporal signals which are sensitive to relevant changes in human anatomy of interest and can employ analog and digital signal processing methods to visualize these signals and increase their specificity towards specific disease progression.

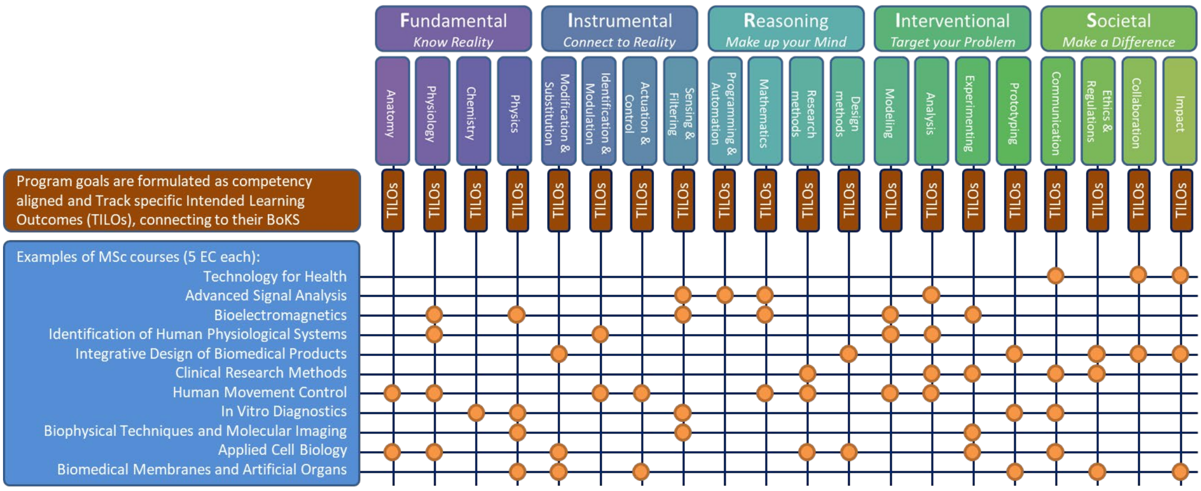


*Fig. 2 The connection between the FIRIS-P framework and the BME BoKS can be realized through the formulation of Track specific program Intended Learning outcomes (TILOs, see textbox 3 for examples). To illustrate curriculum mapping, contributions from several courses from the BME program offer to the FIRIS-P aligned TILOs are depicted.*

| Meijer's Criteria FIRIS-P | Fundamental | Instrumental | Reasoning | Interventional | Societal | Personal |
|---|---|---|---|---|---|---|
| 1. Is competent in one or more scientific disciplines | ☑ | ☑ | ☑ | ☑ | ☑ | |
| 2. Is competent in doing research | | | ☑ | ☑ | | |
| 3. Is competent in designing | | | ☑ | ☑ | | |
| 4. Has a scientific approach | ☑ | ☑ | ☑ | ☑ | | |
| 5. Possesses basic intellectual skills | | | ☑ | ☑ | ☑ | ☑ |
| 6. Is competent in co-operating and communicating | | | | | ☑ | ☑ |
| 7. Takes account of the temporal and the social context | | | | | ☑ | ☑ |

*Fig. 3 Preliminary mapping the FIRIS-P competency framework on the Meijer's criteria.*

### 3.3 Accreditation aspects

Of course, also with FIRIS-P aligned program intended learning outcomes our BME program should still meet the accreditation criteria, in our case the Meijer's criteria. In Fig. 3 is depicted how FIRIS-P core-competencies (preliminary mapping only, subcompetencies omitted for brevity) contribute to meeting the Meijer's criteria. All Meijer's criteria are covered by multiple FIRIS-P competencies, showing where these criteria are relevant in the BME profession.

### 3.4 Student's response

After explanation of the FIRIS-P framework and practicing with recognizing the competencies in the work of TechMed researchers, the students reported their self-reflections on each subcompetency of the FIRIS-P framework (see Fig. 4). Most students reported strong or moderate expertise on all subcompetences, as obtained during their preceeding BSc program. Some students reported subcompetencies on which they rated their expertise as (almost) 'none'. Similarly, the students reported varying ambitions to learn more and estimated importance of subcompetences for their future professional practice. Finally, the students reported the offered program content on each subcompetency as overall 'sufficient', but also expressed their need for more elaborate offer, e.g. on programming & automation and prototyping. It should be noted that the students reports may depend on the track they are following (not analysed here): For example, fundamental knowledge of chemistry is less prominent in tracks other than Bioengineering technologies (12 students), which might explain the reported lack of expertise, ambition and importance.

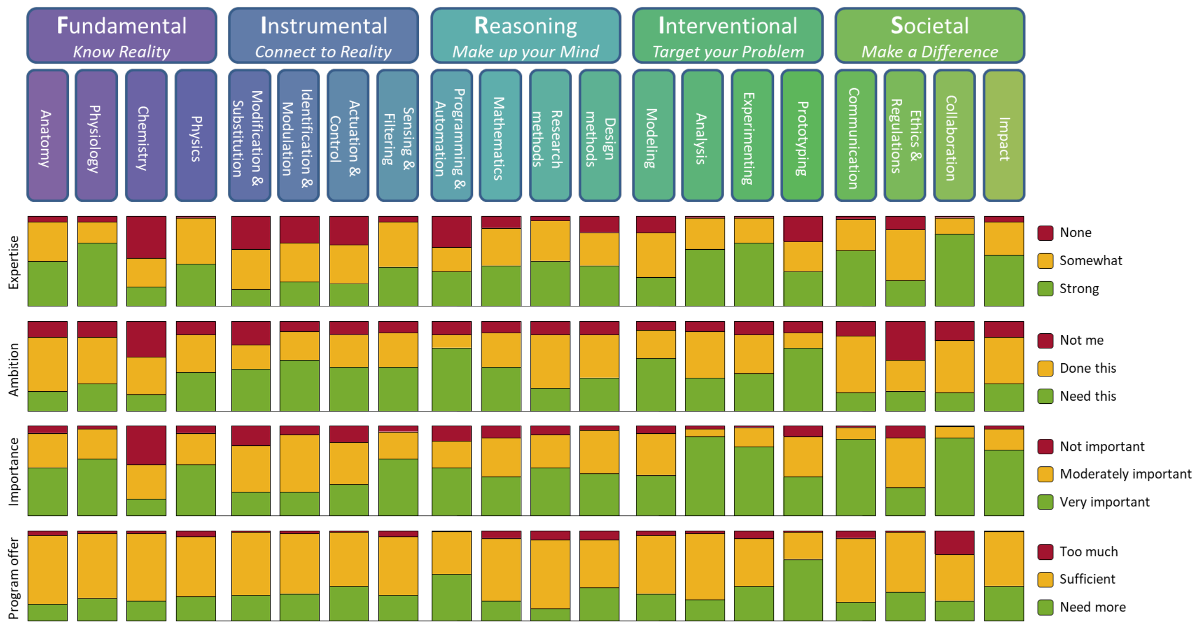


*Fig. 4 Student self-reflections using the FIRIS subcompetencies. For each subcompetency, 60 MSc-BME students reported their level of expertise, their ambition to learn more, the estimated importance in their future professional practice and the learning opportunities offered by the program or at our university.*

# 4 DISCUSSION

We aimed to formulate a novel competency framework that (1) reflects the identity and academic level of the interdisciplinary Biomedical Engineering (BME) profession, (2) permits the alignment of program intended learning outcomes that accommodate the content of the different specialisation tracks of the BME program and (3) guides students and staff by improved curriculum mapping and optimization. The resulting FIRIS-P framework and the preliminary validation we present here is stil work in progress, but can be of interest beyond the BME program for which FIRIS-P was developed.

## 4.1 Methodological aspects

We should note that the FIRIS-P framework is formulated in a local reflective process at our university. A direct benefit of this approach is the ownership of the formulations that arises with the staff contributing to the process, which enhances the teaching of FIRIS-P to students and – practice what you preach – supports being a role-model. Although the involved staff consists of active BME researchers operating in the entrepreneurial ecosystem of our university, the risk of being biased towards the content and identity of the BME professional practice cannot be fully excluded. Hence, it is recommended to validate and refine the FIRIS-P framework also with stakeholders from outside our direct ecosystem and the wider educational community. The initial validation steps we performed show some face validity concerning the connection to the BoKS of specialisation tracks, straightforward curriculum mapping and fulfilment of accreditation criteria. Furthermore a first impression of the instructional and guiding value of FIRIS-P for self-directed learning of students was obtained. As most of our students enter the Master BME after their BSc BME in our institute, many of them have made an informed choice for a specific specialization track during their 3rd year of the BSc program. This provides some level of understanding (e.g. Bloom’s: apply, SOLO: multistructural) needed for making FIRIS-P based formulations of their learning ambitions and matching these to the program offer. However, this level of understanding should be (and is, in the Technology for Health course) monitored and further increased by active engagement of the students and coaching by teachers and study advisors.

## 4.2 Merits of the FIRIS-P framework

In our view, a main improvement we reached with the FIRIS-P framework is the more role based clustering of competencies, i.e. a clustering that that more narratively reflects the way in which scientific and technological insights are employed for the benefit of society and that invites students to develop their personal professional narrative during their educational program and future lifelong learning career. The five-plus-one clustering of the FIRIS-P framework is likely to also allow formulation of the ‘professional narrative’ for other engineering, and perhaps even non-engineering academic programs: all (engineering) professions employ their fundamental knowledge and understanding of reality and instruments in reasoned way for impactful targeting of societal needs. If this is indeed the case, this might indicate that active awareness of the FIRIS-P structure might provide students and professionals with a cognitive structure that fosters interdisciplinary collaboration by providing students with a cognitive structure that facilitates the identification of their own disciplinary strengths using the FIRIS-P subtitles (see fig. 1) to find 'common grounds' with other disciplines (see also Claus and Wiese 2019).

## REFERENCES


Claus, A.M. and Wiese, B.S. 2019. *Development and test of a model of interdisciplinary competencies.* European Journal of Work and Organizational Psychology, 28:2, 191-205, DOI: 10.1080/1359432X.2019.1567491

Degré, A. and Colaux, C. 2016. Training engineers to meet the challenges of a changing world: how a competency framework improves teaching programs and team cohesion. In 8th Conference on Education engineering for sustainable development, edited by B. Mazijn. https://hdl.handle.net/2268/202079.

Lu, H., Yu, X. and Zhu, X. 2019. Research of the Engineering Competence Framework: Analysis Based on the Engineering Education Accreditation Criteria of 15 Countries. In Proceedings of the 2nd International Workshop on Education Reform and Social Sciences (ERSS 2019), 158-167. Atlantis Press. https://doi.org/10.2991/assehr.k.191206.032.

May, D. and Terkowsky, C.. 2014. What should they learn? A short comparison between different areas of competence and accreditation boards' criteria for engineering education. In 2014 IEEE Global Engineering Education Conference (EDUCON), Istanbul, Turkey, pp. 1046-1050, doi: 10.1109/EDUCON.2014.6826235.

Meijers, A. W. M., Borghuis, V. A. J., Mutsaers, E. J. P. J., Overveld, van, C. W. A. M., and Perrenet, J. C. 2005. Criteria for academic bachelor's and master's curricula. 2e, gew. dr. ed. Technische Universiteit Eindhoven, ISBN: 90-386-2217-1.