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**JUST ANOTHER TITLE?
MSC. HUMAN FACTORS ENGINEERING VERSUS SPORTS ENGINEERING**

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Abstract

Winter semester 2012 a new interdisciplinary study course *MSc. Human Factors Engineering* (HFE) has been started at TUM Munich School of Engineering. This four semester study course (120 ECTS) is open for graduates holding a bachelor's degree either in engineering science, natural science or humanities such as sports science or psychology. Sports Engineering is one of three possible focus areas the students can choose by selecting certain required and elective modules. We believe that the combination of Human Factors and Sports Engineering offers a reasonable supplement and a chance for more job opportunities for our graduates – not only in sports industry. The study course is furthermore evaluated in the context of a PhD thesis, with a focus on motivational aspects. The evaluation, based on interviews, a survey and the analysis of job advertisements, gives well-grounded indications for a further development of this Master program.

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1. The study course *Human Factors Engineering*

1.1. Intention and Targets of the Program

Winter semester 2012/13 the study course MSc. Human Factors Engineering (HFE) has been started at TUM Munich School of Engineering. Several other Departments like Informatics, Sports and Health Sciences, Architecture or Electrical and Computer Engineering are actively contributing to this study course. Like most courses at German public Universities no tuition fees are charged for this program and teaching language is German. This four semester study course corresponds to a work load of 120 points according to the European Credit Transfer System (ECTS) and it is open for graduates holding a bachelor's degree either in engineering science, computer science, natural science or humanities such as medicine, sports science or psychology (for more precise admission criteria see chapter 1.2). Students are trained in the interdisciplinary field of human factors engineering. At the end of the study program, students are able to design and evaluate human-machine-interfaces in different technical domains. Human factors specialists can find solutions to the seemingly opposing demands of socio-technical systems like performance, comfort, safety or reliability. Additionally graduates of the program are able to design the information flow and new forms of interaction concepts between users and technical systems. They can enhance the biomechanical and anthropometric design of workplaces in industrial production, but also of home and leisure time products (which certainly include sports equipment) or of automobile or airplane cockpits. Students learn the skills needed to succeed in academic or industrial research, production, safety management, or counselling.

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Besides “Sports Engineering” the students can also focus on “Anthropometry & Biomechanics” or “System Ergonomics & Interactional Design”.

The motivation to realize this study course has not been derived from observing any weaknesses in existing programs. On the contrary: The programs of Sheffield, Loughborough, Manchester (UK), Aalborg (Denmark), Östersund (Sweden), Delft (Netherlands), Magdeburg, Chemnitz, Cologne (Germany), Padua, Torino (Italy) and Vienna (Austria) – just to mention the bigger European programs – they all demonstrate great performance in their teaching and are successfully graduating sports engineers. To our experience however no more than approximately 20-30% of all of these graduates really end up in jobs in sporting goods industry. This approximation is not based on hard facts from longitudinal tracing studies but rather on personal communication with senior researchers and lecturers (one of them being responsible and familiar with Sheffield’s Master’s program). One possible reason for this is given by the observation that sporting goods industry is not as powerful in research & development (compared to other branches in industry) as its turn over might suggest. This statement could certainly be proven by a closer look at the workforce structure of sporting goods industry. To our knowledge no one has ever done that. But knowing the size of adidas’ innovation team at Germany’s headquarter in Herzogenaurach, counting 15-20 people only, it becomes clear, that the number of real R&D-jobs at sporting goods manufacturers is rather limited. A lot more jobs are offered in marketing or sales, but these do not require engineers.

Against this background we have finally decided to integrate Sports Engineering into a study course “Human Factors Engineering” following the intention to attract more students from different fields and secondly to offer them a wider range of job opportunities in branches like automotive, work space design, ergonomics. The scientific journal *Human Factors* (SAGE publisher: <http://hfs.sagepub.com/>) gives an impressive collection of topics related to this discipline showing the wideness of potential occupation fields:

... Table 1. Examples of topics in the field of Human Factors*)

Biomechanical models	Human error analysis
Workplace surveillance	Autonomous driving
Mental workload	Physical work, loading
Interface evaluation	Attentional processes
Robotics	Motivation
Usability testing and evaluation	Designing for the elderly
Sensory and perceptual processes	Environmental Design
*) Topics selected from document http://www.hfes.org/web/PubPages/TopicList-HumanFactorsJournal.pdf ; downloaded January 2016.	

From this overview it becomes obvious, that sports technology is a small subgroup of all those products and services that can be managed by HFE graduates. And it also reveals that a graduate of HFE may work in the design of sports technology but inversely a sports engineer would probably not be hired by the manufacturer of automobiles when it comes to improve the ergonomics of the work space at their assembly line. However: Because of this variety of topics, HFE requests an extended expertise in methods. For this reason we have decided for an interdisciplinary study course, which offers the engineers the opportunity to get an insight to the wide method spectrum of social science and especially to psychology. In return the students with psychology as their background will have to learn the basics of programming or biomechanics.

1.2. Admission criteria and assessment procedure

To apply for the study course, students have to hold a bachelor’s degree of at least six semesters in one of the above mentioned or equivalent disciplines. Further applicants must have passed exams (4 ECTS each) in three of the following six competence fields: mathematics, computer science, mechanics, cognition, research methods and construction. The teaching language in the study course is German, so German language skills at a high level are an important prerequisite to successfully complete the Master’s program. This is certainly one reason why only 9% of the students in this program come from abroad. Another reason might be that this study course is rather new and not yet known in other countries. The proportion of foreign students at Technical University of Munich is 22% (the majority of study courses being taught in German). So there is good reason to believe, that the rate of international students within HFE may increase over time.

The first step in the assessment procedure is the online-registration, including the upload of all relevant documents (high school diploma, undergraduate degree, a resume and a letter of motivation). In a second step, the grades obtained during the Bachelor’s program and the written documents are evaluated using a point system. Depending on the achieved number of points, applicants get an immediate admission, are rejected or invited to a 20 minute personal interview with one of the professors of the

study course. The interview helps to determine, if the applicant is capable of successfully completing the Master's program. After this talk, the applicants get a final decision about their admission.

1.3. Facts and Figures

Students can start the Master's program both in winter and summer semester. Like in most study courses there are more applicants for the winter than for the summer term. In the admission process for summer term 2016 the amount of 30 students has been admitted from a total of 83 applicants. In the preceding winter semester we have admitted $n=39$ students from 131 applicants. This difference in application and enrolment figures is due to tight selection process for that program.

Figure 1 shows the disciplines of entering students.

Overall there are actually 138 students registered in the program, the drop-out rate is 10%. Overall 57% of the students are female. Until summer semester 2015 $n=26$ students have successfully graduated from the program, which - according to the examination regulations - has to be completed within 6 semesters (3 years).

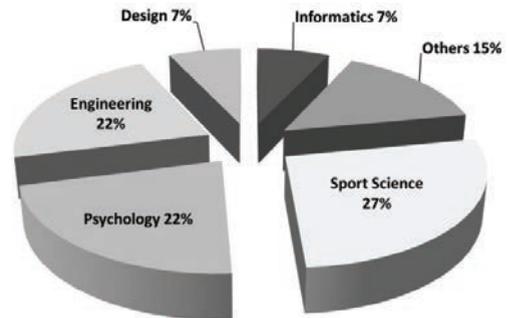


Fig. 1. Bachelor degrees of the students in the Master program *Human Factors Engineering* (state November 2015).

2. Structure of the Master program

The wide opportunities of working fields mentioned above are also represented in the modules the students can share in their curriculum. Some essential modules of the study course are illustrated in Fig.2. Depending on individual interests, students are free to choose own topics or to follow one of the three focus areas: "Sports Engineering", "Anthropometry & Biomechanics" or "System Ergonomics & Interactional Design". Besides a small number of compulsory modules like Ergonomics, Product Ergonomics, Design of Experiments & Statistics or Interdisciplinary Project (see 2.1.) there are wide options for the students to get a deeper insight into specific research fields by choosing elective modules.

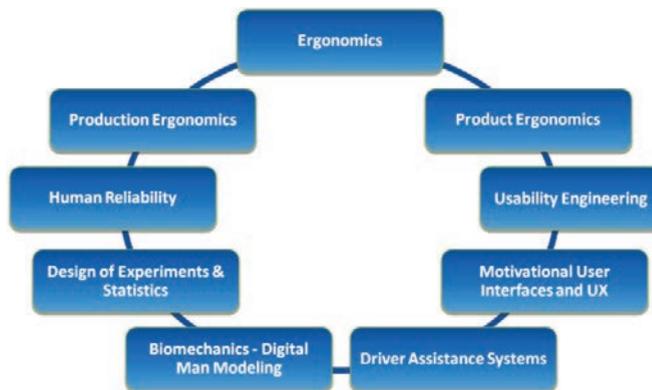


Fig. 2. Essential Modules in the Master's Program *Human Factors Engineering*

All students have to pass 34 ECTS in the required modules, 42 ECTS within the electives of group 1 and 14 ECTS within those of group 2. Whereas group 1 electives mainly provide modules linked to study courses in engineering sciences, group 2 electives contain courses from the cooperating TUM Departments and Schools, i.e. Introduction to Augmented Reality (Informatics), Performance Diagnostics (Sports- and Health Sciences), Industrial Design (Architecture), Advanced Topics in Marketing, Strategy & Leadership (School of Management) or Philosophy of Engineering Science (School of Education). This principle structure of the Master's program guarantees the students a very individual composition of their learning content and an exchange between different scientific "cultures".

2.1. The Interdisciplinary Project

Learning and experiencing interdisciplinarity is one of the major ideas behind our HFE study course. For this reason significant work load (10 ECTS) will have to be spent for what is called the “Interdisciplinary Project” (IDP). After having successfully passed this module, the students should be able to work as a team from different disciplines to solve a limited scientific problem within a defined time frame. As the teams are composed of students with different Bachelor degrees, they all have the chance to get insight to methods, which may not be familiar to them but are being explained and applied by their teammates. Through that they learn to combine methods from different disciplines and to find the best compromise with respect to scientific quality under economy and time restrictions.

Table 2. Examples of topics for the Interdisciplinary Project

Project title
Gesture control of truck infotainment systems
Feedback system for the surveillance of human body water loss
Quantification the support through an exoskeleton when lifting loads
Safety in scaffolding: Prevention of human errors
Evaluation of prism belay glasses for rock climbing

To leave the students room for their own refinement of the project, the research topic given to them is rather generally formulated. It is then to the team and their supervisor(s) to formulate precise research questions which take into consideration the available methods and the given time frame. Table 2 gives typical examples of such widely formulated research topics which need further precision. The project ends with a group presentation and a written group or individual report, both of them are scored.

2.2. Focus Area: Sports Engineering

Students who like to focus on products which are related to leisure and sports (and wish to have this mentioned in their Master’s supplement and their Transcript of Records) can select the focus area “Sports Engineering”. The required electives then include the same name module with a total work load of five ECTS. This teaching module is the continuation of the author’s course “Sports Technology”, which is mandatory within TUM Bachelor’s program “Sports Science”. The lectures in “Sports Engineering” extend the methodological knowledge and the understanding for science-based design, development and evaluation of sports equipment and materials. This includes topics such as strain gauge applications in sports, design of (sports specific) load cells, ice and snow tribology, basics of aero- and numerical fluid dynamics or manufacturing technologies of carbon fiber composites. The module also includes a project seminar (3.5 ECTS) called “Sport Technology Project” which is organized as a block course during the lecture intermission in March/April or July/August. As the subject of this block seminar is to get a practical oriented insight in sport technology related field experiments, it perfectly fits into the mission of the International Sports Engineering Association (isea) winter/summer schools. For that reason the study course in winter semester is partly integrated into the isea *winterschool*. To prepare for this, some seminar units are used to define concrete project goals, to build, organize and learn the required measurement technology and think about possible test protocols. At the winter school, the Munich HFE-students are usually mixed with students from other universities to form an international team. Due to the special requirements and difficulties with experiments in the field of snow sports (i.e. the big observation space, temperature and humidity problems with the measurement equipment, standardization problems) conducting measurements may be rather challenging. By this however, the students learn to deal with difficult boundary conditions and to find compromises w.r.t to practicability and scientific quality. Usually isea *winterschool* is finished with a plenary team presentation of each group’s project. After winterschool the students have several more weeks to further work on their collected data and on an official presentation, which is then scored to form a common grading with a written exam in “Sports Engineering”.

3. Evaluation

The evaluation of the program will be part of a Ph.D dissertation. The focus is set on motivational aspects, using the model of Prenzel [1], which is closely related to motivation theory established by Deci & Ryan [2]. In addition to aspects such as perceived autonomy support, competence support and social relatedness, the relevance of learning content and the strategic orientation of the program are analyzed. Initially, the students will be interviewed and a survey with all students, an analysis of job advertisements in the field of Human Factors and, finally, a survey with graduates who recently started their professional life are planned.

3.1. Survey

A survey (N = 87) conducted among active students, aimed at reasons for study choice, study conditions, the satisfaction with the selectable modules, but also the estimated career prospects. For a considerable number of students the program is interesting because it offers a variety of career options for graduates. 67% of students express that this fact is “rather important” to “very

important” to them. Compared with general data from study courses at universities in Germany (48%) this value is rather high [3]. For more than half of the students the prospects for stable employment and income opportunities were important factors, this is similar to the findings of the study mentioned above. However, the main motivation for the study choice is the interest in the subject and the own abilities (for more than 80% of the students, this aspect was “important” to “very important”). Most of the students got in contact with the subject of Human Factors for the first time during their Bachelor's degree program. Regardless of the field of the Bachelor's degree, students expressed on a five-point scale, that it is possible to arrange the study according to their own ideas and interests (mean: 3.6) and to deal with topics of interest in greater detail (mean: 3.6). When asked what the key characteristic of this course is (out of seven stages: from 0 = “not at all” to 6 = “very strong”), the students especially appreciated the interdisciplinary nature of the program (mean: 4.8) and the extensive collaboration with other students (mean: 4.1); the practical relevance is rated 3.1. Although the preparation for the professional life is rated rather negatively (mean: 2.4), the students are in principle optimistic for their later professional life. Only 5% of surveyed students believe that they will have difficulties finding a job after graduating. Compared with findings from university graduates in the field of engineering (2%), this value is slightly higher [3] In contrast, 23% believe that they will find a job without any problems, this value is lower than the average (35%) of university graduates (ibid.). 42% fear that it will be difficult to find a job that really suits them and 20% suspect that it will be difficult to find a job that corresponds to the education they received in the study course. Students with a study focus on Sports Engineering think their career opportunities tend to be a little worse. The overall study situation is rated positively by the students.

3.2. Content Analysis of Job Advertisements

A second study is currently performed with the method of content analysis, focusing on the evaluation of jobs in the field of human factors. This allows better assessment which skills of graduates are expected by companies (programming languages, soft skills etc.), while at the same time more information about potential employers can be obtained. By using 43 keywords related to Human Factors Engineering, we generated more than 300 jobs over the online portal StepStone. After a first screening, 105 jobs, suitable for our graduates as a first job, remain for a detailed analysis. It turned out that this large number of jobs was achieved due to the searches usability, user research, user interface and interface design. The content analysis refers to different aspects of the job such as: company type, number of employees, industry, job duties, required education, soft skills, language skills and, finally, company offers (flat hierarchies, training, etc.). During the observed period no jobs were found by this search in the field of sports technology and sports engineering. Possibly, the requirements for these jobs are too specialized for job portals. In order to investigate this further, a second search strategy will be set up. The jobs will not be searched via a job portal, but directly on the homepages of potential companies and employers.

4. Comparable Study Programs and Experiences Made

In Germany a total of 15.000 study courses exist at different kind of colleges and universities. According to the database of the Federal Statistical Office (Statistisches Bundesamt), in winter semester 2014/15 433,000 students have started an education program at one of these institutions with a total of 2.7 Million under studies in the same time. With these numbers it seems surprising that besides TUM there are only two other Universities in Germany (University of Berlin and University of Applied Sciences Niederrhein) which currently offer a study course in Human Factors Engineering. To the authors' knowledge no study courses entitled “Human Factors Engineering” or “Human Factors and Engineering” are offered by other European universities (but there are many study programs with “ergonomics” in the title). This lack is even more astonishing if we compare this to the offer in the US: The US-American *Human Factors and Ergonomics Society* (HFES) lists 17 undergraduate programs and 73 graduate programs (17 of which being accredited by HFES).

Looking at the definition of Human Factors / Ergonomics as adopted by the International Ergonomics Association in August 2000:

“Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and other methods to design in order to optimize human well-being and overall system performance.”

it becomes clear, that this statement is including any kind of sport equipment and sports technology. For this reason, the introduction of Human Factors Engineering instead of a study course in Sports Engineering seems more an extension than a restriction of opportunities.

Even though the background of our students entering our Master's program may be rather inhomogeneous, the participants have been able to level out knowledge deficits and to adopt expertise from new disciplines. It is essential however to provide extra preparatory courses, additional exercises and tutorials to make this process of knowledge transfer possible.

In summary we can give a completely positive report of our three years' experience with this study course and the individual feedback of our students is motivating us to maintain this program.

5. Conclusion

In conclusion we like to propose two steps to be considered by those in charge of sports engineering education programs:

1. It is essential to carefully observe the potential market for sports engineers and adapt the number of graduates accordingly. This however needs standardized longer-termed tracing studies, which could be organized under the leadership of the international sports engineering association (isea).
2. The content of sports engineering programs should not focus on sport equipment and materials only but also demonstrate the applicability of those methods in other fields such as ergonomics or works space design.

References

- [1] Prenzel M. Bedingungen für selbstbestimmt motiviertes und interessiertes Lernen im Studium. In: Joachim Lompscher und Heinz Mandl (Hg.): Lehr- und Lernprobleme im Studium. Bedingungen und Veränderungsmöglichkeiten. Bern: Huber. 1996. p. 11–22.
- [2] Deci EL, Ryan RM. Die Selbstbestimmungstheorie der Motivation und ihre Bedeutung für die Pädagogik. In: Zeitschrift für Pädagogik 1993; 39 p. 223–238.
- [3] Ramm M, Multrus F, Bargel T, Schmidt M. Studiensituation und studentische Orientierungen. 12. Studierendensurvey an Universitäten und Fachhochschulen. Bonn/Berlin: Bundesministerium für Bildung und Forschung. 2014.