A material science course based on a blended learning concept using an interdisciplinary approach at HTW Berlin

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Abstract: *The paper introduces the necessity and the ongoing activities to establish an interdisciplinary concept to teach materials science at the applied university HTW Berlin. Mechanical engineering students in their first year as well as students studying technology, renewable energy, microsystems technology, textile technology or industrial design may benefit from standard course contents offering and guaranteeing high quality teaching standards. Interdisciplinary teaching will be a lot easier when new courses can be based on common knowledge of material science. Currently we are establishing a specific "moodle"-based course that offers micro modules of lectures to individually choose and combine for the different purposes. These lectures and materials may be used to invert the classroom and use blended learning methods. The work with the micro modules will enable students to comprehend the principle of different aspects in material science. Self-testing and exercises allow students to check on their learning progress and it may also be used to assess their knowledge in class.*

Key words: *interdisciplinary approach, micro modules, material science, blended learning.*

INTRODUCTION

Material Science is taught as a compulsory course in various undergraduate and some graduate study subjects at HTW Berlin. Altogether there are 15 subjects of study that demand materials science in either their first year bachelor or first year master. These are for example the engineering fields of study: Mechanical -, Automotive-, Electrical -, Renewable Energy -, Civil -, Textile - and Life Science Engineering as well as Microsystems Technology. But there exist also a number of study subjects comprising design and cultural studies, such as: Textile Engineering, Industrial Design, Conservation and Restoration and Museology.

There is a pressing demand for interdisciplinary and project-based teaching, where students from different study subjects work on solving complex projects using and applying their scientific knowledge that they gained during earlier studies. Teams work a lot better if there is a common knowledge of material science which has not been agreed on up to now at HTW Berlin. One of our great challenges - at the same time a huge benefit - at HTW Berlin is that our students enroll into university come from a big variety of educational backgrounds. For example, students begin their education right after high school and "Abitur" or they may have had a practical education on the job and worked for at least 4 years before entering HTW Berlin. Over a thousand of our students come from different countries with different study skills and habits. Material Science in general is not the subject students love when studying mechanical engineering, because other than chemistry, mathematics or physics, that are well-known from high school, material science is completely new to first-year students. Here, the diversity in previous knowledge is great: e.g. some students already know "phase diagrams", others have never heard of "mechanical stress".

Therefore we found it necessary to establish a diversified material science course basically addressing first-year students in a bachelor program of mechanical engineering, economical engineering and automotive engineering that allows for individual teaching, combining subjects that may easily be expanded any time. Once introduced to the students the course has to be available with no regard to place and time. Later we found it very useful to offer the course material to all of the lecturers teaching material science in different study subjects to guarantee a similar "state of the art" when student intermix from different subjects and benefit from colleagues willing to contribute to the HTW material science course. This peer reviewing [1,2] allows for high teaching standards and gives all colleagues at HTW Berlin the possibility to resort to materials science background provided by the HTW material science course. Because the concept applies well for

present teaching there is a need to establish an e-learning course at the same time, aimed to be used in different settings and in different learning programs.

To meet these requirements a moodle-based course for teaching material science was established at the Applied University HTW Berlin during the last 5 years [3].

TEACHING APPROACH

The material science course is based on the "design-led" teaching approach (figure 1) by Professor Mike Ashby developed and applied over 20 years with colleagues at Cambridge and collaborating universities [4,5]. The motivation to establish this route at HTW Berlin -especially in the first year of studying- was to involve students right from the beginning of their studies with the question 'What is the objective of the design? Students begin to investigate and learn with a strong practical motive and critically discuss materials, properties, alternative materials and processes as well as the underlying physics and chemistry. In the conventional "science-led" teaching approach *begins* with the physics and chemistry of materials. It progresses from the atomistic through the microstructure to the macroscopic properties. As a consequence the motivation by the challenges of the design is often lost. Still, it is necessary to understand the theory of material science, but the teaching goal should be to educate students and prepare them for their role as a maker of things [2]. This concept appeals to bachelor students in their first year as well as to master students, not introduced to materials science yet.

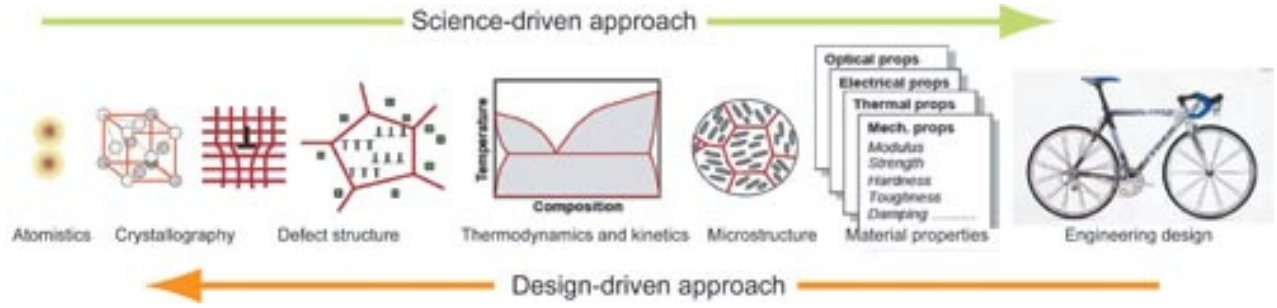

Fig. 1: „science-led-approach" and „design-led-approach" [2]

Therefore it is necessary to provide different learning material, appealing to as many students as possible. This is done via the open source content management system "moodle". Small and focused lectures that include exercises for self-testing and course testing build the main frame of the course. These are called *micro module lectures* and are explained in detail later. Mindmaps summarize the content of the *micro module lectures*, that cover the most important parts of the issues and are combined with films, film demonstrations [6] and self-test questions throughout the lectures. Web Based Trainings (WBTs) offer individual learning and separate film demonstrations enhance memorizing and understanding. Short course mindmaps aim at memorizing of technical terms and understanding the correlation of the micro modules. Self-tests as well as assignments with worked solutions allow students to control their learning progress and allow the lecturer to assess skills and knowledge. Basically the following materials are provided on the "moodle" platform to be individually chosen and compiled in "blended learning" and "inverted classroom" scenarios:

- *Micro module lectures* intermixed with problems and worked solutions
- Worksheets and worked solutions
- Lecture videos (actual semester)
- Teaching videos (from various material science databases and specially produced (peer to peer) for teaching material science at HTW Berlin)

- Lecture slides
- Scriptum for printing out to get an overview on the material science course
- Mindmaps
- Linked mindmaps as roadmaps for each topic
- Memory sheets to memorize most important aspects
- Online tests (for self-testing and assessing through lecturer)
- Web based trainings WBT (corrosion, iron-carbide phase diagram, etc.)
- Glossary of terms (provided by lecturer and students)
- Wikis for presenting and working on team tasks
- Chats and forum for communication

MICROMODULES IN A MOODLE BASED ONLINE COURSE

In general material science learning material covers bigger sections including different aspects that are explained in the lectures taking one step after another introducing the science-led approach [7-10]. Ashby and Jones [11,12] provide a textbook where one chapter introduces one possible lecture, still presuming contents of previous chapters. "Materials" [4] is completely design-led, also enabling to teach one chapter in one lecture –and unique– without presuming knowledge from previous chapters. This very much appeals to the authors when establishing a course that may be taught by many different lecturers teaching material science in different study contexts.

Throughout selecting themes and topics we found it very helpful for students to divide the topics into very small units, now called *micro modul lectures* or *micro modules [13]* (figure 2).

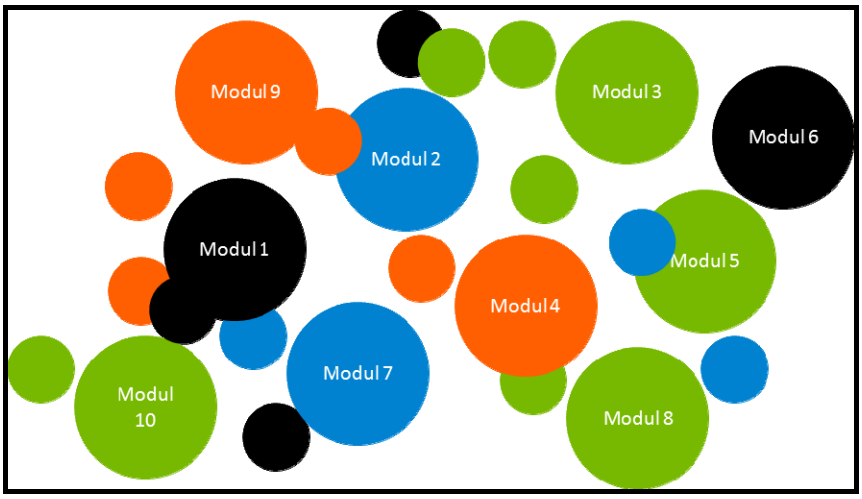

Fig. 2: Micro modules in material science course at HTW

These cover only very small aspects, have very precise titles and summarize the most important issues, allowing self-studying and repeating class lectures. Most important is that these micro modules stand alone, e.g. each module may be taught in different teaching settings with no regard to previous lectures. Sometimes it was necessary to include repetitions, but most of the time the modules may be used single without any introduction. For instance iron and steel usually covers 3 to 4 topics including processing of iron, structure and microstructure, heat treatment and steel qualities [7-12]. Our micro modules have been broken down to 13 micro modules to be individually chosen from. Hardening, for example, may be covered in a lecture without knowledge about annealing

or without knowledge about phase-diagrams, TTT-diagrams, nomenclature or general microstructure. Also, homework assignments and distant learning is very easy using these micro modules, especially when the lecturer does not follow a precise teaching order.

Core of the course concept is that lecturers can choose and individually compile the micro modules as they are based on the specific topics of their courses (figure 3).

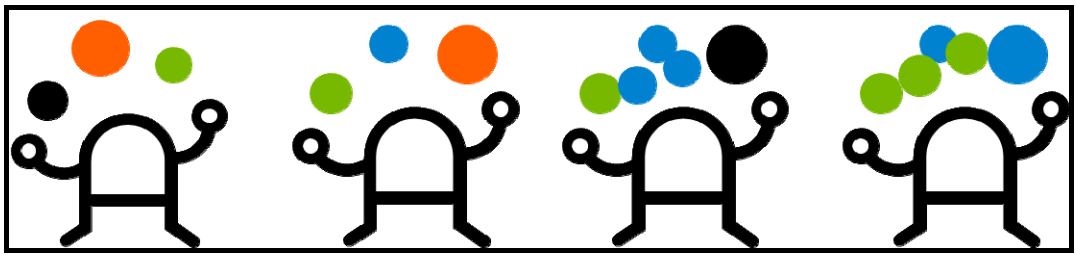

Fig. 3: Individual extraction and compilation of micro modules in material science course at HTW Berlin

Therefore many different topics are covered up to now and will be covered in future always assuring for small *micro module lectures*, mindmaps and tests to give good overviews and guidance for lecturers as well for students. The concept is proved to be successful in present teaching but even more successful in blended learning as well as distant teaching scenarios where the micro modules can be chosen and combined following the demands of the course. The compilation of the moodle-course is based on lectures of materials science and students' works.

LEARNING ACTIVITIES AND EVALUATION

The structure of the course enables lecturers from different fields of studies to pick and skillfully combine lectures even from different head topics, such as "iron and steel" in combination with "strength and ductility". The course is suitable for present and blended learning scenarios and when flipping the classroom [21,22]. In modern learning problem solving is the main focus, but in materials science this can only be managed with profound knowledge on the scientific background and interrelation of microstructure, materials behavior and mechanical parameters. Micro modules enable students to memorize especially those facts necessary to solve problems that cover various aspects of material science. Class results indicate that involving students directly into teaching activities can be very effective in getting students to engage in critical thinking [14,15]; thus, producing deeper learning outcomes [16,17]. Therefore students` projects aim at special topic micro modules, lecture film production [6], glossaries and mindmaps. Blended learning scenarios now allow time in class for well-known teaching methods, such as: "think pair share", peer instruction [18], reciprocal peer tutoring [19] or undergraduate teaching assistance [20]. These learning activities along with the introduction of the micro modules were applied in class.

But overall students enjoyed working on projects in class being able to dispose their material science knowledge gained from micro modules and various teaching material. These projects were established replacing traditional lectures, since this knowledge was assigned to self-studying. Lecturers got an overview of the student`s knowledge using the open-source software "invote" [19,23] for peer reviewing simultaneously allowing the students to assess their learning progress. Questions were answered and important issues individually explained. Those students, who were not able to work properly at home, got different assignments, to ensure that all students start to work on problems at nearly the same level of scientific knowledge. Later all students were intermixed and asked to prepare their results and briefly present these in front of the class as well as hand in a one-page precise summary.

This concept was applied first in spring semester 2015. Therefore up to today there is no data with statistical significance available evaluating the students` learning outcome. We were surprised by the quality of the work the students accomplished at home and presented during projects, in discussions or in hands-on lessons. Moreover all of the students worked seriously in class to achieve best results. For example: during the summer semester in 2015 we got better results when students were to prepare lectures, watch introductory films and do homework exercises prior to the lab courses [24]. Also the fun of learning was dramatically increased, as students in their first semester got to know each other a lot better than before.

CONCLUSIONS AND FUTURE WORK

At HTW Berlin an interdisciplinary highly flexible concept to teach materials science in different study subjects is being established and steadily continued. Moodle was chosen as the suitable content management system to provide small, stand-alone lectures, so called *micro modules*. The contents of the course may be individually chosen and compiled for mechanical engineering students in their first year as well as students studying technology, renewable energy, microsystems technology, textile technology or industrial design. Interdisciplinary teaching will become easier when a standard level of scientific background knowledge is provided and used throughout several classes. This HTW-concept will provide high-quality teaching standards and allow teaching students from different backgrounds with different initial knowledge, because the variety of teaching materials will approach each student individually. In the future we hope to convince as many lecturers from HTW as possible to contribute to this model course and use the teaching resources made available. Long term objective in the future is that eventually colleagues using the modules will provide special topics to complement the course.

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The paper has been reviewed.