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Inverting the Classroom in an Introductory Material Science Course

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Abstract

Inverting the classroom in material science is a method to let students study the science of engineering materials on their own and then take time to discuss their questions and do extended hands-on lectures or exercises in class. A sufficient number and variety of teaching materials aims at different learning skills of the students and meets the diversity of a first year class. Therefore teaching materials and micro-module lectures to individually chose, combine and study from a distance are provided in a newly established moodle-based course. Along with exercises and worked solutions, students can check their learning progress via self-testing. Peer instruction (Simon et al., 2010) is used to assess the learning progress prior to each class. In blended-learning scenarios students use different materials to study and understand the science in theory and then the classroom lectures offer the opportunity for students to comprehend the principle of different aspects in material science and apply their knowledge. Not all of the themes taught the first semester are suitable to apply the inverted classroom approach, but it has been proven to be successful and increase the fun of teaching throughout the first year.

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Keywords: inverted classroom; flipped classroom; blended learning; lecture films; peer-to-peer; first year student.

1. Introduction

Starting in winter semester 2014/15 the first semester material science has to be passed as a course, but the grades are not included into the bachelor`s degree for mechanical and automotive engineering at HTW Berlin (BerlHG, 2016). This challenges the lecturer, because he or she will face a number of students only interested in

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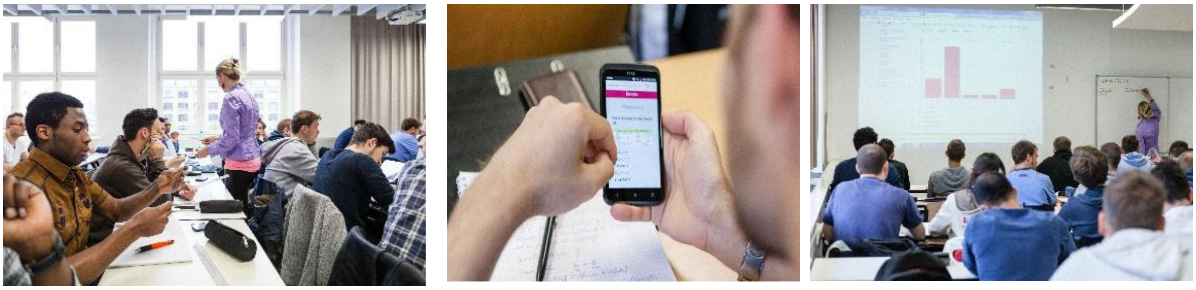
passing rather than learning about the important basics required to pass the second semester or the compulsive laboratory courses. Inverting the classroom (Berret, 2012), (Brame, 2015), (Fischer and Spannagel, 2012), (Braun et al., 2012) seemed to be the appropriate medium to gain student`s attention, motivate them right from the start to continuously study and acquire good exam results assuring each to easily pass the graded exam the second semester.

The flipped classroom constitutes a role change for instructors, who give up their front-of-the-class position in favour of a more collaborative and cooperative contribution to the teaching process. …The flipped model puts more of the responsibility for learning on the shoulders of students…. Activities can be student-led, and communication among students can become the determining dynamic of a session devoted to learning through hands-on work. What the flip does particularly well is to bring about a distinctive shift in priorities— from merely covering material to working toward mastery of it (Educause, 2016).

Moreover students got to know each other much better, were fond of the course, found materials science entertaining and had personal success when understanding complicated contents. The quality of the work comprised in class was successfully high with students working seriously on their tasks resulting in better grades than the previous semester. Lectures are the appropriate platform to exercise, ask questions and discuss matters with student colleagues and lecturers. Methods such as "Think-pair-share" or "peer instruction" (Simon et al., 2010) via the open-source "invote" program (www.invote.de, (invote (2016)) work very well to get a quick overview of students` state of knowledge before questions are answered and students begin working on their assignments (group, pair, single) (Fig. 1).



"think-pair-share" (Pfennig, 2015), (Simon et al., 2010) | peer instruction (Simon et al., 2010), "invote" (Pfennig, 2015) | answering questions

Fig. 1. Students` learning session in class after preparing scientific backgrounds at home.

2. Concept of inverting the classroom in materials science

During summer semester 2015 we got very good results when students were to prepare lectures, watch introductory films (OLP, 2016) and do homework exercises prior to the lecture in presence. An important issue of the concept is, that the students were able to study individually, self-directed, location-independent, asynchronously and according to their individual tempo. In class we had time to discuss problems, work on exercises and engineering related problems, share difficulties and thoughts with classmates and especially experience that the background information (self-taught at home) delivered a great deal of understanding of the correlation between materials properties and microstructure. Study materials are:

- Micro module lectures intermixed with problems and worked solutions
- Worksheets and worked solutions
- Lecture videos (actual semester) and teaching videos (Pfennig and Hadwiger, 2015)
- (interactive) Mindmaps
- Memory sheets to memorize most important aspects
- Online tests (for self-testing and assessing through lecturer)

The material science course for first year mechanical engineering students at HTW Berlin is taught via the "design-led" teaching approach (excelLus, 2015), (Fig. 2). In contrast to the conventional "science-led" teaching approach that begins with the physics and chemistry of materials, progressing from the atomistic through the microstructure to the macroscopic properties (Ashby et al., 2013), the design led approach starts with the needs of the design and then explains why and how properties can be influenced and changed.

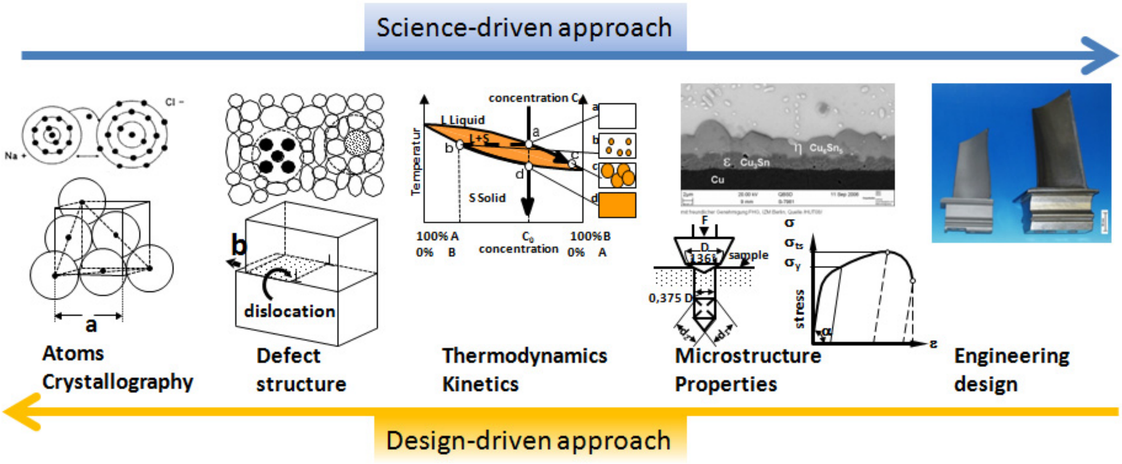


Fig. 2. "science-led-approach" and "design-led-approach", adopted from (Ashby et al., 2013).

2.1. *PRACTICE EXAMPLE 1: Introducing microstructure the first day*

Microstructures are essential to get a fundamental understanding of materials` properties. Therefore easy lectures introducing engineering materials, components and their microstructures were given as homework assignment prior to the first lecture in class. Along with the microstructures the most important properties had to be summarized into given templates, building basically on high school knowledge. Each student then was asked to bring one favorite material the first day. These materials were introduced and the students talked about the materials history and why they chose this component – this also being a method of getting to know each other. The class was given several typical viewgraphs of microstructures and had to match these with the components (Fig. 3) and describe what they thought was characteristic about the microstructure. During the course it was easier for the lecturer to talk about microstructure in any context, because students remembered and combined quickly.

Fig. 3. Matching microstructure and component the very first day of materials science (microstructures: left and middle: (metallograph, 2013) right: (Schumann, 1990), pictures: (Ashby et al., 2013), (CES, 2013).

2.2. PRACTICE EXAMPLE 2: Hardening mechanisms

The scientific background of the four hardening mechanisms in materials science generating changes in microstructure in order to increase the strength of materials was given as homework (moodle-lecture, memory sheets and voluntarily reading of a simple and short scientific research paper). Along with the online lectures questions and tests had to be taken and one specific technical term had to be explained in a topic related glossary. This was commented and corrected by the lecturer in the week of the homework assignment.

In class the open-source software “invote” (invote, 2016) was used for peer reviewing (Simon et al., 2010), giving the lecturer an overview of the student`s knowledge. This also helped students to assess their learning progress. Questions were answered and important issues individually explained. Then students were divided into groups with 4-6 students each. A special template had to be used to summarize one of the 4 mechanisms, including: microstructural changes and impact on mechanical properties. To make sure all students had nearly the same level of scientific knowledge; students who were not able to work properly at home got different, more basic assignments and were then later intermixed with groups doing the hands on lessons on hardening mechanisms. All students were then asked to prepare their results and briefly present these in front of the class as well as hand in a one page precise summary. These summaries were reviewed by the class and lecturer and uploaded in moodle to be available to all students. Then 2 engineering problems focusing on increasing strength in steels were solved in groups of two students each. Testing the following week proved good understanding and delivered better results than obtained the previous semester.

2.3. PRACTICE EXAMPLE 3: Phase Diagrams

To engage students into practical work and team assignments where they have to use their knowledge rather than to listen and memorize during class was proved to be successful when studying phase diagrams. Lectures were assigned as films via "moodle" (Fig. 4).

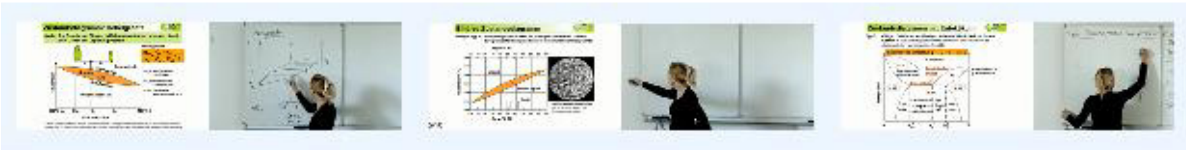


Fig. 4. Lecture films: phase diagrams (9 lecture films) (2:35 hours), (https://www.youtube.com/playlist?list=PLUOlZMSZYz5zha5EbwAKrQ8w8W65ST3fN)

In class students were divided into groups of 4. 15 assignments of different levels were categorized into: A) pass the class, B) pass with C or B, C) pass with A or even better. The students were asked to choose as they felt comfortable. Advantage of teaching small groups was that individual problems were solved and questions of different levels were answered by talking to the students in person and meeting her or his needs.

A compulsory test had to be taken via "moodle" ending the following week and results showed clearly that students had a much better understanding how to practically work with phase diagrams and related problems compared to results of the end of term exam the previous semester. 45% of the students scored very good or excellent (Fig. 5).

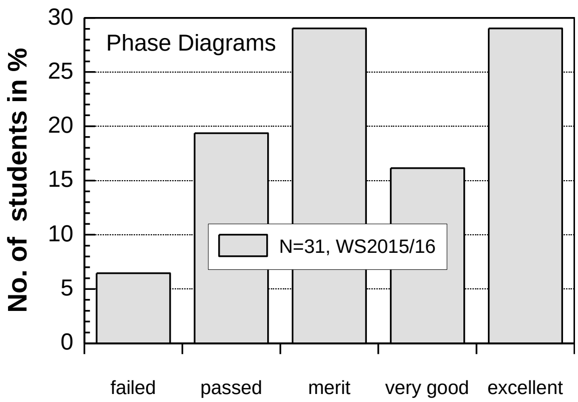


Fig. 5. Results of compulsory online exam on phase diagrams.

3. Evaluation

3.1. Advantages

Because this classroom scenario has been implemented starting summer semester 2015 no significant quantitative measures, such as overall grades or reliable questionnaires, are available yet. But, as many other authors state class results indicate that giving students more responsibility for their learning progress is effective in getting students to engage in critical thinking (CSU, 2015), (Lord, 2012); thus, producing deeper learning outcomes (Goto and Schneider, 2010), (Simon et al., 2010). Lecturers had a better overview on the progress of the class and were able to help and give advice where necessary. The atmosphere in class was very pleasant and students seemed to have fun experiencing and finding their newly gained knowledge useful to find solutions to material science problems.

Especially working with small groups and teaching individually is of great advantage because not only explanations meet the students' needs, but they feel addressed more personally and were therefore more motivated to work on assignments. Lecturers will teach lively students eager to dispose their knowledge and learn more of the details, share their knowledge helping others and contributing to solving problems.

3.2. Disadvantages

The preparation time of the lectures and the teaching material is outrageous and does not compare to conventional lectures. Students who are not willing to study at home will be lost in the long run, first because of lack of background knowledge, second because they are not able to contribute to group or class work or work on assignments independently. Therefore it is always necessary to prepare teaching and learning material involving these students during the lecture and to help them catch up missing information. This also results in more work ahead of the lecture and may demotivate those students that are well prepared.

3.3. Students` opinion

Since this concept has only been applied starting in April 2015 there is little results from evaluation available. The students` evaluation forms are still under survey at the moment of writing this paper. However first opinions are that the course requires an "awful lot of work", which has not changed compared to classes taught earlier, but now the work has to be done during the course and not towards the end with exams following closely. Students participating in the inverted classroom session on phase diagrams rated the lecture films as good to excellent, because of good, slow and repeatable explanations as a very good method to prepare for hand-on exercises and transfer methods in class. Students also found themselves addresses personally and had no problem to follow as they did not have to copy lecture notes and try to understand complicated routines the same time. Most of them watched the lectures on one day, intensively preparing for the next lecture and asked for more lecture films followed by practical lecture sessions especially on the topics "iron carbon phase diagram" and "materials testing". Starting with 41 (second semester) and 55 students (first semester) approximately 26-32 and 42 were present until the end of the semester, who were still very eager to work and gain knowledge. Those present stated that although it is a lot to learn and a very theoretical subject the different learning materials enhanced their learning progress and joy of studying and led to a more homogeneous study atmosphere during class.

4. Conclusion and future work

For the first time the inverted classroom technique was introduced to first year mechanical engineering students enrolled in a material science course. Therefore micro moodle-based online lectures, films, screen casts, lecture slides and various teaching material were provided along with a distinct assignment for one week and regular graded tests and assignments. In class the students focused on discussing scientific backgrounds and solving hands-on engineering problems in groups of 2 to 4 students. Inverting the classroom involved students to take over the responsibility for their own learning process and the method was assessed as beneficial in terms of student grades, concentration and attentiveness as well as joy of studying. Still, evaluation over a long period of time has to prove in future, if this concept will enhance students` material science skills and grades in general.

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