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10 years thermoE - A survey of the online-based support of the basic lecture thermodynamics

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Abstract

Thermodynamik ist ein zentrales Fach in der Ausbildung von Maschinenbauern sowohl im Grund- als auch im Fachstudium. Besonders im Grundstudium ergeben sich besondere Herausforderungen: Heterogenität der Vorkenntnisse der Studierenden, hohe Teilnehmerzahlen in der Vorlesung, rigide Modulvorschriften ohne Berücksichtigung von Praktika und begrenzte Anzahl von wissenschaftlichen Assistenten für die Betreuung. Vor diesem Hintergrund wurde seit 2012 eine online-basierte Begleitung der Vorlesung und der Übungen erarbeitet, die mit Stand heute neben der Unterstützung des Selbststudiums durch E-Assessment mit Feedback-Funktion auch virtuelle Praktikumsversuche, ein barrierefreies Vorlesungsskript sowie eine online-Klausur umfassen. Für Studierende, die dieses Angebot konsequent nutzen, ist ein signifikant besserer Abschluss der Klausur zu beobachten. Anhand ausgewählter Beispiele soll hier das mittlerweile auch in allen anderen Vorlesungen der Professur etablierte Vorgehen einer online-basierten und kompetenzorientierten Vorlesungsbegleitung gezeigt werden.

Thermodynamics as basic subject for mechanical engineers faces certain challenges due to the heterogeneity of students, a high number of lecture participants, a rigid syllabus without consideration of practical training as well as a limited number of teaching staff. Therefore, an online-based teaching tool has been developed since 2012, which comprises up to now a feedback-controlled e-assessment, virtual practical courses, a barrier-free lecture script and an online final test. A consequent use of the assessment during the semester by students resulted in improved marks in written exams and less student fail. Some selected examples are presented here, which are representative for the general approach of the chair to provide online-based and skill-oriented lectures using all digitally possible tools.

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1. Motivation

Technical thermodynamics is a central subject in the basic training of mechanical engineering and is currently located in the third semester of the mechanical engineering curriculum at the TU Dresden. At this early stage of the studies, most of the first-year students are still enrolled and possess very different previous knowledge. This heterogeneity of the mechanical engineering students is additionally increased by the participation of students from other study subjects, such as regenerative energy systems, process engineering and teaching (different subject combinations). This results in a large number of differently motivated students, who have to be supervised by a limited number of academic staff. In addition to lectures, this supervision includes weekly exercises and the examination at the end of the semester (which could not be offered online until 2021 due to a lack of legal foundations, although it would have been possible). Thus, there is an enormous supervision effort during the semester in the exercises and a very high time requirement for the control of the written exams, so that especially at the end of the semester almost all academic staff members are blocked for the control of the exams. Furthermore, in a module plan regulated by credit points (and thus the available semester hours) as well as by historically entrenched structures in the course of studies, no practical courses are provided for thermodynamics. If one compares this constellation for thermodynamics to other universities, including engineering universities, problems become manifest on several levels. Exercises, which mostly consist of calculational tasks, can no longer be collected and individually controlled on a weekly basis due to the high control effort in this constellation, which precludes goal-oriented supervision. Experiences from a topic-appropriate practical course cannot be incorporated into the understanding of lectures and exercises. The large number of weekly group exercises with an increased number of participants reinforces subjective differences, which are introduced into the exercises by individual instructors. This has been proven to hinder weaker students in their learning process, as they are often excluded from becoming active in the exercises. There was a need for action here, and since 2012 this has led to the creation of thermoE and other teaching projects at the chair.

2. Targets

The development of a computer-based learning system is, just like the analog so-called "classical" teaching, a dynamic process, which should permanently question itself, grow with the respective circumstances, thereby develop further and remain alive.

While at the beginning the creation of an online-based exam was in the foreground at the chair, a completely semester-accompanying e-assessment soon came to the fore. The background to this decision of neglecting online exams was the lack of administrative support, as online exam formats require legal frameworks that were outside the professors' own responsibility.

With the focus on a computer-based format for the exercises (and for the exam), the following technical questions arose. Is it possible to transform mathematically based questions into a digital format? How can self-study tasks and potential exam questions ensure a competency-based performance review in the exam? How can the heterogeneity of students be taken into account and thus enable an individual learning process? How can the schedule of the e-assessment tasks adopted to the semester structure without an immediate adjustment of the module description? In which way can the feedback from the e-assessmentbe reflected in the lecture and the tutorial? Can the missing practical course be replaced by the design of virtual experiments and thus enhance the learning effect?

Numerous projects have been dedicated to these and many other issues since 2012, which have contributed to the success of thermoE. However, it should also mentioned that this form of financial support, which essentially provided only student help staff (SHK) funds, is not a truly sustainable and lasting solution. Some presentations [1, 2, 3, 4] and publications have emerged from these projects [5, 6, 7, 8]. During the projects, interdisciplinary collaborations with different partners have contributed to the success. More information can be found on the website of the chair.

It is important to emphasize that the many years of work on thermoE did not focus on creating a substitute for face-to-face time lectures or seminars. The so-called freedom of learning at any time propagated by many sides is unfortunately, in my opinion, in a very simple way related to digital formats which are expected to solve all learning problems. It should be emphasized that the technical CONTENTS transported by digital formats is completely identical to classical analogue formats. In this respect, the new digital world does not represent any added value in terms of content, it transports content differently but not better! In addition, it should also mentioned that it was at all times possible to study at any time, regardless of location and time, simply by picking up a textbook. Since the majority of these are now also available digitally, there have been even no financial hurdles to self-determined learning for many years. Unfortunately, the one-sided propagation of digital formats by means of euphonious project titles, which must contain signal words such as "innovative," is due to the continued funding shortage for teaching at universities. Fine-sounding project titles secure short-term financial resources (mostly temporary staff at undergraduate level), but do not solve the fundamental problem. This problem also includes the fact that more and more institutional committees or staff units for quality control are being created, which in the end are not concerned at all with teaching and work with the students, are served from the general pool of positions and, despite individual positive approaches, do not contribute to an improvement in the teaching situation with their work.

3. thermoE - Competence-oriented E-assessment in thermodynamics

The semester-accompanying self-learning tool is now permanently integrated into the thematic sequence of lectures and exercises. Self-learning tasks, which cover the entire ONYX-Opal task spectrum, supplement lectures and exercises with both theoretical questions and calculational tasks. The quality of the computational examples has always been adapted to the current features of OPAL (use of maxima and consequential error consideration). The immediate response with “correct/wrong” allows an immediate self-control to the students and shall support their further self-studies by including references to literature or the script in the response to an incorrect answer.
In addition, all students may use the “contact button” to their instructors and thus questions can be dealt related to their individual problems in the next exercise. After several years, it appeared that a regular active assessment participation of the students during the whole semester, the number of failed exams decreased significantly. Details can be found here [1-8].
The success of the new teaching structure is illustrated in Figure 1. Shown are here the achieved quota for passing the exam for Technical Thermodynamics in the last winter semester 2021/2022. In contrast to the previous year 2020/2021 , this exam was again written in paper form, as the professorship would not have been able to provide the newly required remote camera monitoring of the online formats of several hundred students. For a comprehensible comparable evaluation of the effect of the e-assessments on the performance of students, a relative representation was chosen, as the number of students without and with bonus points (BP) differed. Therefore, the two data series (with/without BP) were normalized both to the total number of students in each group. It should be emphasized that the collection of bonus points is always on a voluntary basis. During the hybrid Corona winter semester 2021/2022, as in all lectures, access and thus the approach to students was massively limited, so that fewer students actually took up the offer. Since there was no feedback for non-participation, further reasons for the lower usage are not known. In the current WS 2022/2023, participation has visibly increased and can be explained by attendance.

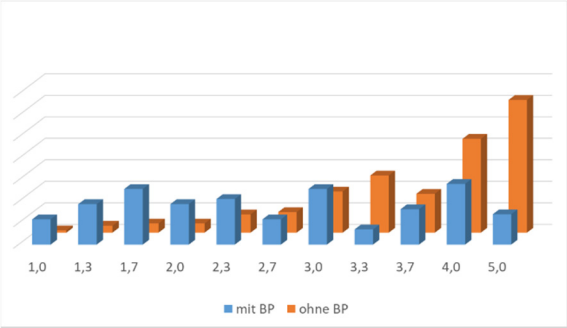

Fig. 1: Normalized representation of the grade distribution for the Technical Thermodynamics exam in 2021/2022. Blue: students with bonus points (BP), orange : students without bonus points.

4. thermoE - expansion through virtual practical experiments

Another focus by the chair was set recently to the creation of virtual practical experiments. This new part of the e-assessment is intended to compensate for the lack of real practical courses and emphasize the practical relevance of thermodynamic knowledge much more clearly than it would be possible via lecture and exercise examples. In addition to provide a basic knowledge for all students, such as the use of calorimetry (enthalpy of combustion) or the determination of heat capacities, the focus is also put on selected improved experiments such as adsorption, Maxwell distribution, isentropic coefficient, etc., which are intended to provide additional input for talented students. Those are also given the opportunity to carry out the real practical experiments in our labs [9]. This offer is mainly used by students of higher semesters. Undergraduate students are often not willing to take advantage of offers outside their prescribed curriculum. So far, only very interested and excellent students have taken advantage of the offer, and they often stay in the working group until they graduate and do their doctorate.

The main challenges for the implementation of virtual experiments were the limited availability of features in ONYX-Opal. Therefore, Python elements were applied preferably and are primarily used to create the new virtual practical experiments, thus ONYX-Opal is only used as a pre-for checking the theoretical background before starting the experiments. Details can be found here [9, 10].

Results for various applications were presented [11]. Currently, the real practical part of the course is supported by the acquisition of a new apparatus within the framework of a teaching project of the Faculty of Mechanical Engineering under the title: "Experience thermodynamics – take active part in innovative energy projects", for which a digital representation is also to be created.

5. thermoE - competence-oriented assessment and online exam

With the development of the various digital assessments, which primarily support the self-study, the focus was given to a competency-oriented content. Thus, different levels of learning (recognizing, evaluating, applying, ...) are addressed. With regard to thermodynamics, the correct recognition of systems, boundary conditions of a process as well as the choice of the appropriate balances for first and second laws are in the foreground. The pure mathematical skills for solving simple algebraic equations are assumed to be known and are not included in the technical evaluation of thermodynamics.

This general approach applies to both the assessment tasks accompanying the semester and the final online exam.

6. thermoE - Conclusion

The addition of electronic assessments to the portfolio of lectures and exercises of the Chair of Thermodynamics has led to an improved teaching-learning environment compared to the previous purely classical offerings. Classroom lecture content is now supplemented by electronic assessments and, thanks to a feedback function, provides more individual support, even for larger groups of students. The students' learning success is higher and the exam results - both classic and online format - are improved significantly. In addition, a more effective tool for communicating with students has been developed, and internal training of staff has been initiated at the same time. Additional offers, such as the combination of virtual and real practical courses, can also be used to interest future employees at an early stage or to make an offer to more talented students. During the Corona period, the existing electronic offerings enabled an immediate transition to the digital world.

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Literature

[1] *Breitkopf, C:* Development of a competence-oriented e-assessment for the subject technical thermodynamics - thermoE. Presentation at 11th Workshop on E-Learning Leipzig, 29.9.2013.

[2] Breitkopf, C.: thermoE - Eine online-basierte Prüfung für das Fach Technische Thermodynamik. Presentation at OLAT User Day, Dresden, 6.11.2013.

[3] Breitkopf, C.: Presentation of the project thermoE - Development of a competence-oriented e-assessment for the subject Technical Thermodynamics. Presentation at project meeting of the network of Saxon universities of applied sciences and universities on online mathematics, Chemnitz, 11.03.2014.

[4] Breitkopf, C.: Experiences in the context of the implementation of e-assessment in the lecture Technical Thermodynamics in WS 2013/14 and WS 2014/15. Presentation at the Joint Meeting of the Working Groups "Mathematics/Physics + E-Learning" and "Innovative Teaching in Computer Science and Natural Sciences", Zwickau, 04.03.2015.

[5] Freudenreich, Ronny, Lorenz, Torsten, Pachtmann, Katrin, Breitkopf, Cornelia, Kretzschmar, Hans-Joachim & Köhler, Thomas. (2014): thermoE - Development of an online-based e-assessment in ONYX using the example of technical thermodynamics. Proceedings of the Workshop on eLearning 2014.HS Zittau/Görlitz, 63-74.

[6] Freudenreich, R.; Kretzschmar, H.-J.; Breitkopf, C.: E-Assess-MINT - Elektronische Übungen im MINT-Bereich. Proceedings 14th Workshop on e-Learning, Görlitz pp. 49-58, September 22, 2016.

[7] Breitkopf, C.; Grau Turuelo, C.; Banos García, O.: thermoEint: Building E-Assessment Content for the Integration and Success of International Students in STEM Fields. EUNIS 2017 Congress Proceedings.

[8] Breitkopf, C.; Freudenreich, R.; Kretzschmar, H.-J.; Herrmann, S.; Umlauft, T.: Erfolgsmodell Fachar-beitskreis Technische Thermodynamik Sachsen. HDS. Journal, 2020, 2020,1, 34-37.

[9] Breitkopf, C.; Pinnau, S.; Lorenz, T.: VirtuaLab - Das virtuelle Labor - Aufbau einer interaktiven Lernplattform für Praktika der Thermodynamik. HDS. Journal, 2020, 2020,2, pp. 32-40.

[10] Breitkopf, C. et al.: Thesenpapier zur digitalen Hochschulbildung. Hochschuldidaktisches Zentrum Sachsen, Universität Leipzig + Arbeitskreis E-Learning der Landesrektorenkonferenz Sachsen (2021).

[11] Breitkopf, C., Grau, C., Pinnau, S., Lorenz, T.: Virtuelle Praktikumsplattform Thermodynamik. Workshop on e-Learning WEL Görlitz, presentation. 22.9. 2022 . https://zfe.hszg.de/wel-1