thermoE^{int}: building e-assessment content for the integration and success of international students in STEM fields

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1. ABSTRACT

The project thermoE^{int} aims to help the integration and success of international students in the field of Thermodynamics through the creation of a comprehensive relation of English e-assessments. In this work, the utilized methodology and workflows for the implementation of the online content in STEM fields are introduced. They are based on the determination of didactic and technical requirements for the online content after analyzing the gathered data obtained from educational staff experience, previous e-learning projects and students' feedback. With the help of the software and learning management service of ONYX and OPAL, a set of proposed solutions are introduced. In the same context, to ensure the quality of the online teaching material, a continuous improvement workflow is proposed on a year-to-year basis.

2. INTRODUCTION

During the last years, the development of e-learning content has been proved to be a very practical tool to enhance existing learning options for students and workers. This is due to the fact that e-learning can be used anytime and anywhere. At the universities, this versatility simplifies the process to reach a wider number of students, especially, those who may have difficulties understanding the lecture. That is particularly true with foreign students as the language is a great barrier to overcome. In order to improve the integration and success rate of foreign students at the Technical University Dresden, the project thermoE^{int} (thermodynamic e-assessments for international students), which is in the testing phase, aims to offer English electronic online exercises (e-assessments) in the fundamental subject of Technical Thermodynamics.

Another particular aspect of this project is the development of exercises for science, technology, engineering, and mathematics (STEM) subjects. In this field, the technical and didactic requirements differ from those in social sciences, where most studies and methodologies have been studied (Breitkopf, Kretzschmar, & Köhler, 2015). As a consequence, contributions guiding the path to the successful implementation of e-learning activities in the STEM field are required.

In this contribution, our methodology for building a comprehensive didactic relation of e-assessments will be introduced. The implementation of a dynamic continuous improvement system through feedback will be also discussed.

3. METHODOLOGY FOR THE CREATION OF E-ASSESSMENTS

The methodology to establish the didactic and technical requirements for the creation of online e-assessments is based on the experience. Teaching is a field which cannot be evaluated only with quantitative data. Qualitative data is crucial to understand the needs of the students and the issues that they have. The educational staff provides the most valuable feedback and ideas as they are in direct contact with the students. Members of the staff have to deal with their problems on a daily basis.

Before establishing the objectives and starting to build the exercises, it is necessary to gather experiences and opinions to determine which issues must be taken into account and transform them into the needed didactic and technical requirements. Figure 1 represents the flow diagram of the process.

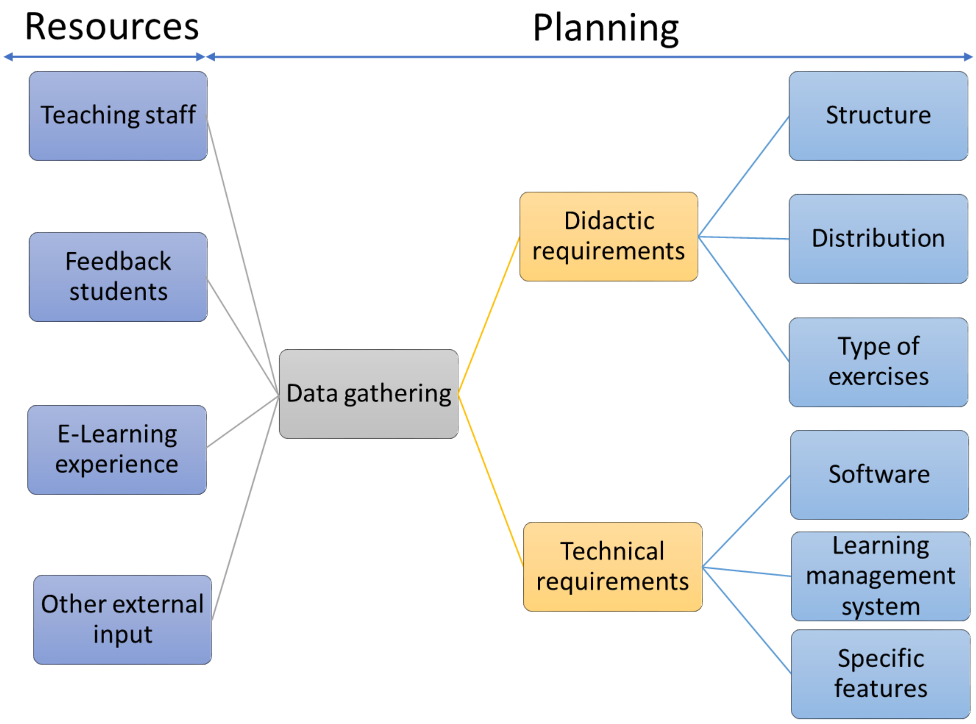


Figure 1. Schematic workflow for planning the e-assessments

The experience is the key factor for the success when implementing any kind of teaching strategies. As a consequence, the foremost source of data gathering comes from the teaching staff. Qualitative data are gathered through interviews and talks with the Professor responsible of the subject, the seminar supervisors, tutors and other chair members. From the Professor, it is possible to learn the structure of the subject and the questions he/she had from the students after the lecture. This experience is then used for the development of conceptual exercises which are meant to build the theoretical background of the subject. From tutors and seminar supervisors, data about current students' solving skills can be acquired and used for developing practical online exercises.

The students' feedback is also of key importance. This feedback can come directly from them in electronic or personal form. The personal form would come by talking directly with them. The second option would be to get their feedback electronically if an e-learning system was already developed. In the case of this work, we had already some experience in this area. It comes from previous projects: thermoE for developing the conceptual, theoretical, and didactical framework for building thermodynamic e-assessments (Freudenreich, Breitkopf, & Kretzschmar, 2016; Breitkopf, Kretzschmar, & Köhler, 2015; Freudenreich, Lorenz, Pachtmann, Breitkopf, Kretzschmar, & Köhler, 2014), thermoSA for the practical implementation of thermodynamic self-assessments (Breitkopf, 2015), and SPAts for the implementation of self-/peer-assessments in thermodynamics and supply chain management (Freudenreich & Lorentz, 2015). After the development of those projects, e-assessments have been used every year by about 500-600 students. Those e-assessments were implemented within the frame of the subject "Technical Thermodynamics". This fact gives us currently about 10-50 feedbacks/comments from students in every online test which are very beneficial for the implementation of new exercises as well as to improve the existing ones.

The last source of information, which was gathered, is the input gained from external resources such as literature, conferences, experiences from other departments, questionnaires and surveys. In this context, as a prerequisite for the development of thermoE^{int}, 22 foreign students from different subjects took part in a questionnaire to know what they expected from the e-learning platform, which their skills were and their suggestions. We found out that 85% of the students who took part in the questionnaire spend the same or more time in self-study as in lectures/seminars, 62% use internet resources frequently for learning and between 60-70% of the participants use internet for downloading subject's material. This quantitative data show that most students are acquainted with online resources and it is easier to approach them using online e-assessments as learning tool.

Once the data was gathered, problems, requirements, and solutions were discussed. Those requirements are classified into two categories: didactic requirements and technical requirements.

3.1. Didactic requirements

The main objective of a learning strategy is to overcome the forgetting curve (Figure 2). The green curve shows the retention during a lecture. Some hours after that, in absence of a review of the content of the lecture, the retention decreases following the red curve (Ebbinghaus, 1913; Murre & Dros, 2015). E-assessments and seminars help to minimize the forgetting curve, refreshing the acquired knowledge and following the orange curve. As the number of repetitions increases, the probability of forgetting the lecture content decreases.

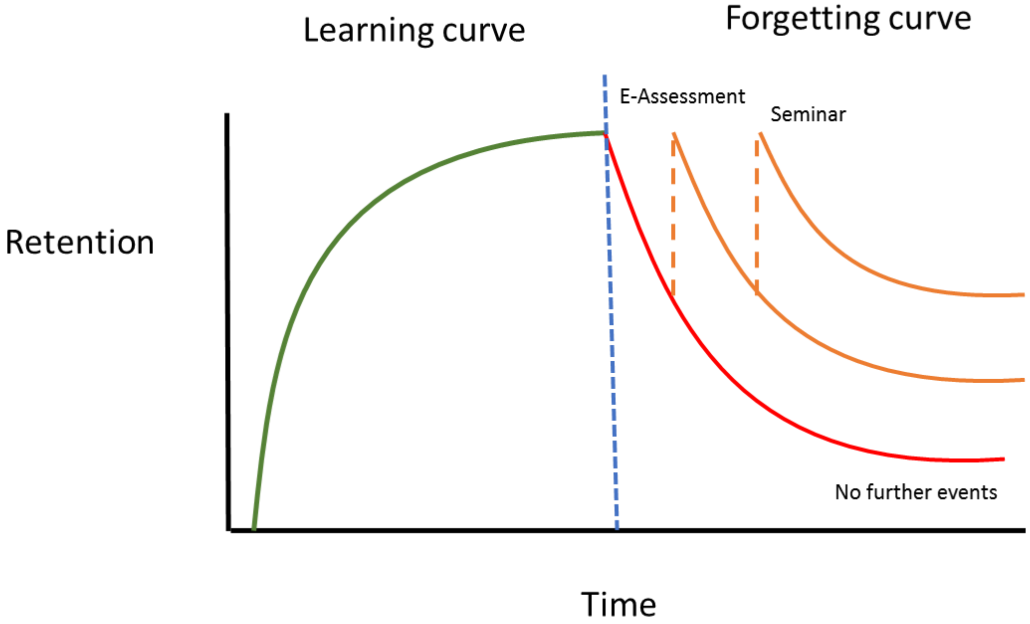


Figure 2. Learning and forgetting curve

The most important step to overcome the forgetting curve is to integrate the tests within the lecture framework. That means to divide and distribute all tests per lecture week or lecture session so that the students can do exercises related with the content of the last lecture. In our project, there were twelve lecture weeks so twelve e-assessments were built. They were available on the same day of the corresponding lecture and the students had access to the test during the whole week until the next lecture session. The number of trials was limited to two in order to encourage a learning effort from the students and avoid "trial and error" techniques.

The exercises had an increasing difficulty level within each test. Easier tasks were placed first and key concepts were shown for its utilization in subsequent tasks within a more complicated context. The distribution of different task types is also important. We divided the tasks into two: conceptual tasks and solving skills tasks. Conceptual tasks are meant to make the student learn the concepts and the theory taught in the lecture. The second objective of these tasks is to get the student acquainted to the learning material, in other words, to force the student to look for the equations that he/she needs and to learn where to find them. In our case, text gap exercises were included where the student had to write the number of an equation from the formulary/subject's manuscript or the page where it is located thus increasing the subject's material management skills. Solving skills tasks are mathematical exercises where the students must solve a problem numerically. In a technical degree, most of the exercises belong to this classification. Solving skills exercises promote reasoning, logic and resolution skills. It is advisable to mix conceptual tasks with solving skills tasks as it helps with the motivation of the students due to the variability of exercises preventing long term boredom. The percentage of conceptual exercises must be higher in the first E-Assessments of the semester to found the basis of the understanding of the subject and to increase the handling ability of the solution tools such as equations, tables, etc. The balance must be gradually changed to a more solving skills based exercises as the course approaches the last lecture weeks. In the project thermoE^{int}, the first test was built with an 86% of short conceptual tasks (out of 29 tasks) while, in the last test, the amount of conceptual task was reduced to a 12.5% (out of 24 tasks). This is done to favor the preparation for the exam which is more practical oriented. The exercises must follow a logical resolution structure so that the students learn how to solve typical exercise types step by step.

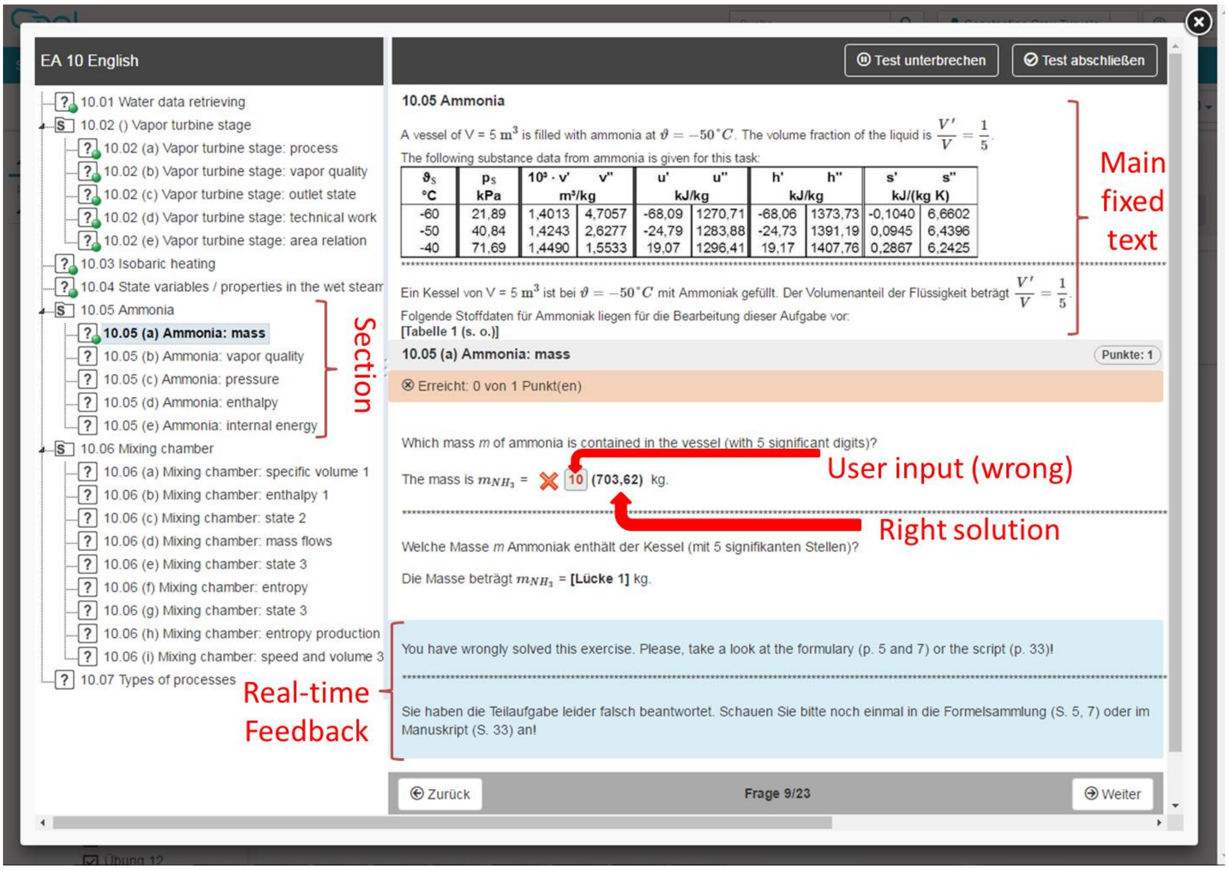
Last and foremost didactic requirement in our project was to help foreign students to get acquainted to the subject content. Let us introduce some quantitative data from the international students' survey first. 52% of the students that participated in the survey had difficulties with the language during their studies, while the 71% affirm that they have a greater barrier to overcome when studying due to the language. The first idea to support international students was to offer English-only tests. However, the real obstacle is to translate the knowledge learnt in German to use it in English e-assessments and vice versa. The found solution was to translate the most important tasks to show the correlation between German and English technical terms and prepare them to use both interchangeably.

For student's preparation and their quick adaptation to the online e-assessments, a tutorial was also developed so that they could understand how the overall system works. According with their comments, the tutorial has been a much appreciated resource by the students.

3.2. Technical requirements

Technical requirements are heavily dependent on the software, the learning management system or platform, and the features they offer. In thermoE^{int}, the requirement of the software is to have plenty of options for exercise customization, while the learning management system (lms) had to be easy to use, transparent to the user and it had to reach the students easily. For these reasons, the chosen software for exercise development was ONYX Editor (Benutzerhandbuch ONYX Testsuite, 2016) as it gives plenty of options and it is very well integrated in OPAL, a lms completely integrated in the Universities of Saxony. Students of our university are already familiarized with OPAL so it is natural for them to use it for every subject. Furthermore, ONYX provides a lot of tools for improving the e-learning experience which allows us to create the e-assessment content.

One of the technical requirements was that the students must learn the logical structure to solve the practical questions. Hence it is important to offer a step by step solution of the exercise so that the students get acquainted with which step comes first and which the solution procedure is. In order to implement this, the ability of ONYX to create exercises with sections was utilized. Section based exercises are those which have different sub-tasks and each sub task is shown sequentially but not concurrently, in other words, sub-task b is not shown until sub-task a is completed. All subtasks share the main text with the formulation of the overall exercise with the initial data so that it is directly accessible while being in the corresponding subtask (see Figure 3). This simplifies the user experience as they do not have to go back and forth to get the initial data of the exercise or to read again the main formulation of the exercise. The second reason to use this structure is to be able to avoid consequential errors. Every subtask can be evaluated before going to the subsequent one. By evaluating the solution, if wrong, the students obtain the right solution and they can use this value in the following subtasks (see Figure 3). In other implementations, that is not possible to do so a mistake in the beginning of the exercise would lead to wrong values in the rest of the exercises after all the time the students spent in performing all the calculations. With the presented method, motivation issues due to consequential errors are minimized and the logical resolution steps are forced to be utilized.



ϑ_S °C	p_S kPa	$10^3 \cdot v'$ m³/kg	v''	u' kJ/kg	u''	h' kJ/kg	h''	s' kJ/(kg K)	s''
-60	21,89	1,4013	4,7057	-68,09	1270,71	-68,06	1373,73	-0,1040	6,6602
-50	40,84	1,4243	2,6277	-24,79	1283,88	-24,73	1391,19	0,0945	6,4396
-40	71,69	1,4490	1,5533	19,07	1296,41	19,17	1407,76	0,2867	6,2425

Figure 3. Capture of one test after a wrong input

Real time feedback is also an advisable feature to have along the section structure as shown in Figure 3. ONYX Editor allows the definition of a text showing a sub-task dependent feedback for the students. If the students wrongly solved a given sub-task, a text appears with hints to learn how to correctly solve that sub-task, for example, by giving the subject's script page, the formulary page, a reference book or, if the sub-task is especially difficult, the complete resolution process. With this methodology, the students can actively look for the solution, increasing the learning experience, and learn immediately what they did wrong. They also learn how to use the provided learning material more efficiently.

In STEM subjects, the students must do many calculation exercises to improve their solving skills. This can be trained with e-assessments. However, every student often has a different solution of a given task due to the use of different decimal numbers or slightly different parameters. To avoid that, tolerances must be implemented. In our project thermoE^{int}, a common used relative tolerance is between 1% and 5% after analyzing the impact of a solution at the extreme sides of the tolerance. The chosen tolerance should also prevent wrong solution procedures to be wrongly taken as right. Tolerance in text gaps were also introduced so that one misspelled letter is not taken as wrong.

As in the didactic section, a variety of exercise types also avoids boredom and increases the motivation of the students. It is recommended to mix exercise types. In the project, the following types of exercises were implemented (ONYX Aufgabentypen, 2016):

- Choice exercises: single and multiple choice options
- Text gaps: the student must fill the gap with the correct solution, different solutions must be defined beforehand

- Drag and Drop exercises: two columns where the student must match two concepts
- Matrix exercise: two-dimensional matrix where the student must select which relations are right
- Order exercise: order different given statements in a requested order
- Hotspot exercise: click the right area of a diagram or picture
- "False text" exercise: the student must find out which terms are wrong
- Textbox exercise: a text where there are gaps, where the student has different options from a drop-down list
- Numerical input: gaps where the students must write the numerical solution
- Calculation exercises: similar as the numerical input but with random initial parameters
- Equation comparison: the student must write the requested algebraic expression

The duration of each test was planned to be between one and two hours for a total amount of 12 tests (12 lecture weeks) with 116 online exercises. They have the feature to stop the test at any time and resume the test another day so the students can freely choose when and where to do the weekly scheduled e-assessments. The higher the number of times they resume the test and make a couple of exercises, the better the forgetting curve is overcome (see Figure 2). It is important to encourage the students not to do all the exercises at once and distribute the time spent in e-assessments along the lecture week.

Finally, a feedback survey was placed after each e-assessment in order to gain knowledge about the behavior of the test, potential issues and satisfaction of the students.

4. DYNAMIC AND CONTINUOUS IMPROVEMENT THROUGH FEEDBACK

Once the first functional version of the e-assessments is built and tested, new revisions must be performed after every year to perfect the e-assessment content (see Figure 4). Two kinds of modifications can be distinguished according to the timeline when they are performed: changes during the semester; and changes between docent years.

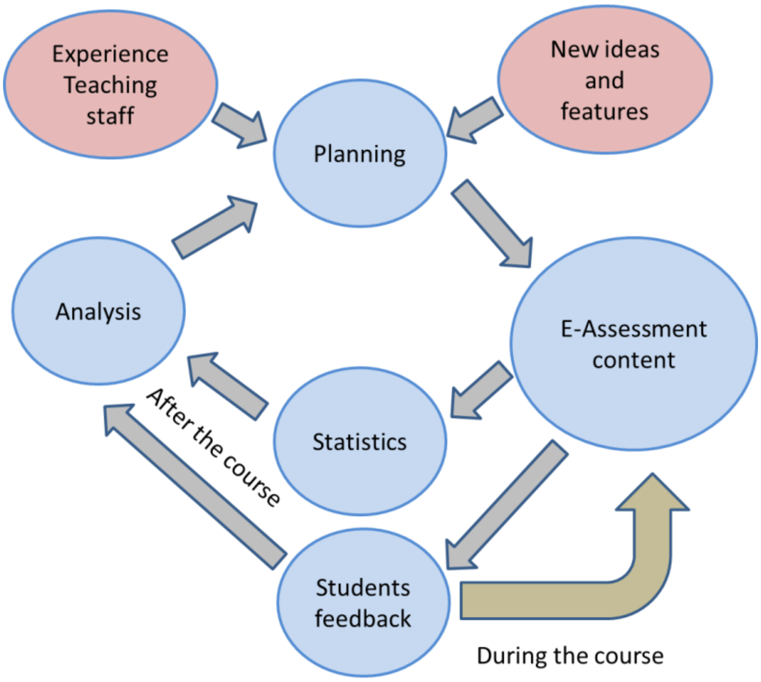


Figure 4. Workflow diagram for the continuous improvement of the online content on year-to-year basis

For the dynamic improvement during the semester, a feedback survey is implemented after every e-assessment. The students can anonymously give their opinion about the duration, suitability and difficulty of the test. Additionally, they can also give feedback about which issues they had and write a free text about suggestions for improvements and other comments. This information can be used to make “on the fly” changes if they do not affect the outcome of the exercise/task. It is advisable to read the initial feedbacks a short period after unlocking the tests to check if everything is working properly and to prepare changes for subsequent e-Assessments in case it is necessary.

For the improvements of the e-assessment from one docent year to the next, there are two sources of information: analysis of the students’ feedbacks after every e-assessment and statistical data. Our learning management system, based on OPAL and ONYX, can register statistical data such as the percentage of right/wrong answered tasks, the summary of the most written values in numerical exercises, and the overall pass/fail rate of each e-assessment. With these data, it is possible to analyze possible deviations of the average results and to determine which exercises are more problematic. This allows the docent staff to perform the corresponding modifications for a more consistent and improved collection of e-assessments and a better teaching quality. During this improvement cycle it is also possible to implement new ideas and/or features.

The project thermoE^{int} is currently in the testing phase. While the introduced workflows are already in use, the analysis of the outcome of the project will be performed at the end of the docent year 2016/2017.

5. SUMMARY AND CONCLUSION

In the project thermoE^{int}, the methodology employed for building a comprehensive relation of online tests or e-assessments for foreign students has been introduced for the field of thermodynamics as a pilot project for other STEM fields.

The foundations of the project have been built around the experience of the teaching staff, previous e-learning projects, and students’ feedback. With the analysis of the gathered data, didactic and technical requirements for the e-assessments have been developed and then translated into online content with the selected tools: ONYX and OPAL. This work deals with the typical issues in STEM fields and provides a practical view of how to overcome them.

Finally, a workflow for the implementation of a continuous improvement cycle for e-assessment content is shown to increase the teaching quality of the online content on a year-to-year basis. After the first currently running implementation, the results will be analyzed and the effectiveness of such methodology will be tested.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

BPS System website (2016). *BPS System – Benutzerhandbuch ONYX Testsuite*. Retrieved February 20, from: https://www.bps-system.de/help/display/ONYX/Hilfe

BPS System website (2016). *BPS System – ONYX Aufgabentypen*. Retrieved February 20, from: https://www.bps-system.de/help/display/ONYX/Aufgabentypen

Breitkopf, C. (2015). *"thermoE und thermoSA" - Erfahrungen in der Umsetzung von E-Assessment in der Vorlesung Technische Thermodynamik im WS 2013/14 und WS 2014/15*. E-Teaching-Day an der TU Dresden 2015. Retrieved July 2015 from : https://tu-dresden.de/ing/maschinenwesen/iet/tt/ressourcen/dateien/thermoE/projektergebnisse/thermoSA_etd_2015

Breitkopf, C.; Kretzschmar, H.-J.; & Köhler, T. (2015). *thermoE - Entwicklung eines online-basierten E-Assessments in ONYX am Beispiel der Technischen Thermodynamik. Projektabschlussbericht - Vorhaben zur Entwicklung des E-Learning in strategischen Handlungsfeldern im Rahmen der Initiative „Bildungsportal Sachsen“ 2013/14*. Bericht zur Zielvereinbarung 2014 zwischen dem

Arbeitskreis E-Learning der Landesrektorenkonferenz Sachsen und dem Sächsischen Staatsministerium für Wissenschaft und Kunst, S. 159-184

Ebbinghaus, H. (1913): *Memory; a contribution to experimental psychology*. New York City: Teachers college, Columbia university

Freudenreich, R.; Lorenz, T.; Pachtmann, K.; Breitkopf, C.; Kretzschmar, H.-J.; & Köhler, T. (2014). *thermoE - Entwicklung eines online-basierten E-Assessments in ONYX am Beispiel der Technischen Thermodynamik*. Görlitz: Tagungsband zum Workshop on eLearning 2014 - Hochschule Zittau/Görlitz, S. 63-74

Freudenreich, R.; & Lorenz, T (2015). *SPAts – kompetenzorientiertes Online-Self-/Peer-Assessment zur Selbstgesteuerten und Kooperativen Prüfungsvorbereitung*. Leipzig: HDS Jounal 2/2015 Lehrpraxis im Transfer - Hochschuldidaktisches Zentrum Sachsen (HDS), S. 29-32

Freudenreich, R.; Breitkopf C.; & Kretzschmar, H.-J. (2016). *E-Assess-MINT - Elektronische Übungen im MINT-Bereich*. Görlitz: Tagungsband zum Workshop on eLearning 2016 - Hochschule Zittau/Görlitz, Görlitz, S. 49-58

Murre J. M. J., & Dros J. (2015): *Replication and Analysis of Ebbinghaus' Forgetting Curve*. doi:10.1371/journal.pone.0120644

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