

# Experience Report: EXaHM – Application Oriented, Digital EXamination System at Hochschule München

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**Abstract:** The COVID-19 pandemic put academic institutions around the world in the difficult position of suddenly having to organize many lectures and examinations over online channels only, due to students' physical access to their campus buildings being restricted. While the search for possible solutions to this problem was often challenging, this situation also offered the unique opportunity to establish remote examination options, that might hold the potential to be continued even after the pandemic has hopefully ended. This report looks at how the Munich University of Applied Sciences (MUAS), one of the biggest universities of applied sciences in Germany, established its own solution for remote examination over the Internet. This report provides an overview of how MUAS developed its on-site competence- and application-oriented digital examination tool to work remotely during the pandemic, its general framework and experiences that were made during its inception. Included are descriptions of the technical setting of the solution, as well as some challenges that were had when implementing it and how those were resolved. As part of this research it was concluded, that support and administrative work for this kind of remote examination was much more intensive than for on-site digital examinations, but also lessened each subsequent semester. A well-organized support system makes it possible to offer remote digital examinations with good conditions regarding, for example, student equal opportunities and secure examination environments, although even now perfect conditions cannot be guaranteed. While not without its own deficiencies, MUAS new established system was lauded by many Bavarian educational facilities and is in the process of being deployed to other Bavarian universities. This paper serves to highlight a qualitative example of how e-learning approaches can be of use in the context of higher education examinations and hopefully provide ideas for others trying to establish their own similar solutions.

**Keywords:** Competence oriented examinations, Application oriented examinations, Digital examinations, Remote examinations, Examination during pandemic

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## 1. Introduction

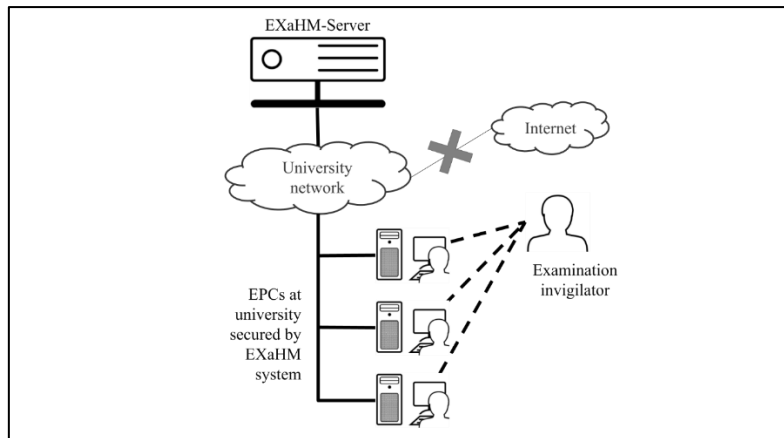
During the COVID-19 pandemic from the summer semester 2020 onwards, at the Munich University of Applied Sciences (MUAS), or Hochschule München in German, on-site examinations were prohibited for several semesters. The already existing examination framework called 'application oriented, digital Examination System at Hochschule München' (EXaHM) was expanded to be used for remote examinations. This paper describes the technical and organizational development for "Remote-EXaHM", remotely accessed EXaHM, examinations including the point of view of the EXaHM competence team, which supports the departments in the realization of their examinations, with special consideration of the support effort and the lessons learned during this period.

### 1.1 What is EXaHM? - Technical Setup

EXaHM is a service provided to all faculties of MUAS by the Center for Innovation in Teaching and Higher Education. The service includes advice, technical realization, and on-call duty (technical support) during the examination and storage of same. EXaHM is a computer-based examination system for application- and competence-oriented, digital examinations, which consists of three basic parts:

- A Linux-Server running the EXaHM-System software.
- PCs with EXaHM software installed in computer labs at campus, called EXaHM-PCs (EPCs).
- The EXaHM-App: WebApp used to create and manage Examinations and EPCs.

The overview of a typical on-site EXaHM examination situation is shown in Figure 1.

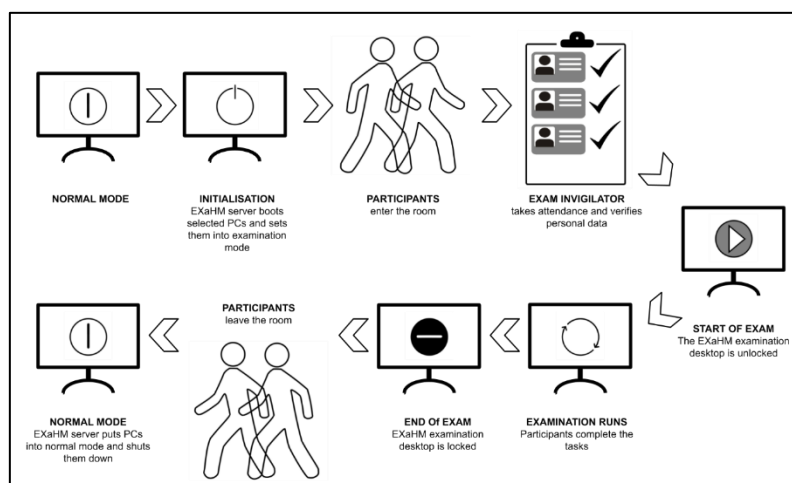


**Figure 1: EXaHM Examination overview**

In contrast to many other existing online examination systems, EXaHM optimizes the use of selected, locally installed applications in a protected desktop environment. With EXaHM, almost any Windows third party software (installed on the examination PC) can be individually allowed for each examination. It is also possible to use additional hardware connected to the PCs. Access to unneeded applications is blocked, as well as communication options via the Internet or to adjoining computers. However, an EXaHM examination can also have individual network configuration: Usually access to all networks is prohibited, but it is possible to allow, for example only certain server. A typical use case for this is when a certain type of license is needed, for example for “MATLAB”.

The student files are initially saved on the EPC, but are regularly backed up, versioned and automatically collected to the EXaHM server at the end of an exam. Instructors receive the students' files digitally for grading purposes, afterwards the graded student files are stored on the EXaHM server. EXaHM also allows the flexible allocation of EPCs: It is possible to start multiple examinations simultaneously in one room or across rooms. It is also possible, for example, to have two different examinations in one room at the same time or two different examinations in two rooms. Combining this with an alternating seat pattern, this can reduce cheating attempts and the amount of supervision needed. For some examinations every student sends in a project work they developed themselves, as data file to the instructor, which is then returned as their individual file to work with during the exam. This way, an instructor can effectively test whether the student is actually familiar with the previously sent in project work. Sometimes students are additionally given access to course notes or other background information.

EXaHM is also an automation framework for digital exams: All steps from booting up the computers, switching to examination mode and starting the examination, to the end of the exam and the shutting down of the computers are automated and can be controlled remotely with the help of a central server. A typical workflow of an on-site EXaHM examination is shown in Figure 2.



**Figure 2: Workflow of an on-site EXaHM Examination**

## 1.2 Competence- and Application-Oriented Digital Examinations

EXaHM works application-oriented, meaning that the examination can be conducted using any application installed on an EPC. Different IT solutions allow a wider range of tasks and activities, enabling instructors to assess students' skills and competences beyond simple recollection. This allows more authentic assessments, that are also aligned with the learning outcomes (University of Reading, n.d.). It is possible to use the same applications and real-life tasks, that students will later need to solve problems during their professional lives, making the examination performance-based and giving an authentic assessment (NCSSFL, n.d.). The aim is to use a computer, with given software, as a problem-solving medium for real life challenges.

## 2. COVID-19 and Remote-EXaHM

EXaHM has been offered at MUAS for competence and application-oriented examinations since 2018 and the number of examinations taken with EXaHM has increased every year through 2020. To make this possible, prior to the service being offered university-wide, the legal and data protection requirements for the service were clarified and enforced with the involvement of the MUAS Data Protection Officer. Also, other Bavarian universities of applied sciences had shown interest in adopting the system, and steps to facilitate this were already progressing well. These plans were disturbed in March 2020 when MUAS, like so many other educational institutes, was forced to move to emergency remote teaching. Soon it became clear that a return to "normal" teaching would not be possible before the examination period. Therefore, the examinations needed to be done remotely (Bozkurt & al et, 2020). At MUAS the following overall conditions for remote examinations were set:

- Examination must be feasible from home.
- The infrastructure must be in place, established and stable by June 2020.
- The legal requirements must be set by the Bavarian Ministry of Education.

At first, it was unclear whether or not EXaHM could be used to provide any sort of examinations at all, as students were not allowed onto campus under any circumstances. After some brainstorming, it was decided to try an approach where students use remote access, earlier reserved only for support staff, to access EPCs on campus using their own equipment and web browser at home. This way, students would be able to use software not installed and/or licensed on their own device.

This also solved the important equal opportunities' requirement for examinations, as students with better equipment (at home) would not have a considerable advantage over others, as all processing is done on EPCs at campus.

As an additional measure, it was decided upon to use a lockdown browser tool called "Safe Exam Browser" when using EXaHM. Safe Exam Browser (SEB) is a separate browser application students install on their personal computers before the exam. While running, SEB restricts access to system functions, specific websites, applications and more. After the examination, students can either just close the SEB application, in order to not have to reinstall it again for future exams, or uninstall the application altogether. The Examiner can decide which resources are permitted or prohibited (ETH Zürich, Educational Development and Technology, 2021). Figure 3 visualizes the interplay of SEB and EXaHM.

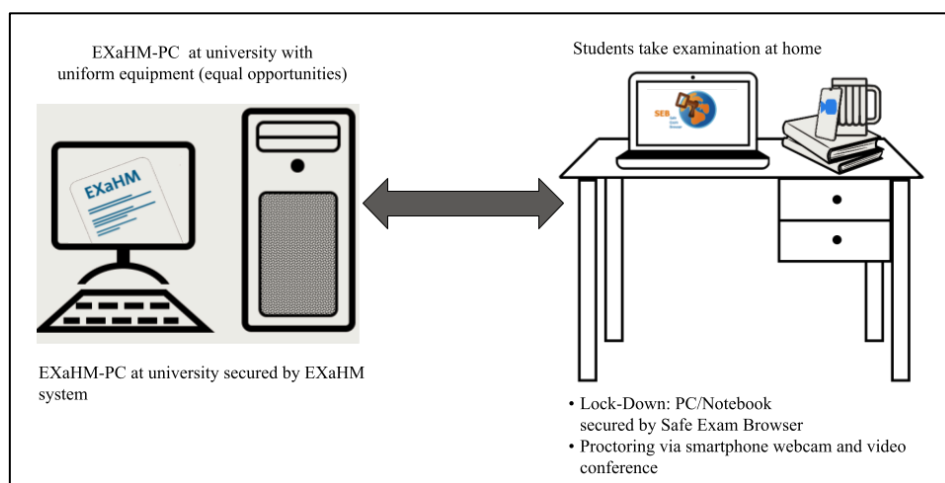


Figure 3: Remote-EXaHM setup

The legal basis for Remote-EXaHM is “The Bavarian regulation for the testing of electronic remote assessments (BayFEV)” from September 16th, 2020. This regulatory text applies to all Bavarian universities retroactively to April 20th, 2020, thus ensuring legal certainty for the examinations that were conducted as electronic remote examinations in the 2020 summer semester during the Corona pandemic. This law is meant to be tested and reevaluated over the next four years regardless of the pandemic situation. BayFEV states that at Bavarian higher education institutions electronic remote assessments can be offered, under firm legal guidelines, in the form of proctored examinations, conducted in a specified time slot using electronic communication technology and video supervision.

### 3. Organizational Challenges

The first task for the Center for Innovation in Teaching and Higher Education, after committing to this approach, was to define the minimum requirements for the IT equipment of the examinees. This was:

- A PC/notebook with Safe Exam Browser installed (Windows 10 or MacOS, as there is no Linux version of the SEB) and VPN access to the “Münchner Wissenschaftsnetz” with the VPN service of the Leibniz Supercomputing Centre (Leibniz-Rechenzentrum, LRZ).
- A smartphone (or other secondary device capable of videoconferencing) with the “Zoom” app.
- A stable internet connection on both devices.

On the technical side, the following modifications of the EXaHM system were needed:

- Increase in server capacity for remote connections.
- Secure gateway for the internet connection of the EXaHM servers.
- Automated, individualized, and secure connection between the participant (at home) and the EPC at the university (particularly for the creation and protection of access URLs).

In the first test run with students, it was noticed that, in our setting, SEB did not work well on Apple devices (Local Mac device/keyboard connected to a remote Windows desktop screen). Therefore, it was decided to limit access to Windows devices only. Students who do not own a Windows device were encouraged to borrow a device from friends/relatives or from their department or faculty.

During this process the guiding principle has been to ensure equal opportunities for all examinees, and at the same time, ensure as secure an examination environment as possible. Regarding both these issues, it was acknowledged that it would not be possible to achieve completely satisfactory results or avoid all critique. Some issues considered are:

- Some students have bigger or more displays than others. This was solved with a limitation of the resolution of the remote access. It was restricted to full HD (1920x1080). SEB can be configured in such a way that it allows only one (browser) window with a given size to be opened. A student with a bigger display does not have more working space than a student with a smaller display.
- There are methods to “cheat” the Safe Exam Browser. That is the reason the examinations are proctored with a second camera. It is placed so that proctors have a view of the examinees monitor. This way, though the text an examinee is writing cannot be seen, it is observable whether he/she is working in the EXaHM environment.
- Because of Data Protection concerns proctoring and support is done only in person by university personnel.
- Due to server capacities and functionalities in Zoom, the number of participants is limited to approx. 50 (2x25) participants per examination run. In big examinations with more than 25 students, breakout rooms are being used and have one proctor and one support in each room.
- According to BayFEV, students must have the opportunity to familiarize themselves with the examination setup. This is being offered in the form of a mock exam.
- As not all problems were solvable (e.g. unstable or poor internet connection, no Windows device) it was decided to give those students the possibility to write their examination at the campus under strict hygiene rules (this offer was used very little) or postpone their examination without any consequences. This only affected three students.

#### 3.1 Examination Administration

For administrative work, a Moodle course was created for each individual exam. All examinees were required to register to the respective courses prior to examination. In these courses, examinees were given the following information:

- Technical and other requirements for taking part in the remote examination.
- Date and time of their examination, Zoom meeting information.
- Detailed instructions on how to prepare their PC and Smartphone for the exam (installation of SEB, VPN and Zoom, creating a VPN connection, and joining the Zoom-conference via Single sign-on).
- Test-Link for the SEB with detailed video instruction guides to find out whether the SEB is working.

All examinees also had to read a disclaimer, declare their voluntary willingness and consent to data processing before they were shown their individual link to start the examination. The student's point of view on the Moodle Course is shown in figure 4.

The screenshot shows a Moodle course page for 'SoSe21 Messen mit IoT und Apps'. The breadcrumb trail is: Dashboard / Courses / Pruefung / SoSe21 / [redacted] / Messen mit IoT und Apps / SoSe21 Messen mit IoT und Apps. The main heading is 'Remote-EXaHM-Prüfung'. Under 'General notes', it states: 'In order to be able to sit a Remote-EXaHM-exam, you need: 1. Your student identity card, 2. A tidy and clear workspace, 3. A smartphone with the Zoom app, a University account and charging device, 4. A PC/notebook (Windows 10, not MacOS) with access to a VPN, SafeExamBrowser and a power adapter, 5. A stable internet connection for your smartphone and PC. Further explanation follows in part 1 "Technical requirements".' A highlighted box says: 'Complete Section 1 "Technical requirements" as soon as possible, ideally several days before the exam (at the latest by 21/07/2021, 12:00 noon). Only once this is complete can you work through the following steps.' Below, it says: 'If necessary, you may borrow a smartphone or PC/notebook from somebody else. Please ensure you follow all relevant hygiene regulations. If you borrow a device, you must discuss the installation of the required software and access to the Internet with the owner. Do not forget your charging device or power adapter. To participate, you must follow this procedure: 1. Complete "Section 1: Technical requirements" as soon as possible, ideally several days before the exam (at the latest by 21/07/2021, 12:00 Uhr). Only once this is complete can you work through the following steps. 2. Log onto this website at 10:30 on 22/07/2021. If you go onto this website earlier, refresh the page at 10:30. 3. Then work through "Section 2: Prepare for the start of the exam" followed by "Section 3: Start exam in SafeExamBrowser" to sit the exam.' The page is divided into three sections: 'Section 1: Technical requirements' with a link 'Technische Voraussetzungen' and a 'Thank you' message; 'Section 2: Prepare for the start of the exam' with a link 'Vorbereitung' and an 'Important' note; and 'Section 3: Start the exam in SafeExamBrowser' with a link 'Zum Remote-EXaHM-Desktop'. At the bottom, there is a section 'Close SafeExamBrowser' with a note about a code to be published later.

Figure 4: Example of a Moodle Course used for administrative work

### 3.1.1 Workflow of a Remote-EXaHM:

- A member of the support team starts the exam via EXaHM server.
- The last part of the Moodle course is unlocked. Here students find the Zoom meeting ID, password, and code for starting the SEB.
- At the starting time of the examination, an SEB-link in the Moodle course is unlocked. This link automatically starts the Safe Exam Browser and opens a remote connection to an EPC on campus.

- Students land directly at the EXaHM start-window and can fill in their personal information.
- The EXaHM starter-code is announced via Zoom meeting. Then, the examination proceeds exactly as an EXaHM examination at the campus.

As an additional security measure, SEB-configuration files used in the exam are uploaded to EXaHM server only for the duration of the examination and removed afterwards.

#### 4. An Example of Remote-EXaHM

The module "Measuring with IoT and Apps" of the bachelor's degree programs Mechatronics and Technical Physics was assessed with Remote-EXaHM in the winter semester of 2020/2021. The module had the following learning objectives:

- Students learn how to gather, store, and evaluate measurement data in the context of the Internet of Things (IoT).
- Students learn the Python programming language with open-source frameworks.
- Furthermore, students are introduced to basic network concepts.

A total of 37 examinees took part, supervised via two "breakout rooms" per Zoom. To test whether the sought-after competencies were achieved, the examination was designed to contain the following components:

- A HTML viewer for the assignment and lecture notes (which were permitted to be used).
- A Local IoT development environment with VSCode as Python IDE and a local MQTT (Message Queuing Telemetry Transport) server with a MQTT explorer.

A Text editor for answering questions about the basics of network technology.

Figure 5 shows the lock screen for EXaHM and the EXaHM desktop in use, as they were encountered and used by students taking the exam.

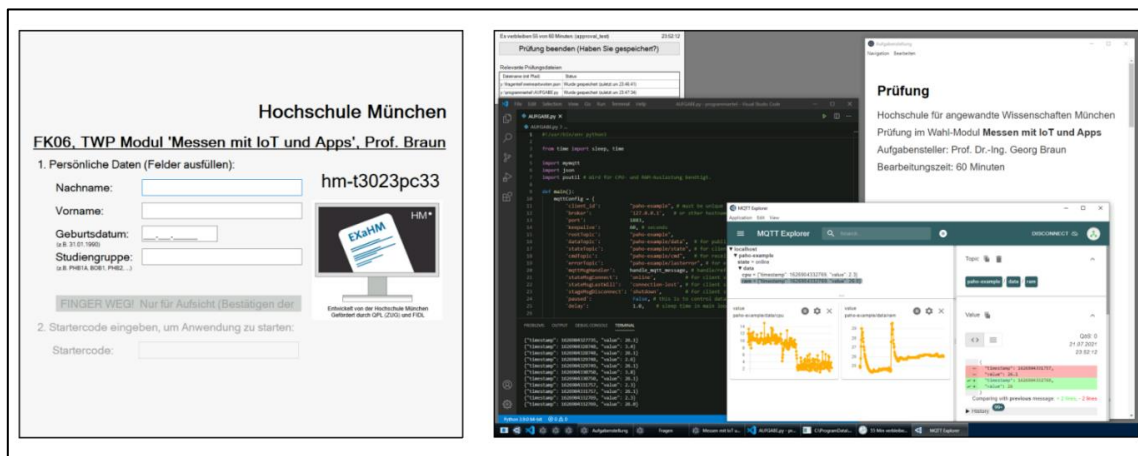


Figure 5: EXaHM lock screen and EXaHM-Desktop with third-party applications

The great benefit of this kind of examination, when compared to so-called pen and paper examinations, is that not only is it possible to test the student's ability to use the applications they will later need in their professional lives, but also assessment can be conducted with those same applications. Thus, the practical knowledge of the chosen software can be tested with authentic real-life assignments and conditions.

#### 5. Lessons Learned and Perspective

##### 5.1 Lessons Learned by the Support Team

The commitment to offer a mock exam on the grounds of the BayFEV showed to have distinct benefits. Remote exams offer both students and examiners the chance to become acquainted with the new situation. In every mock session, support staff were present, so that bigger technical problems could be resolved beforehand. Every student was also advised on what were the best positions and angles for their cameras beforehand. This way, students were less stressed and the time it took to begin the actual examination was shorter. In three terms, only one of the approximately 600 students taking the remote exams was not able to complete the examination



due to technical difficulties. Even learning about how many students could realistically be supervised by one proctor in one Zoom conference (the number differs depending on what kind of exam is being run) is considered useful information.

The support during Remote-EXaHM has been much more intensive than on-site. However, a deeper understanding of the students' problems was gained and the workflow, e.g. the Moodle courses were improved upon. One of the big improvements to the Moodle courses was a test-link students could use to test their SEB-installation on their own before the mock exam. This drastically reduced the support work during the mock exams.

As the students became used to Remote-EXaHM in the three terms, the number of exam takers for mock exams decreased in comparison to that for real exams, because the students have become accustomed to the setup. At the moment, it is considered dropping the individual mock exam before every examination and offering general technical framework mocks instead.

Other lessons learned included: During the first two semesters, each EPC had its own SEB configuration file with a unique "start URL" address for remote connections. This was necessary because in the Moodle course each student had to be assigned to a specific EPC. This was done via Moodle's group assignments. Each group corresponded to an EPC, so only one student was assigned to each group. However, this approach was very time-consuming as it required a lot of manual work (manually creating hundreds of configuration files and preparing each Moodle course so that each student could only see one link), so for the third semester this was changed.

Currently only one SEB configuration file is used for each examination and students are assigned to EPCs via a remote desktop gateway.

## **5.2 Perspective Plans for the Near Future**

In the near future, the work that was postponed due to the Corona-pandemic will be continued. There are many PC-Pools at MUAS that would be a benefit if tied to the EXaHM framework. The cooperation with other Bavarian Universities of applied sciences is planned to be continued and expanded upon. MUAS has the leading role in a project called "digitales kompetenzorientiertes Prüfen implementieren", or ii.oo for short (Hochschule für angewandte Wissenschaften München, 2023), a joint project with eight other Bavarian universities of applied sciences with the aim of developing good practices for digital competence-oriented examinations. In this project, the plan is to expand the research on didactic methods and the implementation of digital face-to-face and online exams, as well as the integration of experiences gained during the Corona semesters. A technical implementation of the software should ensure compatibility with campus management systems, as well as a cloud solution that universities can utilize jointly. The ii.oo project started in August of 2021 and will continue until July 2024. The final goal, as of now, is to develop the EXaHM platform in a way that decreases the workload on the support team while the number of examinations per semester grows.

With the current progression of the Bavarian-wide implementation, there are good chances, that the remote-EXaHM system will serve as a prominent solution for remote digital exams for years to come.

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