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## DELIVERABLE D1.1

### Report on implementation of new elements in the lab

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## EXECUTIVE SUMMARY

In the new virtual laboratory, much of the activities of the current and previous CINCH projects will be brought together and made easily accessible to the end user. One of the main applications in the laboratory will be virtual hands-on training (HoT), which will introduce students and pupils to various aspects of working with radioactive substances in a playful way. For the implementation of these HoTs, it is necessary to extensively expand the existing laboratory from the MEET-CINCH project and to provide it with many new features.

In order to represent different subdisciplines of radiochemistry, the laboratory will be extended by several rooms, whose equipment is specially adapted to the requirements of the corresponding subdisciplines. A mini-map and a quest system will be developed, which will also show the next steps during a HoT, so that users can easily find their way around the lab. In order to represent the work in the laboratory as realistically as possible, many 3D objects are created, which are not available in 3D model databases. Different interaction possibilities with these objects and the combination of different objects are programmed. In addition, a personal inventory was developed, which allows the user to transport objects from one work station to another. To support the user in performing the HoTs, a so-called quest system was developed, which divides the HoT into several subtasks. The analysis of a radiochemical experiment is usually carried out by interpreting a radiometric measurement. In order to be able to generate spectra that are as realistic as possible for this purpose, an app was developed that can simulate different detectors by setting various parameters, which in turn can simulate different spectra.

All new elements in the laboratory are developed in close collaboration between programmers and radiochemists in an agile fashion. Agile programming means that the first prototypes are available for testing at an early stage and possible inconsistencies can be dealt with quickly. The entire development process of the laboratory is thus an iterative process between programming and testing of the new elements.

At this point in time, all work is running according to schedule and the first HoT is almost complete.

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## **1 INTRODUCTION**

The virtual laboratory developed during the previous CINCH project was very well received. It was used to train representatives of authorities responsible for the approval of a radioactive controlled area. Therefore, the focus in the first lab was mainly on allowing users to take a close look at all construction and radiation protection details, while the interaction options were very limited. The aim of the new extended laboratory is to introduce young people to the subject of radiochemistry in a playful way and to give teachers the opportunity to use virtual experiments in addition to real laboratory exercises in order to make their teaching more versatile and modern.

Therefore, the virtual laboratory will not only be extended in terms of interaction possibilities, but also the technical equipment and the number of rooms will be expanded so that users can dive deeper into the world of radiochemistry and learn about different aspects such as radiation protection, radiopharmacy or various analytical methods.

## 2 NEW ELEMENTS

The new lab will also be developed in Unity like the old one, which serves as a prototype. Unity is a real-time development platform to create 2D and 3D virtual environments, which allows test versions for individual applications to be obtained at an early stage through agile programming and thus allows close collaboration between programmers and radiochemists. To make the virtual lab as accessible as possible, the new lab is being developed as a web-based application so that the end user does not need to install anything to enter the virtual lab.

At this stage, all additional elements and features required for game-based learning and virtual hands-on training (HoT) have been identified. The individual applications are now being programmed one by one and can be tested by all project partners during the development process, ensuring that discrepancies can be identified and resolved at an early stage.

### 2.1 Extension of the lab

First, the new floor plan of the extended lab was developed. This plan includes eight rooms in total, which are connected by a corridor. Besides the specialized laboratories for neutron activation analysis and radiopharmaceutical applications, an air lock entry, including a changing, cloak and decontamination room, a detector room and an additional room for radioactive waste management was implemented to represent the special requirements of a radionuclide laboratory and to make it interesting for a larger target group, such as representatives of the authorities. All existing functionalities from the previous version of the lab were transferred into this new lab. All rooms can already be explored completely by the user in the current version of the virtual lab.

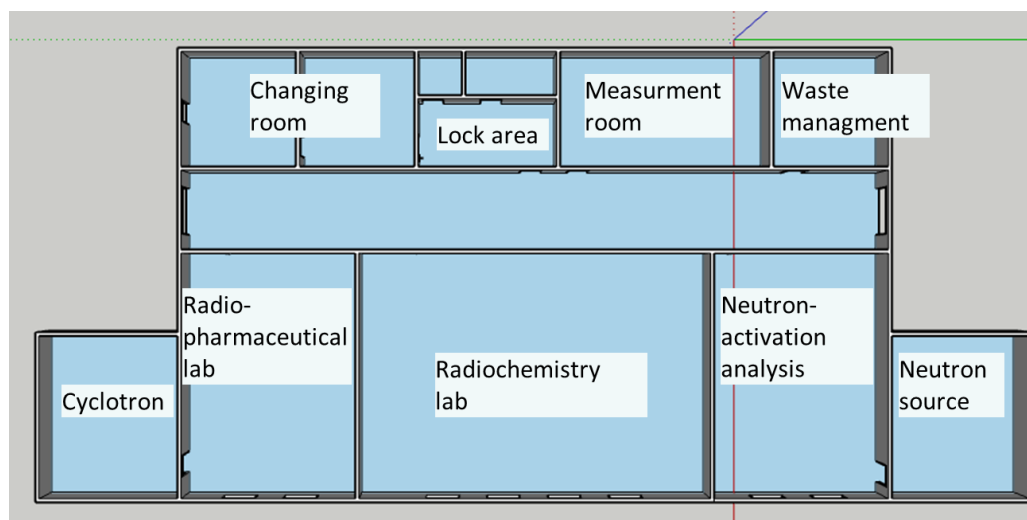


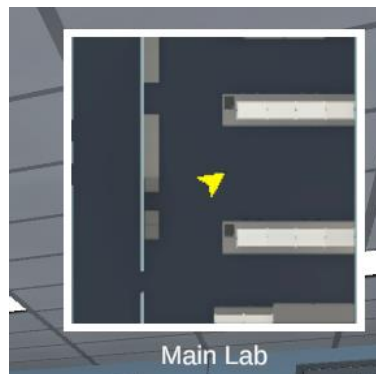
Figure 1: Floor plan of the extended virtual lab.



Figure 2: Screenshots of the corridor and the main lab of the current version of the virtual lab.

## 2.2 Mini-map

A mini-map, as known from video games, was implemented to support the orientation in the laboratory. As shown in Figure 3, the current position in the room is displayed as an arrow from a bird's eye view. Thus, the user always has a relation of her position to other objects in the room. In addition, this mini-map can be used in the future, e.g., to set markers for guiding the user to a certain location. In addition, the current room in which the user is currently located is always displayed below the mini-map.



**Figure 3: Screenshot of the implemented minimap that is used to improve the orientation of the user inside the lab. The current room is displayed below the mini-map.**

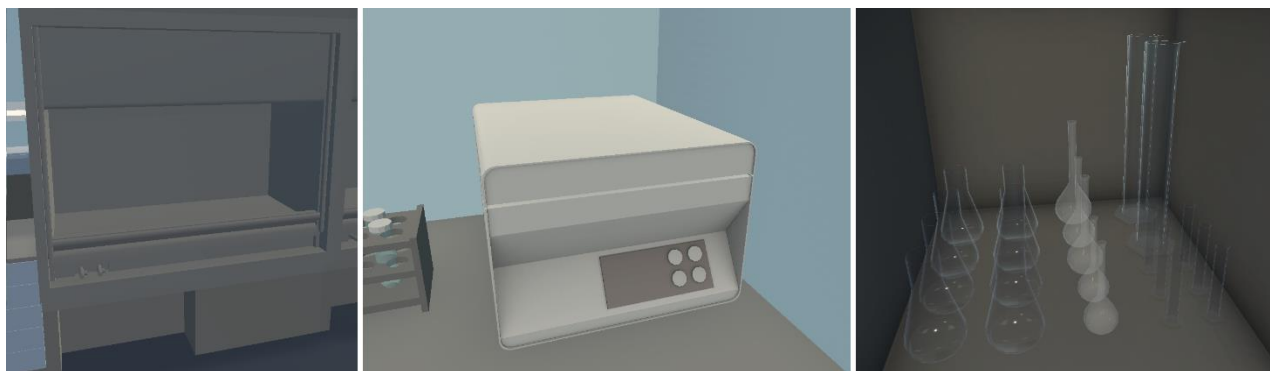
In addition, a visualization in the form of footprints was implemented to support navigation. The trail of footprints on the ground and on the mini-map helps the user to find specific locations, where they can do the next step of the HoT.



**Figure 4: Visualization leading to the next location for the HoT.**

## 2.3 Lab interior and equipment

The laboratory interior includes usable large-scale devices, cabinets for storing glassware and chemicals and fume hoods. The equipment includes glassware, chemicals and other laboratory utensils. All these objects often have unique characteristics and thus are not available e.g., in large online 3D object databases. Therefore, many geometric models have to be created. From the current object list (with around 130 models), about 45% of all required objects have been modeled. Examples for created 3D objects are a fume hood, a centrifuge and different types of glassware and shown in figure 5 **Chyba! Nenalezen zdroj odkazů..** By editing and revising the HoTs/Storyboards, new objects are still added, or already existing objects have to be adapted.



**Figure 5: Examples of created 3D models, from left to right: Fume hood, centriuge and glass ware.**

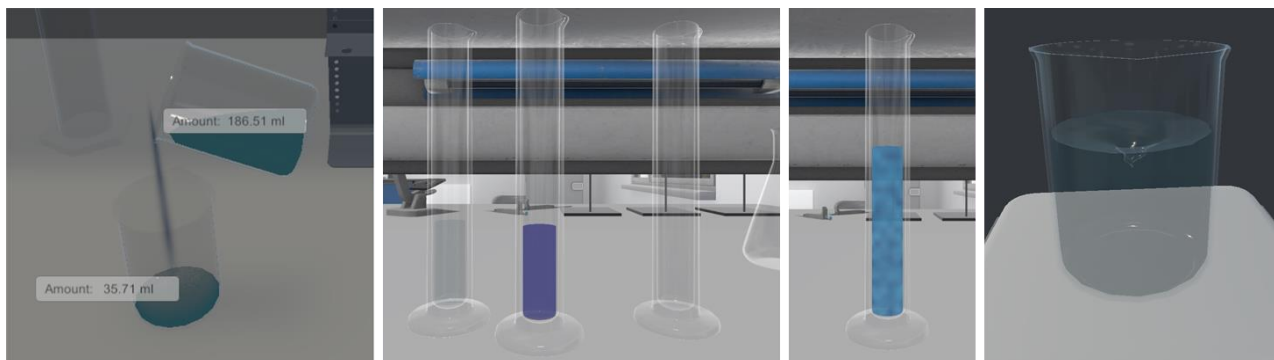
Certain cabinets in the laboratory are to be used to create laboratory equipment and chemicals. Thus, not all usable objects have to be available directly in the scene, but can be created dynamically. The first version of this object storage can be seen in figure 6. With the help of drag and drop interaction, objects from this object storage can be dragged into the personal inventory (see next chapter) to use them at the corresponding workstations.



**Figure 6: First version of the object storages for lab equipment and chemicals. On the left screenshot two interactable cupboards are displayed (indicated by hovering indicators).**

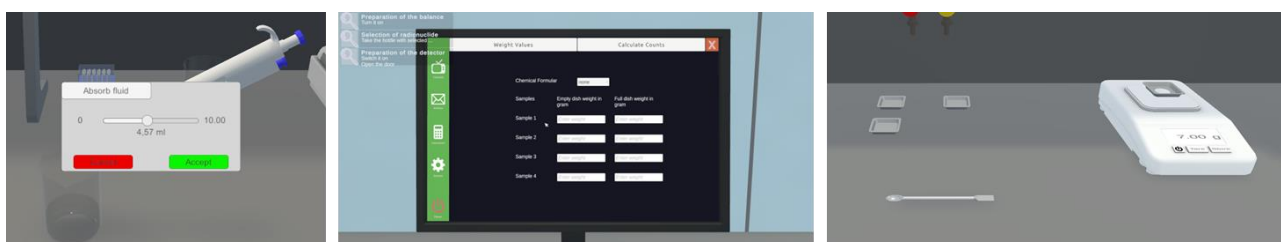
The movement and combination of different objects is essential for performing the HoTs. It was decided to use a free movement style to move objects at workplaces. This gives more freedom to experiment with certain objects and is closer to reality. The handling is similar to the desktop-metaphor on a PC in which objects can be moved on the desktop via drag and drop. If two objects are dragged on top of each other, it is checked whether this object combination is possible. If this is the case, a preview is displayed and after the mouse button is released, the combination is executed. First, the combination of different glass devices was programmed to transfer and mix liquids. For this purpose, the visualization of liquids also had to be developed. Since the fluids often need to be stirred to create the desired mixture, visualization of a vortex that can slowly appear and disappear depending on the input parameters was developed. This is intended to increase the level of realism and assist in the process of understanding the mixing.





**Figure 7: Visualisation of liquids. From left to right: Combination of two beakers to transfer liquid, automatic mixing of two liquids (light grey and dark blue) to lighter blue and vortex on a magnetic stirrer.**

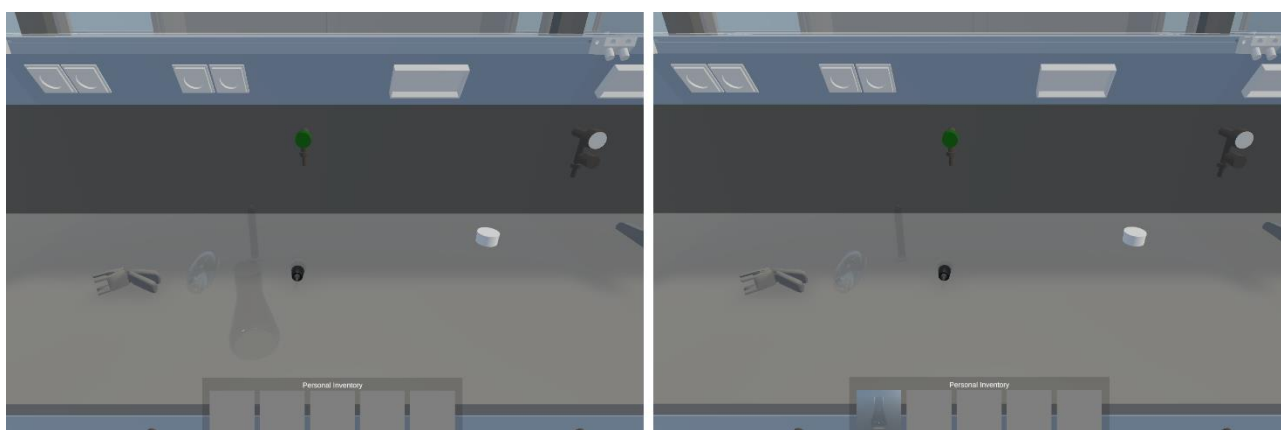
By now there are very many possibilities to combine different things beside various glassware such as using the water tap to create water, placing tubes in a centrifuge, using a pipette, balance or PC.



**Figure 8: Left transferring liquids with a pipette, middle interactive PC screen, where user can enter weights, which were measured with the balance on the right.**

## 2.4 Personal inventory

An easy-to-use personal inventory with five object slots was implemented, so that the user can carry objects between workplaces. The inventory is always displayed on the bottom part of the screen. On the left image in figure 9 9a conical flask is placed on the workbench. The right image shows a snapshot of this conical flask in the inventory. In this way, not only an image of this kind of object is shown, also possible fluid inside this flask is visible in the snapshot. This means that the user can always see the current state of the object.



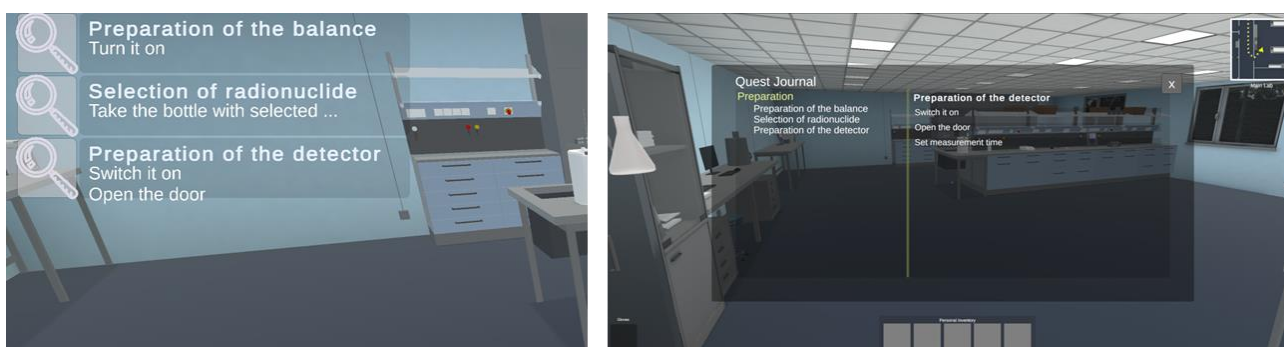
**Figure 9: Easy to use drag and drop personal inventory. On the left side, the inventory is empty. On the right side, the conical flask was taken by the user into the inventory and can be carried around to another workplace.**

## 2.5 Quest system

In order to support the user during the experiments, a quest system was designed. This is a commonly used part in video games to guide the player through a story. These quests will be shown to the user in the virtual lab to guide her/him through the experiment. The quest system is divided into four hierarchical levels:

1. HoT: The HoT itself is the highest level of the hierarchy.
2. Major Quests: A HoT is structured into different major quests and are more like a rough task description (e.g., “preparation”).
3. Minor Quests: Major quests are subdivided into several minor quests. These minor quests clarify the task a bit more (e.g., “preparation of the balance”).
4. Tasks: To complete a minor quest, multiple tasks need to be finished (e.g., turn on the balance, weight the powder).

This structure is based on an analyses of several HoTs. All partners used this structure to design their HoT. For the first HoT, the quest system is already implemented in the virtual lab. As shown in Figure 10, the user have a task preview of the current minor quest in the upper left corner of the screen. This preview is always visible while carrying out a HoT. The whole quest journal can be opened by mouse click so that the user sees the complete structure of the HoT and how far his/her progress in the HoT is.



**Figure 10: Screenshots of the quest system. Left task preview of the current minor quest. Right quest journal which can be opened by pressing a button on the keyboard.**

## 2.6 Simulation application for radiation

In addition to other analytical methods, radiometric measurements are essential in all areas of radiochemistry. To provide the students with a way to investigate this aspect, a radiation simulation was developed and will be integrated into the virtual lab. Figure 11 shows the web demo of the app where the user can adjust several parameters like detector material, distance between detector and source or the characteristics of the radiation source. The detector materials are defined by a background spectrum they create, the behaviour of the response function, as well as their geometry. One material is equivalent to an HPGe (High-Purity Germanium detector), showing narrow peaks. This will be the basis for other, less precise detectors that can be approximated by “worsening” the HPGe detector. Therefore, it is possible to simulate different types of detectors and their resulting spectra. When the app is implemented in the virtual lab, only a simplified user interface will be visible. Parameters such as the distance between source and detector or detector material are adapted to the respective measuring station, so that the user only has to place his sample on the detector and set the measuring time to obtain a sufficient realistic spectrum.

Movable detector and source

Different detector materials

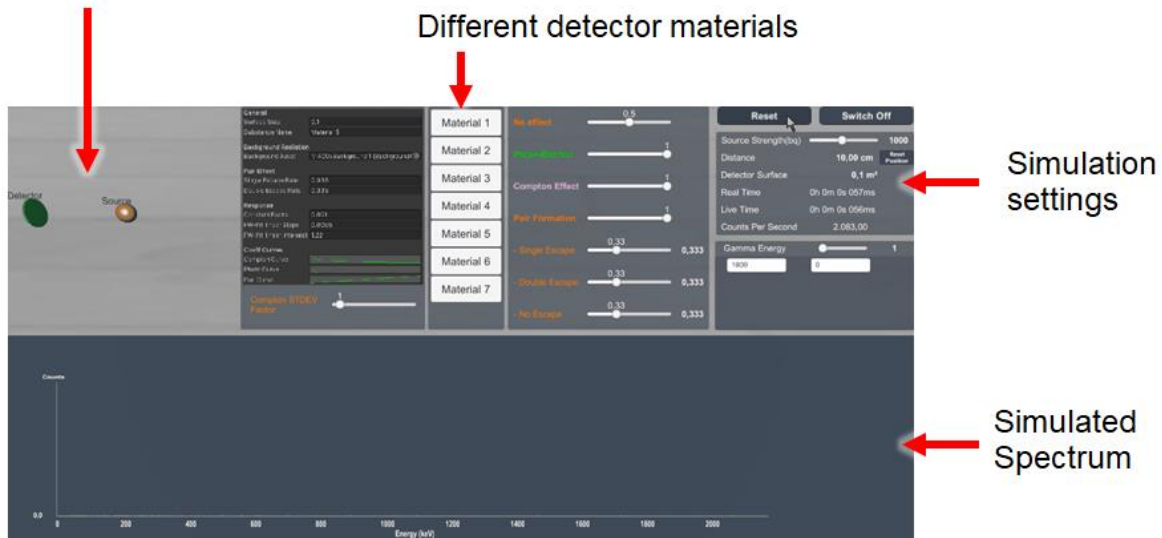


Figure 11: Overview of gamma radiation simulation web application.

The application is able to simulate different effects photons can cause at a detector. These include the photoelectric effect, the Compton effect and the pair effect. The intensity of each effect can be adjusted in the app to obtain a realistic spectrum for different gamma emitters. Such a spectrum is shown in figure 12. By adapting several parameters, the app can be used to generate alpha and beta spectrums, too.

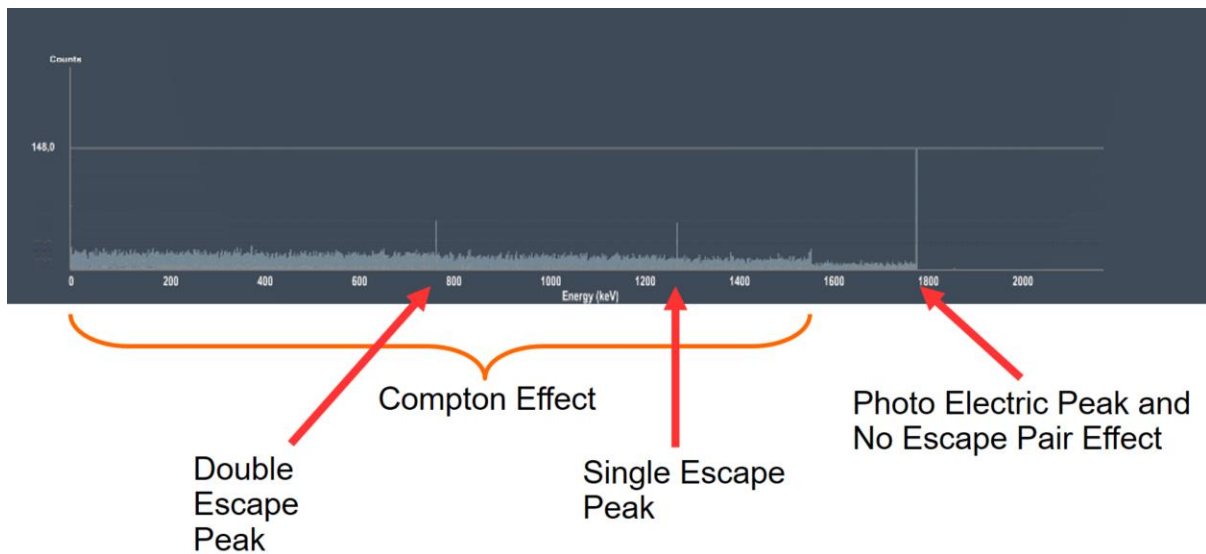


Figure 12: Spectrum of the radiation simulation showing the three effects.

### **3 CONCLUSIONS**

The development of the virtual laboratory, in which users can perform radiochemical experiments, requires a lot of programming work and close collaboration between programmers and radiochemists. Key elements needed for the virtual hands-on training have been identified and programming of these have begun. The delivery of first prototypes of different applications ensures that the final lab meets all expectations and requirements. So far, all work has proceeded within the planned period.

