أكاديمية البحث العلمي والتكنولوجيا

Progress Report No. 2 Project ID: 7830

I: Basic Data (one page maximum)

Field	Education	
Funding Scheme/ Program	Initiatives	
Arabic title	بيئة التعلم المعملية عبر الانترنت لتعليم الهندسة والعلوم والتكنولوجيا	
English title	Online Laboratory Learning Environment for Engineering, Science and Technology Education	
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Affiliation of the PI	Department: Electronics and Communications Engineering Faculty/Institute: Faculty of Engineering at Helwan University/Research Center: Helwan University	
Number of team members	6 Members	
Partners	Academic: Industry: Smart Systems – Scientific and Lab Equipment Local authority: NGO: International:	
Budget	3,452,263 EGP	
Duration of the project	18 Months	
Start Date: 26/01/2021		End Date: 26/07/2022

II: Scientific Content of the report

1: Main Objective(s) of the project:

The main objective of the project is to drive and promote the adoption of online laboratory experimentations across different domains such as engineering, science and technology through designing and developing an efficient laboratory learning environment. The specific objectives of the project can be stated as follows:

1- Design and development of efficient Laboratory Learning System (LLS) for online laboratory experimentations activities.
2- Provides more hands-on time for students in an efficient, flexible and cost effective manner.
3- Provides robust learning experiences under a safe environment to conduct experiments especially for post-COVID-19 era.
4- Removing the barriers of time and distance and achieving the social distancing requirements due to COVID-19 pandemic.
5- Efficient and effective utilization of the available laboratory resources in universities, which can be remotely shared and utilized by different users.
6- Reduce the laboratory supervision burden and its required human resources through the introducing of virtual assistant service (E-Instructor) for online laboratory experimentations.
7- Prepare students for tomorrow's workplace in which remote work and mass collaboration will be the norm.
8- Help in solving the problem of limited resources and funding for laboratory experiments especially for public universities and laboratories that need expensive resources.

2: Objectives of the reporting period:

The main objectives of the reporting period can be stated as follows:

1- Design and Development of Basic Services of the LLS including users' management service, users' authentication and authorization service.
2- Design and Development of laboratory assignment and scheduling services as well as LLS users and learning database.
3- Development of an Embedded Laboratory Experiment Authoring Tool in the LLS
4- Design of an efficient integration model between LLS and LMSs
5- Design an efficient virtual assistant technique for online laboratory experimentations. (M8-M9)
6- Design of an effective evaluation and assessment criteria for online experimentation activities.
7- Develop and test the designed evaluation and assessment criteria.
8- Preparation and Configuration of Virtual and Remote Laboratory Experimentation Resources
9- Preparation of Laboratory Learning Objects (LLOs) for Electronics and Telecommunication experiments

3: **English Summary:**

The main scope of this report is to provide the main outcomes and deliverables for the second six months of the project. According to the project GANTT chart, all project activities that were already scheduled to be implemented in the second six months (the reporting period) have been carried out with very good results. The report includes the Development of a high-level architecture design for the laboratory experiment authoring tool to facilitate the operation of creating a laboratory experiments content that fulfills a chosen course requirements. The designed authoring tool allows the instructors to author a new experiment that consisting of multiple pages. On each page, the author can create a learning content in different forms such as text, image, table, Virtual and Remote Lab object (VRL), etc.. Also the assessment questions in different forms can be created by using the designed authoring tool such as multiple choice questions, fill in blanks questions, matching questions, etc. The created experiments and student's activities in addition to the association relations between students, courses, Instructors are stored in the LLS users and learning database.

The report also includes the design of laboratory assignment and scheduling platform, which provides a maximum experimentation capacity and minimum blocking rate for students during the booking and experimentation runtime. Here a Matching Game based Resource Association (MGRA) technique is used to optimize the lab's resources allocation for the students who applied for remote access experimentation. After allocating the resources for a specific remote lab experimentation and before the running time of the experiment, the hardware/instruments resources are prepared and configured to be remotely accessed and controlled through the a designed control program developed using the Standard Commands for Programmable Instruments (SCPI) commands.

The design and development of a communication service platform that enables synchronous and asynchronous way of communication between students while performing required laboratory experiments in LLS are also presented in the report. Two models for students group interaction are designed with the consideration in each model the group management, way of communication, and sharing aspects. The first model is the sequential interaction which reflects the synchronous interaction between students with a constructed group. The Second model of interaction is concurrent interaction, which reflects both types the synchronous and asynchronous.

Moreover, an efficient design for a virtual assistant (VA) that offers different types of assistance to students who are facing difficulties while conducting the online experiment is provided. To provide an efficient design for the VA, a survey of the existing techniques for virtual laboratory assistants is first conducted. The designed VA is based on estimating the student's level of difficulties according to the real-time mouse activities of the student while conducting the experiment in which the offered help is decided according to the estimated cognitive style of the student.

A survey of existing techniques for student performance evaluation and assessment in the online learning process is covered in this report to address the difficulties, practices, and solutions that arise when offering successful methods of assessment to students in laboratory experiments. Based on the survey, the most suitable assessment tools for the proposed LLS are are decided to be short electronic quizzes, performance observation assessment tools, and E-Portfolios.

A booklet contains laboratory learning contents and learning scenarios for Electronics and Telecommunication experiments are prepared and reported in this report. The prepared learning contents reflect the added features in the proposed authoring tool and ease the creation of satisfied laboratory learning content. The different laboratory experiments prepared to take into consideration how the added features in the proposed authoring tool will ease the laboratory experiment creation process and fulfill each laboratory experiment requirements.

A survey of the different standard integration technologies between the traditional Learning Management Systems (LMS) and the Laboratory Learning Systems (LLS) is provided in order to be fully aware of the main integration aspects to be considered during the design and implementation of the integration model. Based on the conducted survey, the most popular and widespread standards related to the interactivity and architecture that allow or facilitate the integration of online laboratory-type educational content in learning platforms are LTI, xAPI and SCORM. Also, from the study of the basic operation of LTI and xAPIs integration technologies, we found that both LTI and xAPI are required for the integration of the proposed LLS with LMSs and other educational environments. Finally, an integration model between LLS and the LMSs provides seamless and secure information exchange are proposed to allow the users to seamlessly login to the LLS through the LMS (using LTI Module) and manage the access privileges of the different users and do all the required tasks for their roles.

4: **Arabic Summary:**

الهدف الرئيسي لهذا التقرير هو تقديم النتائج والمخرجات الرئيسية للأشهر الستة الثانية من المشروع الذي يستهدف انشاء بيئة التعلم المعملية عبر الانترنت. وفقًا لمخطط الإطار الزمنى الخاص بأنشطة المشروع، فقد تم تنفيذ جميع أنشطة المشروع التي كان من المقرر بالفعل تنفيذها في الستة أشهر الثانية (الفترة الخاصة بالتقرير) بنتائج جيدة. يتضمن التقرير تطوير تصميم هيكلى عالي المستوى لأداة تأليف التجربة المعملية لتسهيل عملية إنشاء محتوى تجارب معملية يلبي متطلبات المقرر المختارة. تتيح أداة التأليف المصممة للمعلمين تأليف تجربة جديدة تتكون من عدة صفحات. في كل صفحة، يمكن للمؤلف إنشاء محتوى تعليمي مختلف مثل نص وصورة وجدول وكائن مختبر افتراضي عن بعد (VRL) وما إلى ذلك أو أسئلة التقييم المختلفة مثل الاختيار من متعدد، املأ الفراغات والمطابقة وما إلى ذلك حيث يتم تخزين جميع التجارب التي تم إنشاؤها وأنشطة الطلاب وعلاقات الارتباط بين الطلاب والمقررات والمعلمين في قاعدة بيانات التعلم الخاصة بالنظام.

يتضمن التقرير أيضًا تصميم منصة لجدولة وتخصيص التجارب المعملية للطلاب والتي توفر أقصى سعة تجريبية وأدنى معدل لحظر الطلاب أثناء الحجز ووقت تشغيل التجربة. هنا يتم استخدام تقنية جمعية الموارد المستندة إلى لعبة المطابقة (MGRA) لتحسين تخصيص موارد المختبر وخدمات إدارة الموارد للطلاب المتقدمين اثناء الوصول إليه عن بُعد. بعد تخصيص موارد المعمل لتجربة معملية محددة

عن بُعد وقبل وقت تشغيل التجربة، يتم إعداد موارد الأجهزة / الأدوات وتهيئتها بحيث يمكن الوصول إليها عن بُعد والتحكم فيها عبر الإنترنت باستخدام برنامج التحكم المنفذ باستخدام الأوامر القياسية للأدوات القابلة للبرمجة) .

تم ايضا تقديم تصميم وتطوير منصة خدمة الاتصال التي تتيح طريقة متزامنة وغير متزامنة للاتصال بين الطلاب أثناء إجراء التجارب المعملية المطلوبة في LLS في هذا التقرير. تم تصميم نماذج تفاعل جماعية من الطلاب تأخذ في الاعتبار في كل نموذج إدارة المجموعة وطريقة الاتصال وجوانب المشاركة. النموذج الأول هو التفاعل المتسلسل الذي يعكس التفاعل المتزامن بين مجموعة من الطلاب. والنموذج الثاني للتفاعل هو التفاعل المتوازى الذي يعكس كلا النوعين غير المتزامن والمتزامن.

علاوة على ذلك ، تم تقديم تصميم فعال لمساعد افتراضي (VA) يقدم أنواعًا مختلفة من المساعدة للطلاب الذين يواجهون صعوبات أثناء إجراء التجربة عبر الإنترنت. لتصميم ذلك المساعد الافتراضي الفعال، تم إجراء مسح للتقنيات الحالية لمساعدي المختبرات الافتراضية، وتم تصميم تقنية نمذجة سلوك الطالب واختبارها. يعتمد المساعد الافتراضي المصمم على تقدير مستوى الصعوبات التي يواجهها الطالب وفقًا لأنشطة الماوس في الوقت الفعلي للطالب أثناء إجراء التجربة ويقدم المساعدة وفقًا للأسلوب المعرفي المقدر للطالب.

يتناول هذا التقرير ايضا مسحًا للتقنيات الحالية لتقييم أداء الطلاب وتقييمه في عملية التعلم عبر الإنترنت، وذلك من اجل الوصول الى معالجة الصعوبات ومعرفة الممارسات وتقديم حلول تقييم مناسبة للطلاب في التجارب المعملية. بناءً على الاستبيان، فإن أنسب أدوات التقييم لـ LLS المقترحة هي الاختبارات القصيرة الإلكترونية، وأدوات تقييم مراقبة الأداء، والمحافظ الإلكترونية.

في هذا التقرير، تم إعداد كتيب يحتوي على محتويات التعلم المختبر وسيناريوهات التعلم والتقييم لتجارب الإلكترونيات والاتصالات. تعكس محتويات التعلم المعدة الميزات المضافة في أداة التأليف المقترحة وتسهل إنشاء محتوى تعليمي مختبري. تم اعداد التجارب المعملية المختلفة لتأخذ في الاعتبار كيف أن الميزات المضافة في أداة التأليف المقترحة ستسهل عملية إنشاء التجارب المعملية وتفي بمتطلبات كل تجربة معملية.

تم تقديم ايضا مسح لتقنيات التكامل القياسية المختلفة بين أنظمة إدارة التعلم التقليدية (LMS) وأنظمة التعلم المختبري (LLS) للوصول الى دراية كاملة بجوانب التكامل الرئيسية التي يجب مراعاتها أثناء تصميم نموذج التكامل. بناءً على الدراسة التي تم إجراؤها، فإن المعايير الأكثر شيوعًا والأكثر انتشارًا المتعلقة بالتفاعل والبنية التي تسمح أو تسهل دمج المحتوى التعليمي من نوع المختبر عبر الإنترنت في منصات التعلم هي SCORM و xAPI و LTI . من دراسة التشغيل الأساسي لتقنيات تكامل LTI و xAPI ، وجدنا أن كلا من LTI وxAPI مطلوبان لدمج LLS المقترح مع LMSs والبيئات التعليمية الأخرى. أخيرًا، تم اقتراح نموذج تكامل بين LLS و LMSs يوفر تبادلًا سلسًا وآمنًا للمعلومات، مما يسمح للمستخدمين بتسجيل الدخول بسلاسة إلى LLS من خلال LMS باستخدام وحدة LTI وإدارة امتيازات الوصول للمستخدمين المختلفين والقيام بكل المهام المطلوبة لدورهم.

5: Achievements Summary of Past Reports

The past report, which is the first report, was including a comprehensive survey on the existing architectures and models for online laboratory experimentations. Furthermore, the report presented a high-level architecture for the proposed laboratory learning system (LLS) that was designed considering the different defined requirements and services. Moreover, the report was specifying the various software developments and configurations required by the LLS server platform to allow users to remotely access the different virtual/physical resources required by various laboratory learning objects (LLOs). Also, a low-fidelity prototype sketches that show the basic services and features of the proposed LLS were presented, and a survey on the various authoring tools used in the learning management systems and their suitability for the application in the laboratory experimentation system were provided.

The detailed past report tasks are as follows:

T1.1: Survey and investigate existing architectures and models for online laboratory experimentations.

- **Start Month: M1 – End Month: M1.**

A survey on the existing architectures and models for online laboratory experimentations. The survey starts by describing the different components of a traditional LMS and the relationship between each of them. Then, a survey on different laboratory learning systems developed in either research work, universities' projects and commercials were provided. Based on this survey, a comparison between these presented systems and our proposed one was clearly stated showing the new required features that should be developed in the proposed LLS system compared with the existing systems.

T1.2: Identify system requirements for the proposed online laboratory experimentations environment.

- **Start Month: M2 – End Month: M2.**

Based on the conducted survey for system requirements elicitation process, data had been collected from N=332 individuals which they located in 9 public universities and 3 private universities. 79.3% of respondent have previous experience in e-learning systems, and 90% of them took the experience of courses. The reliability was calculated using Cronbach's alpha and reached α of 0.82 which this result reflects the highest consistency of the LLS requirements that have been presented in this questionnaire. On the other hand, an identification of the system requirements for the proposed online laboratory experimentations environment. The system requirements can be divided into functional and non-functional requirements, software and hardware system requirements. A description for each of these requirements were presented.

T1.3: Develop a high-level architecture design for the proposed system.

- **Start Month: M2 – End Month: M2.**

High-level architecture for the proposed laboratory learning system (LLS) that was designed considering the different defined requirements and services was presented. A description of the different components of the proposed high-level architecture design was illustrated. The high-level architecture design includes users' management, experiments management, remote virtual lab, remote lab station, authoring tool, virtual assistant service, assessment, and analytics service, integration service, learning record store, web interface module, and the infrastructure hardware and software components. Moreover, the report was specifying the various software developments and configurations required by the LLS server platform to allow users to remotely access the different virtual/physical resources required by various laboratory learning objects (LLOs).

T1.4: Preparation of the low-fidelity prototype (paper-based sketches) that shows basic services and features of the Laboratory Learning System (LLS).

- **Start Month: M3 – End Month: M4.**

The low-fidelity prototype sketches that show the basic services and features of the proposed LLS were presented in the past report. First, the authorized functions of the different roles in the proposed LLS were reported. Then, low-fidelity prototype sketches for the different LLS functions were presented along with a detailed description for each function.

T2.1: Design of different user interfaces (UIs) for the basic services provided by the LLS.

- **Start Month: M3 – End Month: M5.**

Based on the designed low-fidelity prototype sketches, the high-fidelity user interfaces for the basic services such as user management, authentication and authorization were developed and the UIs prototype for the proposed system with respect to agile software development were implemented.

T2.2 Design and development of users' management service.

- **Start Month: M4 – End Month: M7.**

A user control panel running as API services was developed using ASP.NET core framework, along with the related frontend user interfaces developed using Angular framework. The backend was deployed on Heroku online platform using Docker containers, and the frontend was deployed on Netlify online platform.

T2.3 Design and development of users' authentication and authorization service.

- **Start Month: M4 – End Month: M7.**

We have used Angular framework with separating the models and views for better flexibility in our system components. Also, the backend was deployed with REST-API for more reusability of components over different platforms. The main issue with most LMS is the integration with several on the shelf products. Some known software design patterns were used for better performance of our LLMS which are singleton, object pool, observer, strategy and others. Each of those design patterns assure one of the software engineering primitive principles. The singleton and object pool assure single instance of connections to the database for scalability and fast reusages of connections. The observer design pattern is used for notifications and allowing adding observers without changing code. The strategy design pattern was used for changing between different roles for execution. A web page for user authentication was deployed applying notifications and login functionality.

T2.6 Design and development of LLS users and learning database.

- **Start Month: M4 – End Month: M11.**

A primitive design for the database was implemented to assure permission, roles management. PostgreSQL was selected as the database management system, which was deployed on Heroku online platform as a docker container.

T3.1 Survey and investigate existing e-learning authoring tools.

- **Start Month: M5 – End Month: M5.**

All the available off-the-shelf authoring tools were studied, the different authoring tools components were defined, and different learning theories are presented. Also, a brief about SCORM standard for authoring tool was presented and finally, a comparison between different available authoring tools are conducted and Concluded our needs.

T3.2 Identify key requirements for the laboratory experiment authoring tool.

- **Start Month: M5 – End Month: M5.**

A survey on the various authoring tools used in the learning management systems and their suitability for the application in the laboratory experimentation system were provided. Based on this survey, the key requirements for the proposed laboratory experiment authoring tool were explored and identified. Finally, the needed software tools for the development process and testing were specified.

T3.3 Develop a high-level architecture design for the laboratory experiment authoring tool.

- **Start Month: M6 – End Month: M7.**

The design of the high-level architecture for the laboratory experiment-authoring tool, which include all the facilities that assist the author to create an efficient e-content for laboratory experiments.

T7.1 Prepare and configure the laboratory server platform for remote access of laboratory resources.

- **Start Month: M5 – End Month: M10.**

Two models are adopted by the proposed LLS to access and manage the available lab resources by different users, session-based model and VM-based model. In session-based model, the experimentation software application is centrally installed on the lab server and accessed simultaneously by multiple users through independent virtual sessions. In this model, the computation and memory resources of the lab server will be shared between users according to the requirements for each running experimentation application. The session-based virtualization model is mainly suitable for experimentations that require specific software application. On the other hand, the VM-based model allows the user to full access the desktop of a specific machine with the privileges to use the required applications to conduct the assigned virtual or remote-controlled experiment. In this model, a pool of VMs is established on the lab server in which one of the VMs is assigned on demand to each user according to the type of conducted experiment. The computation and memory resources for each VM are customized and assigned to fit the demands of different software applications running by each experiment. The VM-based virtualization model is mainly suitable for experimentations that require to run a set of software applications with specific computation and memory resources requirements.

6: Newly implemented tasks during this reporting period:

(Brief, concise and supported with HD graphics, photos and statistically analyzed data). Title of the task, start and end dates, objectives, methodology and results must be given for each task. Additional sheets can be used. Keep adhered to this report form. Reports can be given in Arabic or English, however summaries must be in Arabic and English.

WP2: Design and Development of Basic Services of the LLS (M3-M14)

T2.3 Design and development of users' authentication and authorization service (Continued).

- **Start Month: M4 – End Month: M7.**
- **Detailed results of this task are provided in the attached Appendix (1).**

- **Objectives:**

  Reliable authentication and authorization of any user in order to use any function offered by the proposed LLS is mandatory. Hence, the development of a flexible authentication and authorization services was maintained, taking into consideration the future integration for users with existing LMSs.

- **Methodology:**

The following methodology was used to design and develop the authentication and authorization services for users:

1) JSON web tokens mechanism is used to retain the user logged in the system.
2) Authentication is conducted from the developed user interface login screen or via SSO mechanism.
3) Each offered API by the system is considered a permission, which should be attainable by the user in order to fulfil his request.

- **Results:**

We have used Angular framework with separating the models and views for better flexibility in our system components. Also, the backend was deployed with REST-API for more reusability of components over different platforms. The main issue with most LMS is the integration with several on the shelf products. Some known software design patterns were used for better performance of our LLS which are singleton, object pool, observer, strategy and others.

Each of those design patterns assure one of the software engineering primitive principles. The singleton and object pool assure single instance of connections to the database for scalability and fast reuses of connections. The observer design pattern is used for notifications and allowing adding observers without changing code. The strategy design pattern was used for changing between different roles for execution. A web page for user authentication was deployed applying notifications and login functionality.

T2.4: Design and development of laboratory assignment and scheduling services.

- **Start Month: M8 – End Month: M11.**
- **Detailed results of this task are provided in the attached Appendix (2).**

- **Objectives:**

To design and develop the lab assignment and scheduling services in order to facilitate the remote access of the laboratory resources. The laboratory resource platform should be designed to manage the laboratory resources assignment and scheduling in order to provide a maximum experimentation capacity and minimum blocking rate for students during the booking and experimentation runtime.

- **Methodology:**

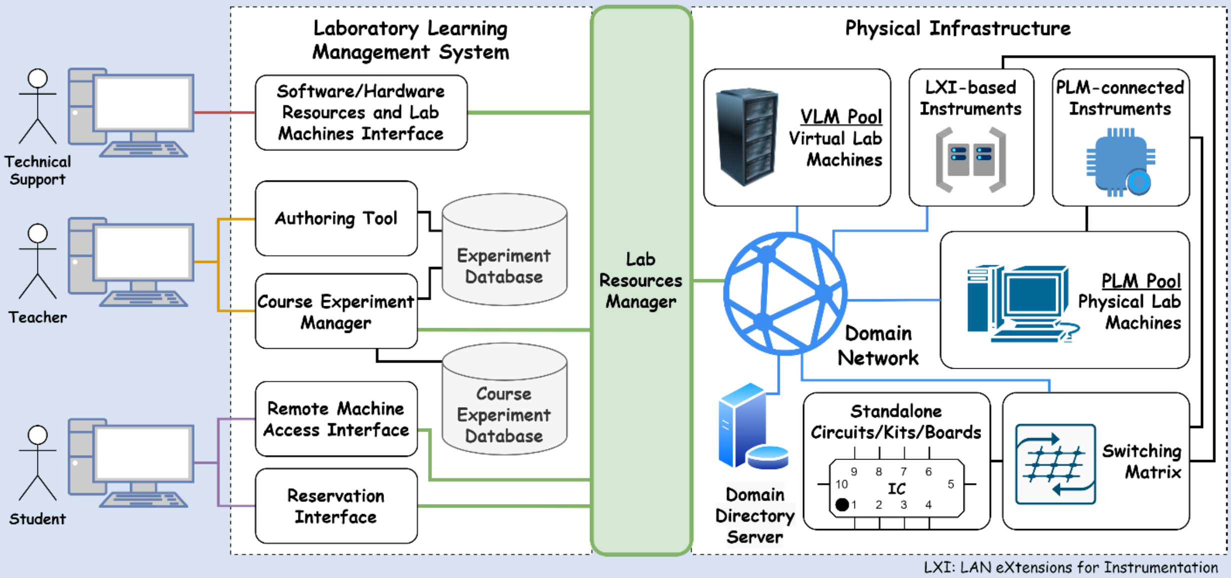
In order to prepare and configure the laboratory resource manager for optimum scheduling and resources assignment, the following procedures are carried out:

1) A mathematical formulation for the laboratory resource management in the laboratory learning system is conducted.
2) The problem of minimizing the student’s number of blocked time slots is formulated, which reflects the maximization of the system capacity in terms of student’s assignment.

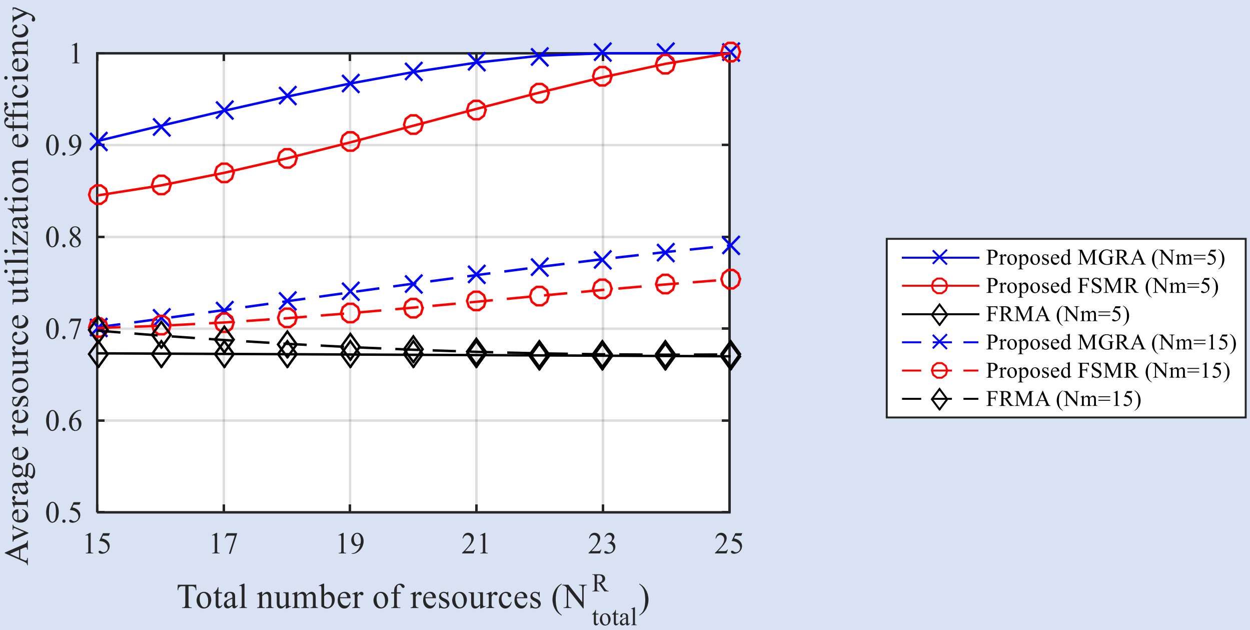
3) Three laboratory learning management systems are proposed based on Fixed Student to Machine Reservation (FSMR), Fixed Resource to Machine Assignment (FRMA), and Matching Game based Resource Association (MGRA) to solve the formulated problem.
4) The performance of the proposed remote laboratory management systems are evaluated using simulation tools.

- **Results:**

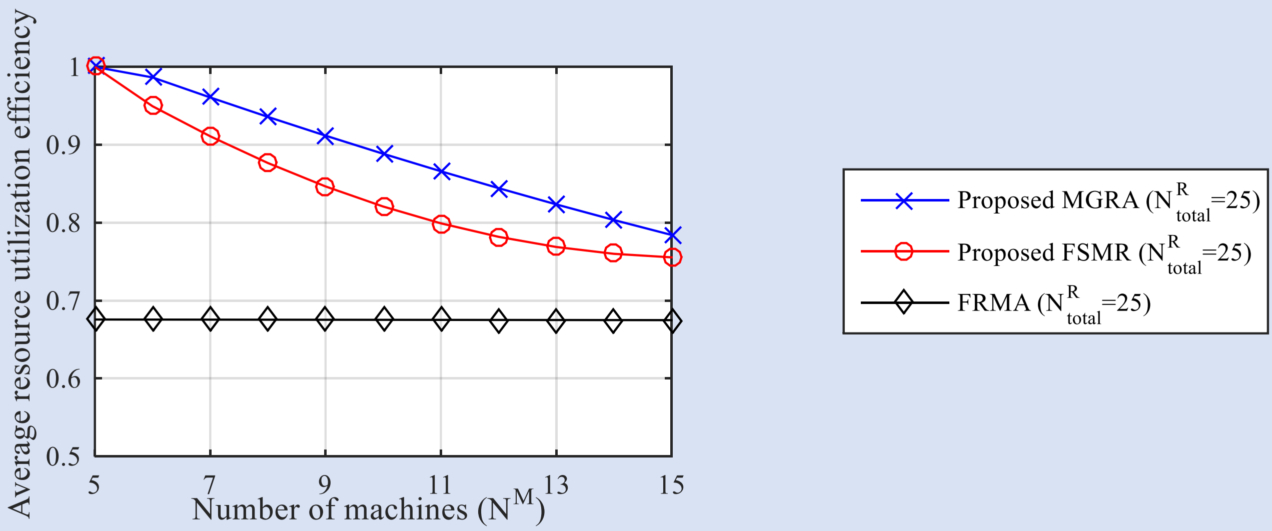
The proposed laboratory learning system consists of three main subsystems:



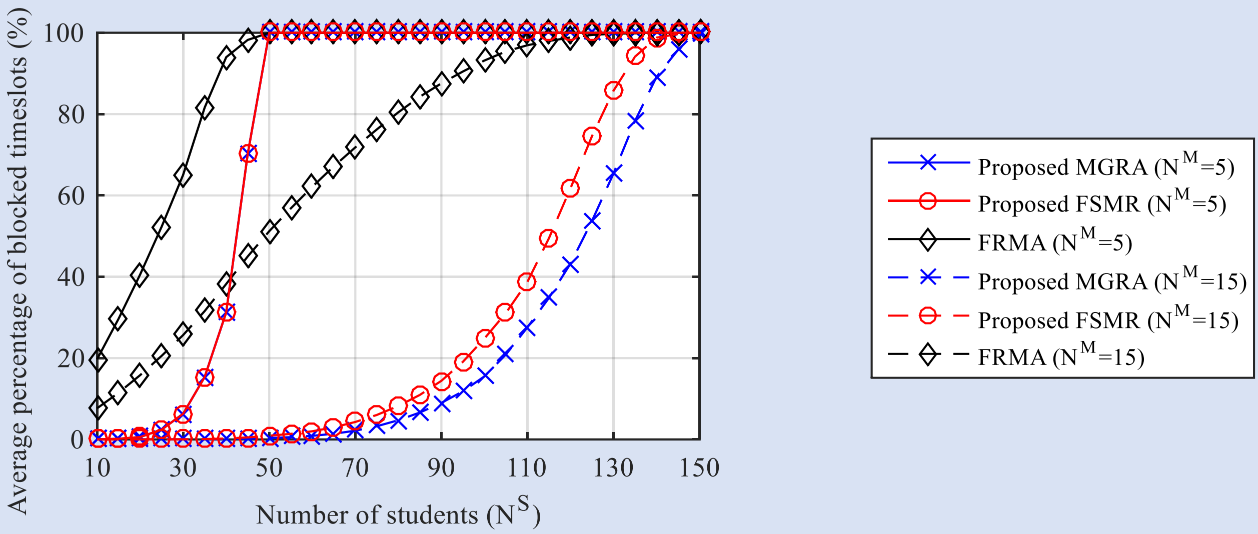
- **The laboratory learning management subsystem:** Which is the management software that helps teachers to create the Laboratory Learning Object (experiment) and manage the way of experiment execution, the interface between the student and the physical lab resources, and allow technical support to manage the hardware and software lab resources.
- **The physical laboratory infrastructure:** Which includes all virtual and physical lab machines in addition to the different instruments and tools of remote controlled labs.
- **The Laboratory Resource Manager:** Which manages the laboratory resources. A comparison between the different remote laboratory management schemes in terms of the average resource utilization efficiency while changing the total number of resources in the system, at number of machines = 5 and number of machines =15, is presented in the following figure. It can be shown that the both the proposed management schemes MGRA and FSMR outperform the FRMA management scheme at different number of machines, while increasing the number of resources, in terms of resource utilization efficiency.



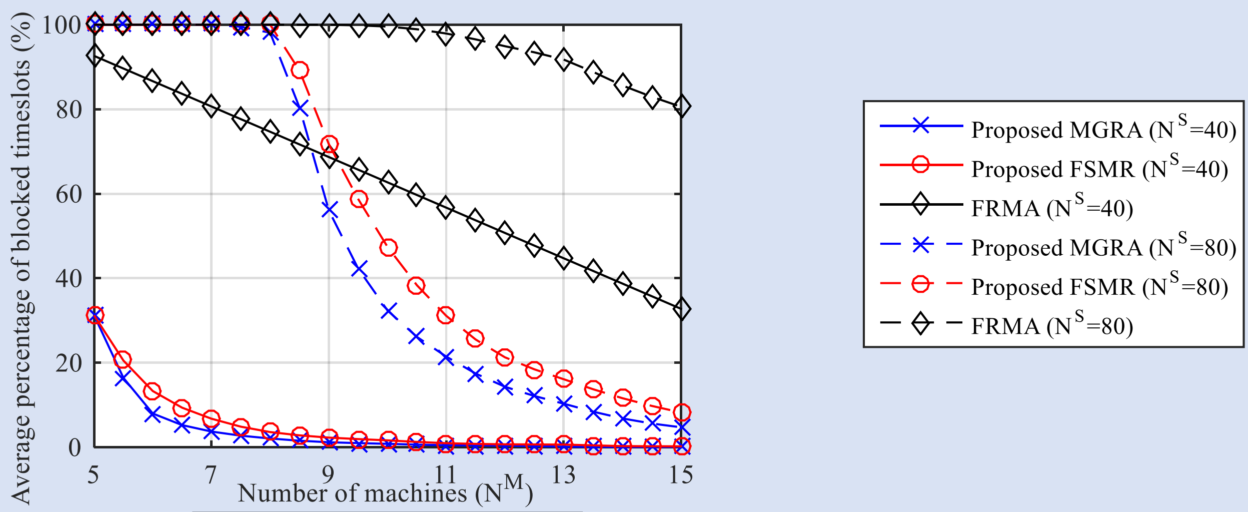
Moreover, the effect of changing the number of physical and virtual machines for the different management schemes in terms of average resource utilization efficiency is shown in the following figure. It can be shown that both the proposed management schemes MGRA and FSMR achieves higher resource utilization efficiency compared to the FRMA management scheme while increasing the number of machines.



Also, to study the effect of increasing the number of students on the remote laboratory management schemes, the figure below shows the performance of the different management schemes in terms of average percentage of blocked timeslots at different number of machines while changing the number of students in the system. It can be shown that the both the proposed management schemes MGRA and FSMR achieves lower percentage of blocked timeslots compared to the FRMA management scheme while increasing the number of students in the system, at different number of machines, which indicates better performance.



Furthermore, the effect of increasing the number of machines on the performance of the different remote laboratory management schemes in terms of average percentage of blocked timeslots at different number of students in the system is studied in the below figure. It can be shown that also both the proposed management schemes MGRA and FSMR achieves lower percentage of blocked timeslots compared to the FRMA management scheme while increasing the number of machines, at different number of students in the system, which indicates better performance.



From the previous results, we can conclude that using the traditional FRMA management scheme can only achieves the same performance of both the MGRA and FSMR management schemes when each software or instrument resource is assigned to a single physical or virtual machine, which is considered a costly solution. However, if the physical and virtual machines are having multiple softwares installed or connected to multiple instruments, using the MGRA will always outperforms other management schemes.

T2.5: Design and development of laboratory synchronous and asynchronous communication services.

- **Start Month: M11 – End Month: M14.**
- **Detailed results of this task are provided in the attached Appendix (3).**

- **Objectives:**

Design and develop a communication service platform that enable synchronous and asynchronous way of communication between students while performing required laboratory experiment in LLS.

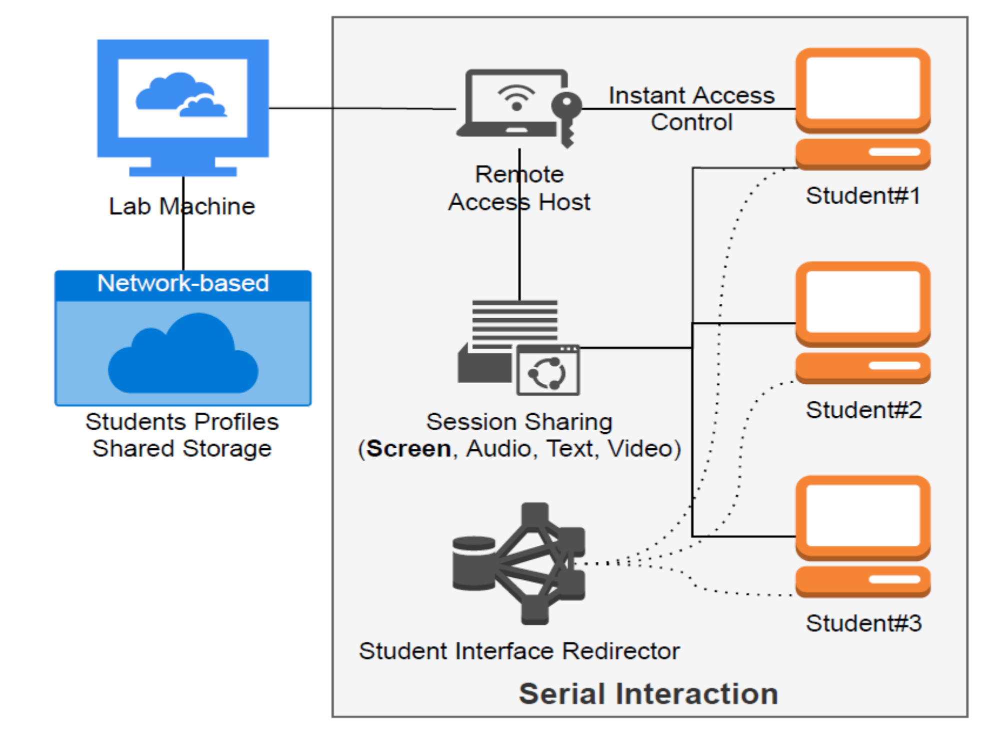
- **Methodology:**

In order to show the synchronous and a synchronous way of communication between groups of students while performing a specified laboratory experiment in a registered course, we design and present two models for students group interaction that considering in each interaction model, group management, way of communication and sharing aspects.

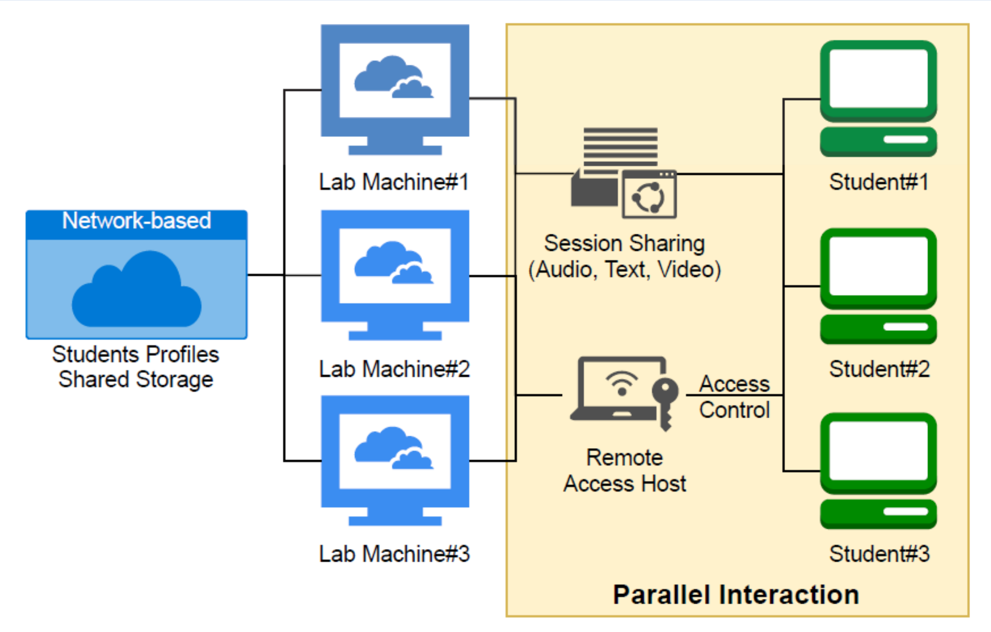
- **Results:**

Present two types of student's interaction that show synchronous and asynchronous way of communication between students. We also designed a runtime experiment student's web-based graphical user interface to show all added features.

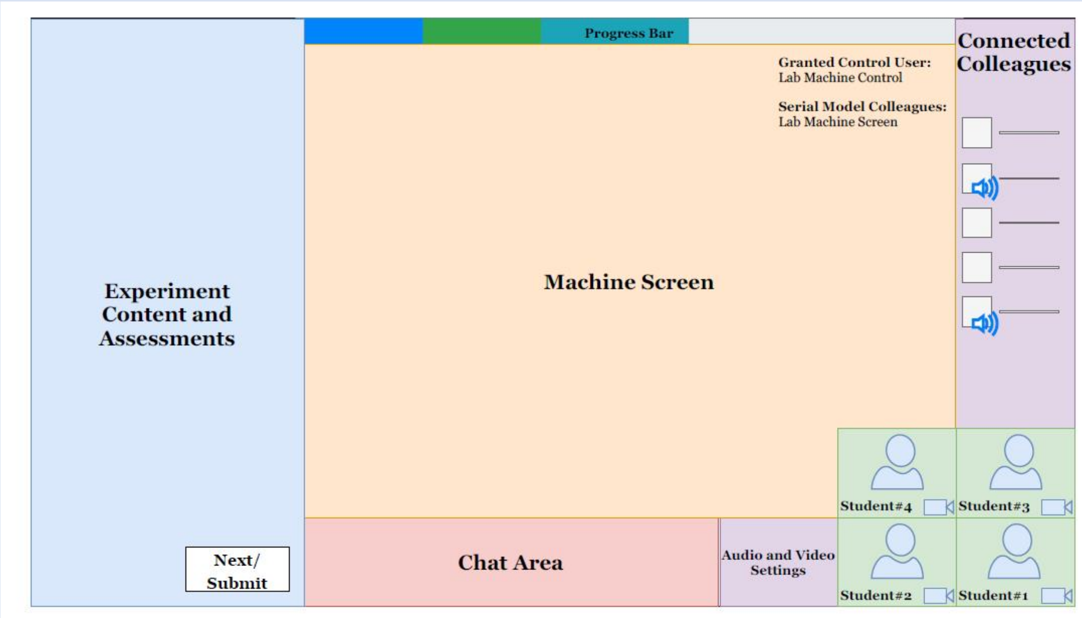
First, the sequential interaction model as shown in figure below, that reflects the synchronous interaction between students with a constructed group. This type of interaction allows only one student to access remotely and control lab machine to perform his assigned part while other students can share allowed student his activity using a session sharing module that is created to allow 4 types of sharing and collaboration between students: Video sharing, Audio sharing, Chat and Screen sharing. Students in turns can switch interface and control the lab machine to finish the assigned parts using students interface switch module. When a student finish his assigned part, the results will be saved in lab machine under student profile in a group-shared folder.



The second type of interaction is the concurrent interaction model as shown in figure below, which reflects both types the asynchronous and synchronous. In this type of interaction, each student will perform his assigned part of experiment alone (asynchronously) and then share his own results in a shared folder. A session sharing module is also added in this type to allow synchronization in form of video, audio and chat between students.



A Runtime experiment student's web-based graphical user interface is also designed which can include at the center, the remotely connected lab machine screen that can be shared among students, if one of students own the instant access control. The right hand side of the screen shows the information of each student in the constructed group. The bottom of screen shows the chat area, the students audio video settings to switch camera/voice on/off, and the multi-video conference area showing the video coming from each student which help a synchronous communication between students.



Published Paper:

Ahmed M. Abd El-Haleem, Noha A. Elmosilhy, Abdullah I. Salama, Eman Serag El Din, and Mahmoud M. Elmesalawy, "Efficient Collaborative and Cooperative Laboratory Experimentation System for Online Engineering, Science and Technology Education," 19th International Conference on Remote Engineering and Virtual Instrumentation (REV 2022), 2022.

T2.6: Design and development of LLS users and learning database.

- **Start Month: M4 – End Month: M11.**
- **Detailed results of this task are provided in the attached Appendix (4).**

- **Objectives:**

Designing the first sprint database that can handle the assignment of roles flexibility and the process of creating courses with experiments and the ability of assigning teachers and students with the needed information about the student activity through the course.

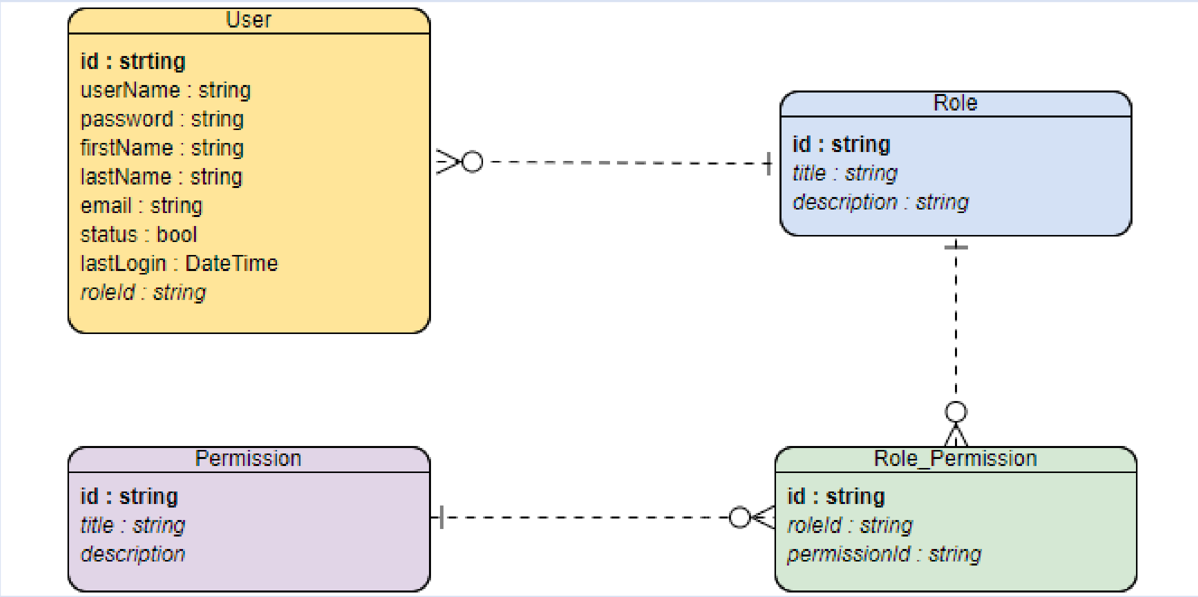
- **Methodology:**

Making the assignment of roles and permission responsibilities dynamic and can be changed at any time. This feature was achieved by adding all the pages and functionalities that could be accessed by any user as rows to the database and then the functionality of controlling who accessed what was implemented by using a many to many relational tables.

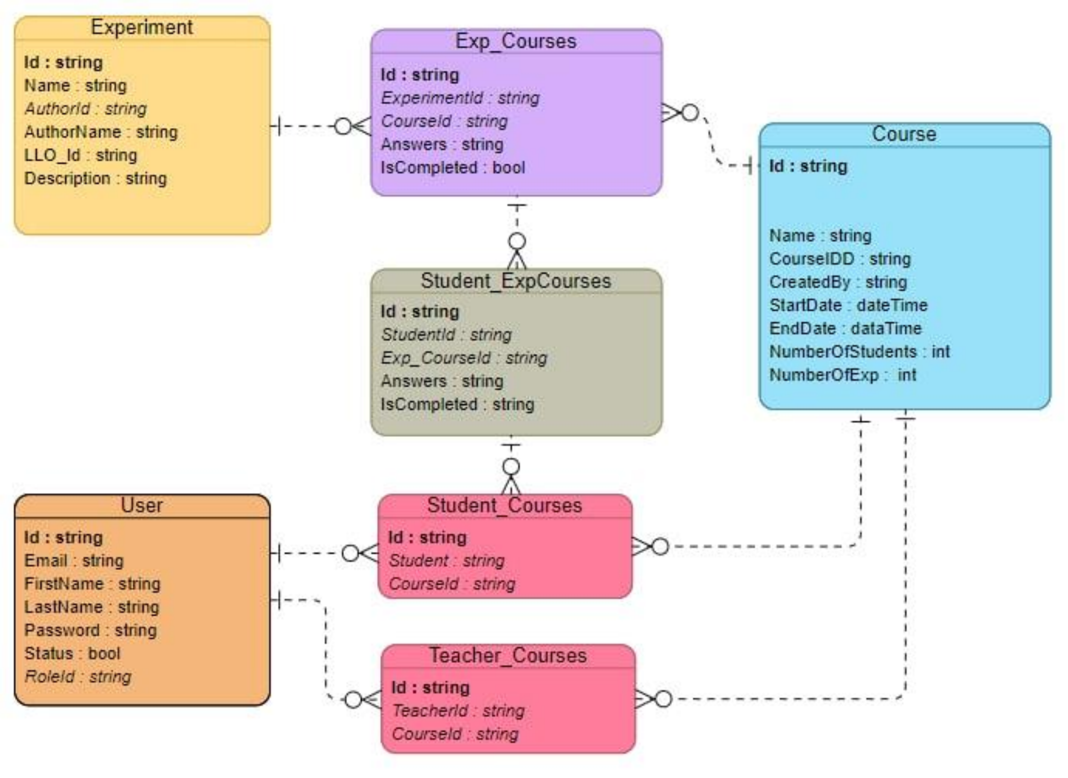
- **Results:**

A primitive design for the database was implemented to assure permission, roles management, course and experiment's management. PostgreSQL was selected as the database management system, which was deployed on Heroku online platform as a docker container.

  - ERD that represent the relation between the role and permission.



  - ERD that represent the relation between the course and experiment including the students and teachers.



WP3: Development of an Embedded Laboratory Experiment Authoring Tool in the LLS (M5-M14)

T3.4: Develop an embedded laboratory experiment authoring tool in the LLS.

- **Start Month: M8 – End Month: M13.**
- **Detailed results of this task are provided in the attached Appendix (5).**

- **Objectives:**

Develop a high-level architecture design for the laboratory experiment-authoring tool to facilitate the operation of creating a laboratory experiments content that fulfill a chosen course requirements. Through the authoring tool, an instructor can author new experiment that consists of multiple pages. In each page, the author can create a learning content such as text, image, table, etc. or assessment questions such as multiple choice; fill in blanks and matching questions, etc.

- **Methodology:**

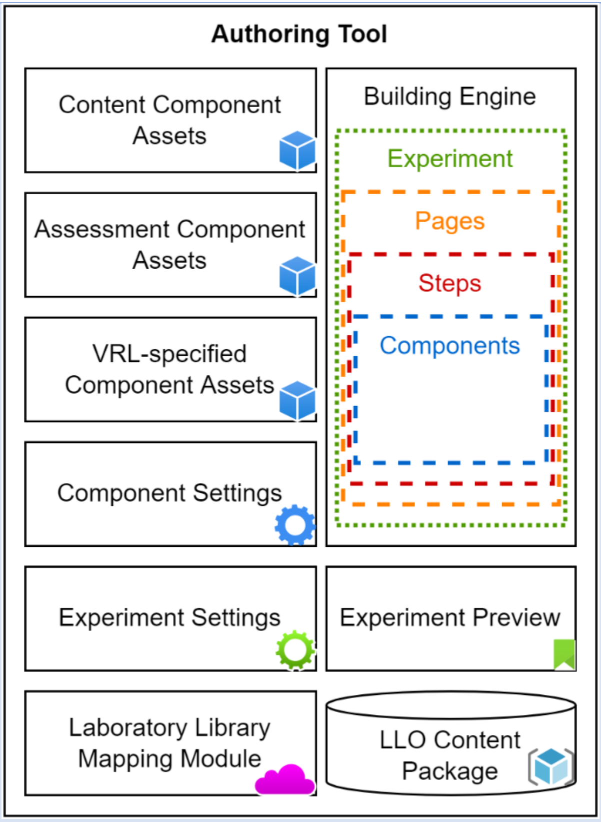
Design a high-level architecture design for the laboratory experiment-authoring tool, by designing new authoring modules that help the operation of creating laboratory experiments for those unaware to develop web pages. We start by dividing the experiment into multiple pages; each page consists of many steps, where each step is composed of drag and drop components.

Which can be content such as text, image, table, etc., and/ or assessment question such as multiple choice, fill-in-blanks, matching, etc., and also VRL-related component as previously discussed. We also add experiment settings, content component settings and assessment settings as shown below in Table. The help option within component settings includes upload feature that allows attaching images, videos, and documents, as well as plain text for helping the student in specific experiment step that fit with the student's learning cognitive style.

We study the full cycle after creating a new experiment via instructor through authoring tool, until the student starting the assigned experiment. Starting by creation process, registration process, reservation of a time-slot to perform assigned laboratory experiment including all needed software and hardware to fulfill the laboratory experiment requirements. Ended by the assessment and grading process.

- **Results:**

The proposed design succeed to include added features that allow sufficient transition of real laboratory experiment to be held remotely. The following figure illustrates the modules that comes out of the box with the authoring tool. Components are the smallest building unit in the experiment. Pre-built-in assets are available within our proposed authoring tool for the three categories: content, assessment, and VRL-specific. Settings per component and for the whole experiment can be customized through the authoring tool, with an option to preview student's view. The authoring tool is well integrated with the Laboratory Library Mapping module that interfaces with the Laboratory Library Manager that responsible on managing the storage. The authoring tool stores the experiment in a JSON package called the Laboratory Learning Object (LLO).



WP4: Integration of LLS with the Learning Management Systems “LMSs” (M10-M15)

T4.1: Survey and investigate different standard integration technologies and models for LMSs.

- **Start Month: M10 – End Month: M10.**
- **Detailed results of this task are provided in the attached Appendix (6).**

- **Objectives:**

The objective of this task is to provide a survey of the different standard integration technologies between the traditional Learning Management Systems (LMS) and the Laboratory Learning Systems (LLS) in order to be fully aware of the main integration aspects to be considered during the design of our integration model. The survey starts by describing the different locations and interaction levels between the LMS and LLS and states the criteria used in evaluating the integration quality. Then the different standard integration technologies are studied.

Methodology:

The following methodology was used to conduct the required survey on the different standard integration technologies:

1) Study and investigate the different integration levels between the LMS and the LLS.

2) Study and investigate the different criterias used in evaluating the integration quality.
3) Study and investigate the various integration standards used for the Integration of online labs into educational systems.
4) Determine the main location and interaction levels as well as the standard integration technologies used in the integration of our proposed LLS with the standard LMS systems.

- **Results:**

The most popular and widespread standards related to interactivity and architecture that allow or facilitate the integration of online laboratory-type educational content in learning platforms are SCORM, xAPI and LTI. On the other hand, a standard not yet widely used, but directly related to the integration of online laboratories and learning platforms, the IEEE 1876-2019 standard, has recently appeared.

T4.2: Study the basic operation of LTI and xAPIs integration technologies.

- **Start Month: M10 – End Month: M11.**
- **Detailed results of this task are provided in the attached Appendix (7).**

- **Objectives:**

The objective of this task is to provide a study for the the basic operation of the most popular integration standard technologies, which are Learning Tools Interoperability (LTI) and Experience Application Programming Interface (xAPI). The study starts by describing the objectives and the key concepts of the LTI standard, then the standard basic operation/ workflow, and statement's structure are also described, followed by a conducted comparison between the different LTI versions. Also, the Experience API standard, its operation, and xAPI statements are the structured data about a learning experience are described. Finally, a comparison between the LTI and xAPI is conducted and clearly stated showing the strength and weak points in each one of them, which help in the integration design process of our LLS system, followed by some real integration examples.

- **Methodology:**

The following methodology was used to conduct the required study on the LTI and xAPI standard integration technologies operations:

1) Study and investigate the different LTI standard versions, objectives, operation, and its statement's structure.
2) Study and investigate the xAPI standard, statements object model, and its operation.
3) Determine the main differences between the LTI and xAPI standard.

- **Results:**

We conclude our study with a comparison to show the differences between LTI and xAPI integration standard. The most important similarity is that learning content does not have to be within the LMS but can also reside on a content server. The table below shows the main differences, in which the LTI used for integrating web-based learning applications with LMSs and other educational environments (no support for non-web-based activities), and the xAPI can support integration of any online or offline activity - session-less communication with LMSs and other educational environments. Also, LTI reports a limited number of activities that can be stored by the LMS Gradebook, where xAPI record and analyze different learning experiences and send detailed reporting. Finally, LTI has a fixed number of standard statements, where xAPI statements can be easily customized and built an advanced statement.

LTI	xAPI
Standard, extendable way of integrating rich learning application	Experience tracking integration utilizing activity streams
Applications and content are web-based, extremally hosted	Can support online or offline activity– session-less communication
Grade and outcome data can be returned to the LMS	Content can exist in any system (i.e. outside of the LMS)

From the study we can conclude that both LTI and xAPI are required for the integration of our proposed LLS with LMSs and other educational environments. On the other hand, our proposed LLS system will bbe developed to support an intelligent assessment and virtual assistant which required a new learning experience to be reported using xAPI standard to the intelligent assessment and virtual assistant modules.

T4.3: Design of an efficient integration model between LLS and LMSs.

- **Start Month: M10 – End Month: M11.**
- **Detailed results of this task are provided in the attached <u>Appendix (8).</u>**

- **<u>Objectives:</u>**

To design an integration model between LLS and the LMSs that supports the exchange of information between them including all courses information and user identity, which ensures that users can easily navigate from the LMS to the LLS without having to log in to each system separately and without having multiple credentials. Also, to provide secure transfer of information from LLS to the LMS as an example for the results of the activity that students have done in the LLS. Finally, the conclusion is that our target is to create smooth and consistent learning and teaching experience through the proposed integration model.

- **Methodology:**

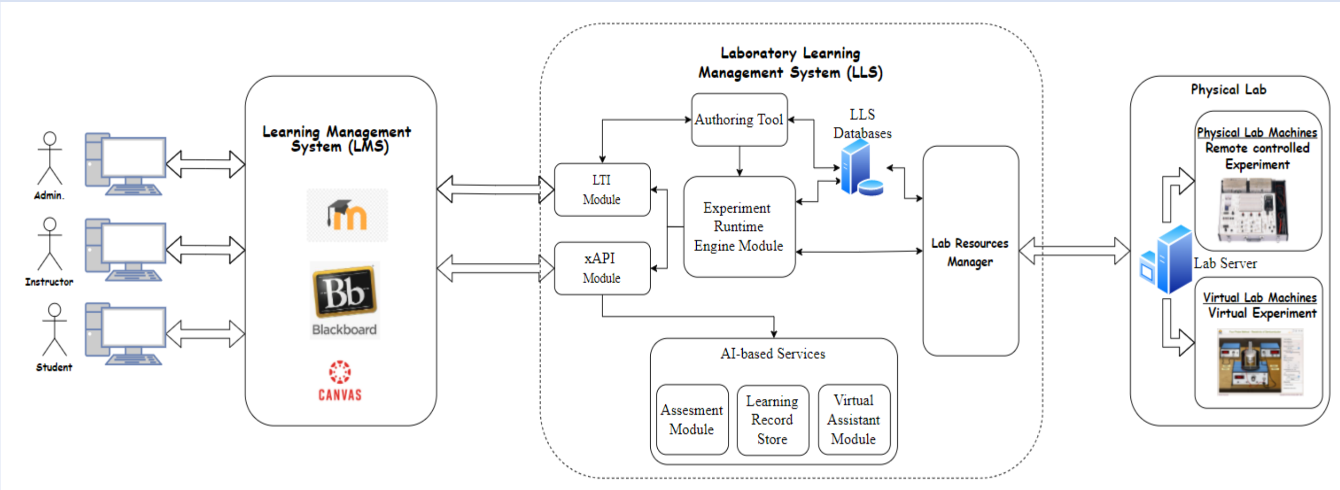
The following methodology was used:

1. Study and investigate the various online lab projects to study the different integration scenarios.
2. Study and investigate the different interactions and information exchange between the LLS and any LMS.
3. Determine the required integration standard technologies.
4. Proposes an efficient integration model.

- **Results:**

The designed integration model allow the administrators to seamlessly login to the LLS through the LMS (using LTI Module) to configure the lab resources and manage the access privileges of the different users and do all the required tasks for their role. In similar way, the instructors can login seamlessly and create and edit experiments/assignments/quizzes (using Authoring tool), add experiment to course, assign and schedule different experiments for their students, mark the unmarked experiments/assignments /quizzes, see the student finished experiments.

The LTI module allows students to access the LLS system seamlessly from their LMS course web page to book any assigned experiment, run the experiment during the scheduled time slot, and see the final grading and feedback. During the experiment execution, the xAPI module collects all students' activities from the experiment runtime engine and sends them to the AI-based services subsystem to analyze the student activity (Mouse action and keyboard strokes), evaluate the students' performance, assist students facing difficulties, and store the result in the learning record store.



WP5: Design and Development of Virtual Assistant (E-Instructor) for online Laboratory Experimentations (M7-M13)

T5.1: Survey and investigate existing techniques for virtual laboratory assistant.

- **Start Month: M7 – End Month: M7.**
- **Detailed results of this task are provided in the attached Appendix (9).**

- **Objectives:**

The aim of this task is to explore the best practices in employing technology to give online virtual assistance through online learning systems. The survey was done based on the literature review for the assistance in online learning process to address the difficulties that the student faced during conducting the experiment.

- **Methodology:**

In this review of the educational assistance literature, we used the method of comprehensive survey of educational assistance methodologies existed in the last years, using some research keywords such as: lab experiments and students' conceptual understanding, Interactive computer simulations, detecting cognitive stress, and assistance of online learning. There is a large volume of publications that described the role of online virtual assistant in thhe online learning process. These papers were published in conferences and journals with high impact factor in Scopus databases and Web of Science. The studies published in non-English language are excluded, in addition to the studies applied in the fields other than engineering, science, and technology are also excluded. The result was 56 applied studies in the field of virtual assistant in the online learning process are considered.

- **Results:**

Due to the spreading of the Covid-19 unfortunately around the global level, several online virtual assistants used in online educational courses had to appear. It was necessary to search for online virtual assistant that fit the teaching methods used to be an alternative to the traditional assistance tools used in face-to-face learning, e.g.; real assistant.

T5.2: Design an efficient virtual assistant technique for online laboratory experimentations.

- **Start Month: M8 – End Month: M9.**
- **Detailed results of this task are provided in the attached Appendix (10).**

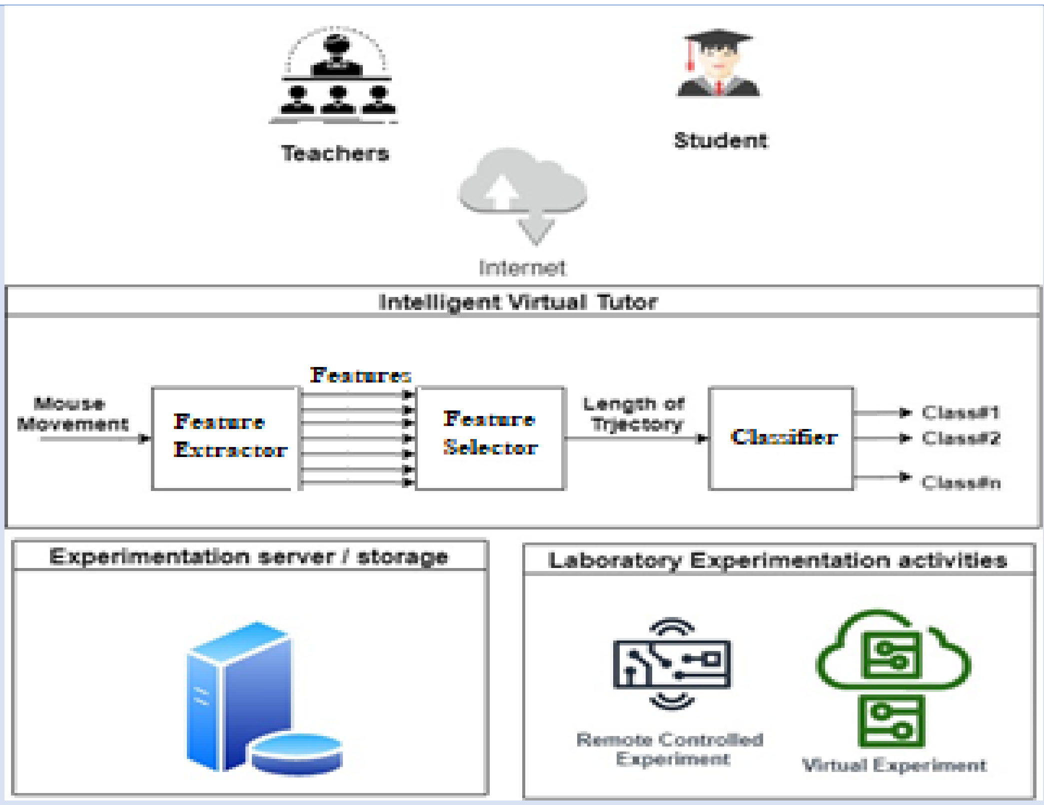
- **Objectives:**

The aim of this task is to design of an efficient virtual assistant (VA) for online laboratory experimentation in the form of Intelligent Virtual Tutor (IVT), including modelling the student's behavior during conducting remote laboratory experiments to detect the level of difficulty facing the students and his needs for assistance.

- **Methodology:**

The proposed IVT system is one of the main components of a complete system that offers online remote and virtual lab experimentation services. The online experimentation system, where the students can access any remote controlled or virtual experiment through the lab server which allocates the required experiment resources and store the students' activities. The IVT system is composed of three blocks, the feature extractor, feature selector and the classifier. The applied input pattern to the feature extraction stage is the mouse cursor motion captured during the online experiment execution. The extracted features or descriptors; which are the back button counter, sum of left clicks, next button counter, sum of right clicks, time of the step, sum of mouse leave question, sum of mouse stand on question, and length of trajectories; are applied to the feature selector. Then, the most efficient feature is selected via the correlation and then applied to the classifier. The classified output will be the level of difficulty facing the students. Then, according to the student's difficulty class facing, the IVT will offer the suitable help to achieve any step of the online experiment.

The operation of proposed system is based on several efficient features. All of these features are used with certain weights in order to improve the performance. Then, these features are compared with certain thresholds. The weight and threshold values are adjusted and optimized automatically using the Genetic Algorithm (GA).



- **Results:**

Virtual assistant (VA) has been designed in online laboratory experimentations. The designed IVT is based on detecting the difficulties that the student faced during conducting the online experiment. The level of difficulties is estimated according to the real-time mouse activities of the student according to the explored relationship between the mouse behavior of the student and the level of difficulty the student facing during conducting the experiment.

T5.3: Develop and test the designed virtual assistant technique.

- **Start Month: M10 – End Month: M13.**
- **Detailed results of this task are provided in the attached Appendix (11).**

- **Objectives:**

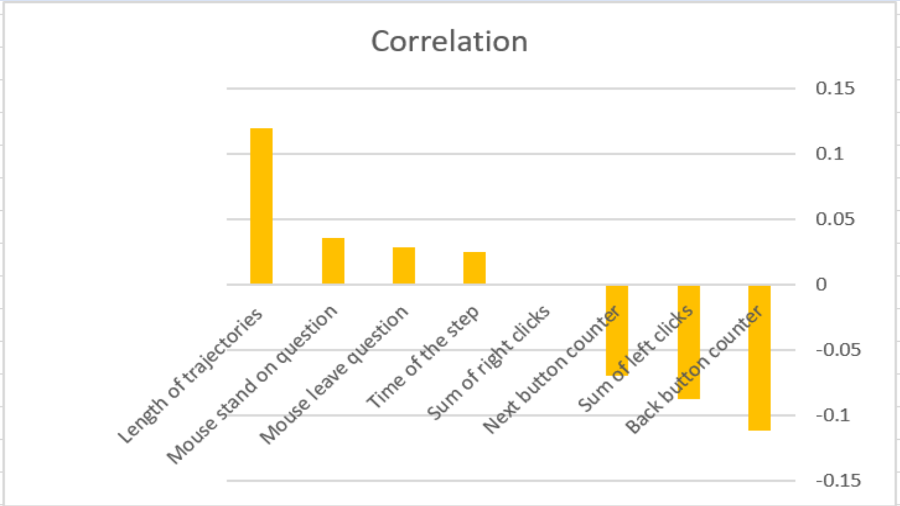
The objective of this task is to develop and test of the designed virtual assistant for online laboratory.

- **Methodology:**

The correlation is used as a feature selection method in order to select the most efficient feature. The number of pixels of the trajectories of the mouse movements in different steps of different students is used to estimate level of difficulties that the student faced during conducting the experiment.

- **Results:**

The correlation between the extracted feature and the student's score is computed in order to select the most efficient feature, which has the maximum correlation. Figure below shows the computed correlation in ascending order. It should be noted that the length of mouse trajectory is selected as the most efficient feature.



The level of difficulties is conducted by comparing the length of the mouse movement trajectory done by the student during conducting the experiment with a threshold that is determined from the trajectory length done by the teacher or the real assistant (RA).

T5.4: Prepare and submit scientific paper.

- **Start Month: M11 – End Month: M13.**

A. Atia, A. M. F. Yousef, A. Hamdy, A. M. A. El-Haleem and M. M. Elmesalawy, "Intelligent Virtual Tutor for Online Laboratory Experiments Based on Modelling the Student’s Mouse Interaction Behavior," 2021 IEEE 12th Annual Ubiquitous Computing, Electronics & Mobile Communication Conference (UEMCON), 2021, pp. 0154-0159, doi: 10.1109/UEMCON53757.2021.9666511.

WP6: Design and Development of Evaluation and Assessment Service for Online Experimentation Activities (M7-M13)

T6.1: Survey and investigate existing techniques for student performance evaluation and assessment in online learning process.

- **Start Month: M7 – End Month: M7.**
- **Detailed results of this task are provided in the attached Appendix (12).**

- **Objectives:**

The aim of this task is to explore the best practices in employing technology to give online assessment in the online learning process. The survey was done based on the literature review for student performance evaluation and assessment in online learning process to address the difficulties, practices, and solutions that arise when offering successful methods of assessment to large groups of students in laboratory experiments.

- **Methodology:**

In this review of the educational assessment literature, we used the method of comprehensive survey of educational assessment methodologies in the last three years, using research keywords: alternative assessment, evaluation in virtual laboratories, assessment practices strategies, online laboratory training assessment, and assessment of online learning. There is a large volume of published studies describing the role of online assessment in the online learning process, around 300 research paper published in journals and conferences with a high impact factor in the Web of Science and Scopus databases were found. Studies that did not have applied results, as well as studies published in a language other than English, were excluded, in addition to the exclusion of studies that were applied in fields other than science, technology and engineering. The result was 25 applied studies in the field of educational assessment in virtual laboratories.

- **Results:**

With the spread of the Covid-19 pandemic at the global level, many online systems and programs used in online educational courses had to appear, and it was necessary to think and search for online assessment tools that fit the teaching methods used to be an alternative to the traditional tools used in face-to-face learning. The different aspects of this topic were highlighted through a selection of studies presented in two dimensions. The first dimension discusses the methods of evaluating online learning in general, in terms of the competencies that should be focused on the assessment, the appropriate strategies for students' assessment from a distance, ways to implement new technologies in assessments strategies, and the opportunities and challenges involved in using modern technologies in online assessment. The second dimension was devoted to presenting some experiences of evaluating students remotely and the challenges faced by education systems around the world in evaluating students during the pandemic period, with an explanation of alternatives and solutions that can be followed for the success of student education and evaluation remotely.

This survey and investigate existing techniques for student performance evaluation and assessment in online learning process has found that generally the following items is the most suitable tools for our LLS project.

1. Short electronic quizzes
2. Performance observation assessment tool
3. E-Portfolios

T6.2: Design of an effective evaluation and assessment criteria for online experimentation activities.

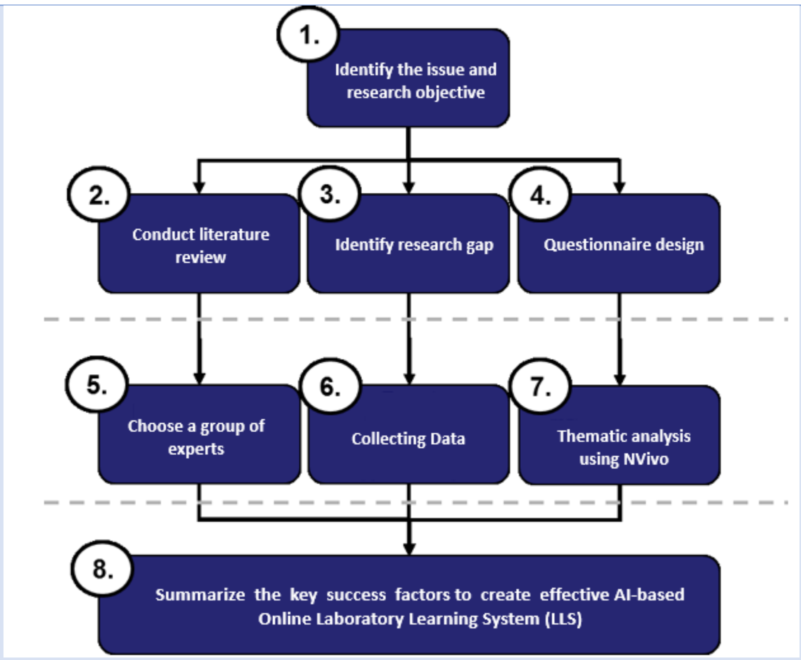
- **Start Month: M8 – End Month: M9.**
- **Detailed results of this task are provided in the attached Appendix (13).**

Objectives:

The aim of this task is to design of an effective evaluation and assessment criteria for online experimentation activities. Including evaluation of remote laboratory experiments through a number of international standards.

Methodology:

Our method consists of eight main activities as illustrated below. In the first step, we defined the study objective which was for designing an online laboratory learning system assessment to conduct student experiences in the field of science, engineering, and technology. Steps 2, 3 and 4 being conducted partially in parallel and independent from each other, based on a literature review that confirmed the research gap in the design criteria for assessment methods in laboratories. The open questionnaire was used as one of the strategies for gathering data from a panel of experts in this study. This questionnaire relies on experts who are knowledgeable about design and implementations of eLearning applications so they can forecast the outcome of future LLS assessment design scenarios, predict the likelihood of assessment use cases, or reach consensus about evaluation design criteria for online experimentation activities as depicted below. The fifth step dealt with identifying a group of experts to participate in the open-ended questionnaire. The expert has to meet certain criteria, such as designing some eLearning assessment applications and publishing research in the same field. An invitation to participate in this study was sent to (60) eLearning experts and (43) participants were accepted, and (31) of them completed the questionnaire successfully. The participants were representative with respect to gender, just over half the sample (52%) was male, the ages ranged between 35 and 60 years old. The sample was also representative of a number of different cultures, as 48% are representatives of Arab universities, 30% of European universities, and the rest are from North America.



Data collection

Researchers used an open-ended questionnaire to obtain information from the panel of experts regarding the following questions:

Which design requirements that contributes to assessing the learner performance?

- **Results:**

Assessment has been implemented in a variety of evaluation practices in online learning, whether in formative or summative evaluation. Summative assessment is utilized as part of the grading system at the end of the learning process to certify competency and evaluate the success of the teaching and learning process. While, formative assessment, which includes intermediate, diagnostic, predictive, and benchmark assessments, is used to provide real-time feedback to improve the learning process.

T6.3: Develop and test the designed evaluation and assessment criteria.

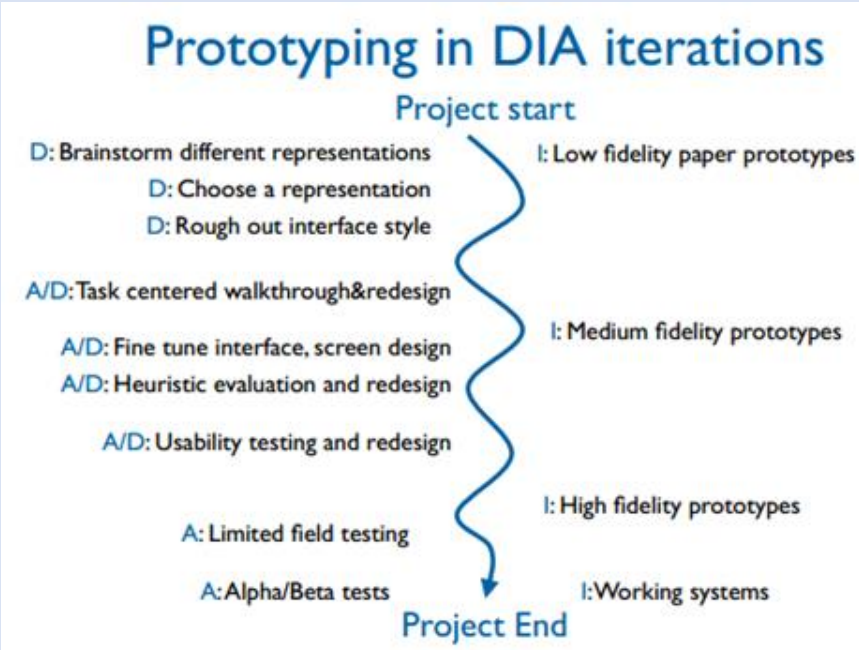
- **Start Month: M10 – End Month: M13.**
- **Detailed results of this task are provided in the attached Appendix (14).**

- **Objectives:**

The objective of this task is to design and development of online assessment quizzes and grading services for online laboratory.

- **Methodology:**

The DIA cycle, which is depicted below is used from the start until end for the development and test of the assessment criteria. DIA cycle is used because it uses an iterative process and after every iteration system reaches toward final goal. Previous iteration provides input to the next iteration, which is used to solve problems, correct issues, and do further implementation.



- **Results:**

The result has provided a deeper insight into design the three modules indicated in the survey namely, Short electronic quizzes, Performance observation assessment tool and E-Portfolios.

T6.5: Prepare and submit scientific paper.

- **Start Month: M10 – End Month: M13.**

1. M. F. Yousef et al., "Automatic Identification of Student's Cognitive Style from Online Laboratory Experimentation using Machine Learning Techniques," 2021 IEEE 12th Annual Ubiquitous Computing, Electronics & Mobile Communication Conference (UEMCON), USA, 2021, pp. 0143-0149, doi: 10.1109/UEMCON53757.2021.9666516.
2. M. F. Yousef, A. M. A. El-Haleem and M. M. Elmesalawy, "Identifying Success Criteria for Sustainable Online Laboratory Courseware System" EDUCON2022 – IEEE Global Engineering Education Conference, March 2022.

WP7: Preparation and Configuration of Virtual and Remote Laboratory Experimentation Resources (M5-M12)

T7.2: Prepare and configure the hardware/instruments for remote access and control through Internet.

- **Start Month: M8 – End Month: M10.**
- **Detailed results of this task are provided in the attached Appendix (15).**

- **Objectives:**

To prepare and configure the available instruments in the laboratory to be remotely accessed and controlled through internet.

- **Methodology:**

In order to prepare and configure the available laboratory instruments to be remotely accessed and controlled, the following procedures are carried out:

1. Preparing the laboratory physical resources architecture.
2. Defining the features and specifications of the laboratory available instruments.
3. Configuring the laboratory instruments for remote access and control.
4. Installing and illustrating the different remote-control interfaces software for the different instruments.

- **Results:**

After presenting and preparing the laboratory physical resources architecture for remote access and control, and after defining and illustrating the features and specifications of the available laboratory instruments, the instruments different methods of configurations for remote control are described below as an example:

To configure RIGOL instruments to be remotely controlled, the instruments should be connected via USB interface, or via LAN interface to the local network. This will allow the RIGOL instruments to be remotely accessed by a PC or a virtual machine. The remote controlling can be realized by using the standard Commands for Programmable Instruments (SCPI) commands. These commands can be used through the following two methods:

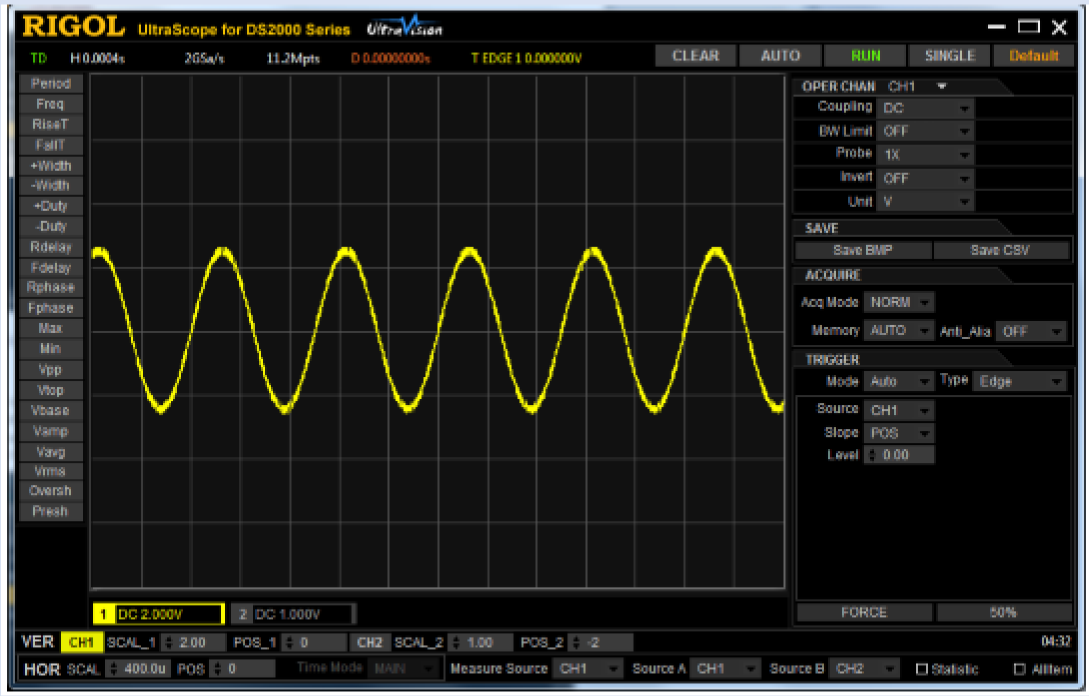
1. **User defined programming**

   Where the RIGOL instruments can be remotely controlled using the SCPI commands through National Instrument – Virtual Instrument Software Architecture (NI-VISA) library.

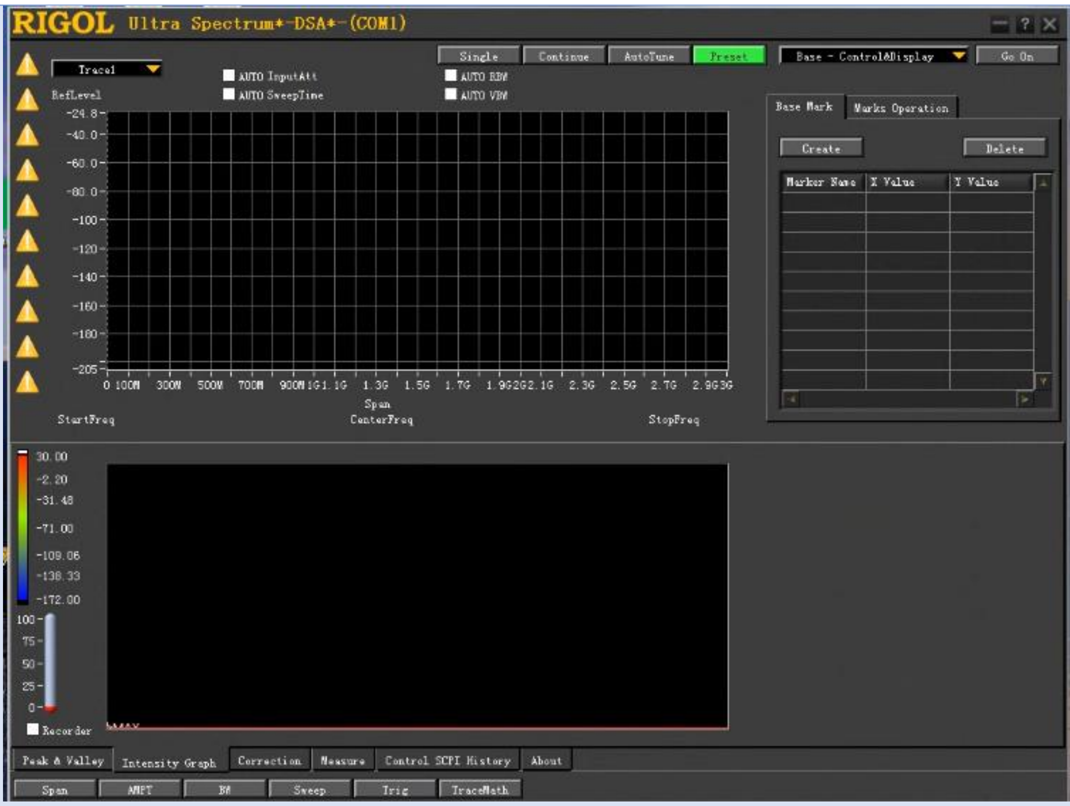
2. **PC software**

   Where the RIGOL instruments can be remotely controlled using the SCPI commands through the Ultra Sigma software when installed on a PC or a virtual machine. Using the Ultra Sigma software, we will describe how to configure the RIGOL instruments for remote control vis USB or LAN interfaces. Then, we exploited the available PC software interfaces for each instrument to control the laboratory instruments remotely as shown in figures below.

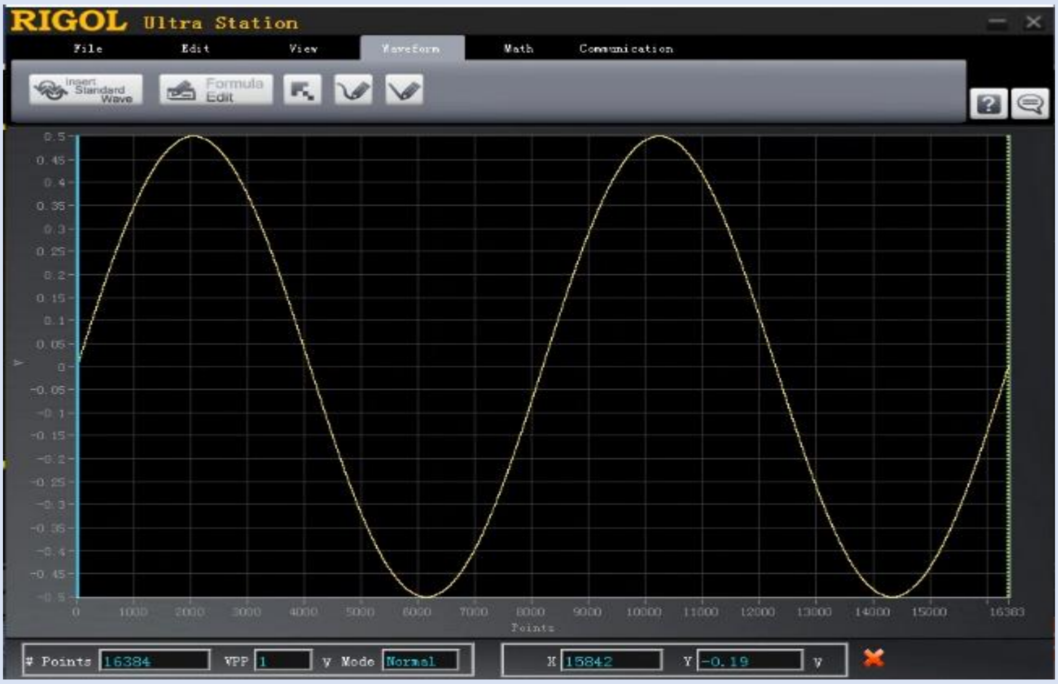
- Ultra Scope software designed to control the RIGOL digital oscilloscopes remotely.



- Ultra Spectrum software designed to control the RIGOL spectrum analyzers remotely.



- Ultra Station software designed to control the RIGOL Function/Arbitrary Waveform Generators remotely.



T7.3: Test the remote access functionality and performance of the experimentation resources.

- **Start Month: M10 – End Month: M12.**
- **Detailed results of this task are provided in the attached <u>Appendix (16).</u>**

Objectives:

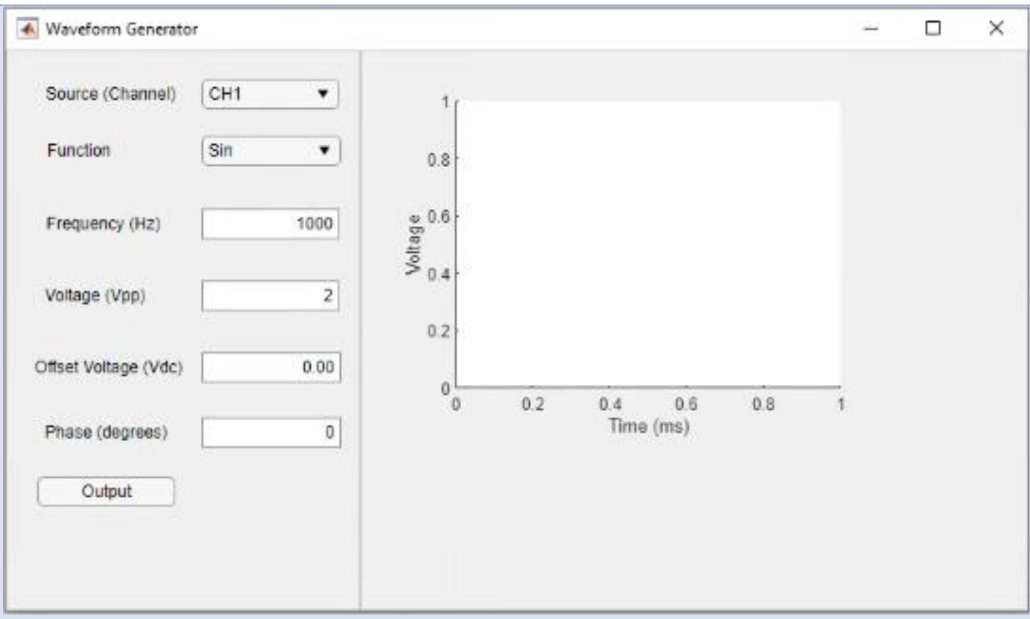
To enhance and test the performance of the remote access and control functionality for the laboratory resources.

Methodology:

In order to enhance the performance of the laboratory resources' remote access and control functionality, and to support experiments that requires multiple instruments, a unified remote access and control interface for some RIGOL instruments is designed and developed, to prevent the users from opening and closing multiple different interface software.

Results:

In order to unify the electronic circuits instruments remote controlled interfaces, and to support experiments that requires multiple instruments we developed a MATLAB application that can be used to control the electronic circuit instruments remotely. The developed application can control the signal waveform generators and the digital oscilloscope remotely. Instead of using the SCPI programming commands to control the different instruments, and to make it easier for the instructors and students to control the instruments remotely, we designed and developed a unified interactive MATLAB application for controlling the RIGOL instruments remotely, by exploiting the VISA library and the SCPI programming commands for each instrument. The function/arbitrary waveform generator MATLAB application is shown in the below figure. The application GUI shows a demo for the basic functionalities used in function/arbitrary waveform generator.



The digital oscilloscope MATLAB application developed is shown in the figure below. The developed application shows a demo for the basic functionalities of the digital oscilloscope. For detailed explanation for these laboratory resources' remote control MATLAB applications.

WP8: Preparation and Development of Laboratory Learning Objects (LLOs) (M5-M12)

T8.1: Preparation of the laboratory learning contents and learning scenarios for Electronics and Telecommunication experiments.

- **Start Month: M6 – End Month: M11.**
- **Detailed results of this task are provided in the attached Appendix (17).**

- **Objectives:**

Prepare Electronics and Telecommunication Laboratory experiments learning contents and learning scenarios to fit in our designed authoring tool with all the added features considering VRL specified settings, Component Settings, different Content components (Image, Text, Table, etc.), different Content Assessments and General experiment settings.

- **Methodology:**

Prepare a number of Electronics and Telecommunication Laboratory experiments learning content that explain the whole creation process of new laboratory experiment considering all the added features in proposed authoring tool. Created Laboratory Learning Content can include,

- Different Content components, as the author can add a text box to write the experiment objective and introduction, add image to define for example main circuit design, or to provide a network architecture, add table, add equation and other content component that fulfill the experiment content requirement.
- VRL specified settings, the laboratory learning content is prepared to reflect the added VRL settings as follows
    1. Author can add virtual/remote lab tool using "Add VRL" and select the needed VRL tool from VRL tool list, for example (Matlab, LabView, Packet tracer, etc..)

Add VRL	Select LabView from VRL tool list
Add Text	Click Start to open LabView

    2. Author can add, "Take snapshot from VRL" to allow Student to take snapshot from student's results or progress based on experiment requirement, As shown in figure below, the author add "Take snapshot from VRL" which allow student to take snapshot of Matlab/LabView Results.

Add Text Box	Run Matlab File , Snapshot your results using "Take A snapshot" from VRL
Add "Take Snapshot from VRL"	Allow student to take snapshot from Running VRL

3. Author can add “Submit File from VRL”, which allow student to submit his work/lab progress from VRL.

Add Text Box	Upload m.file using “Submit file from VRL”
Add “ Submit file from VRL”	Allow student to submit a file from running VRL

4. Component Settings, author also can add time crosseponding to the beginning of practical part (VRL) as shown in figure below

Add VRL	Select Matlab from VRL tool list	
Add Text	Click Start to open Matlab	Add Time

5. General Experiments Settings,
    a) Author can add a progress bar at the beginning of student’s laboratory work, show the students’ progress
    b) Author also can add a co-author to share with the creation of laboratory learning content
    c) By dividing the whole laboratory learning content into several pages, author also can customize each page theme
    d) Author can add Virtual Assistant (VA) help, to help the student while performing the experiment.

General Experiments Settings," add progress bar"

Add VRL	Select LabView from VRL tool list	
Add Text	Click Start to open LabView	Add Progress Bar

General Experiments settings " change page theme"

Add Figure Caption	BFSK Modulation Block diagram	
Add Page		Change Page Theme

- **Results:**

A number of Electronics and Telecommunication Laboratory experiments learning contents that reflect the added features in the designed authoring tool and ease the creation of satisfied laboratory learning content was prepared.

T8.2: Preparation of the laboratory learning tools for Electronics and Telecommunication experiments.

- **Start Month: M7 – End Month: M12.**
- **Detailed results of this task are provided in the attached Appendix (17).**

- **Objectives:**

Prepare a laboratory learning tools to introduce different electronics and telecommunication experiment types and requirements. Exploiting the added features in proposed authoring tool that ease the process of providing a laboratory-learning tool.

- **Methodology:**

Preparing a laboratory learning tool that reflect the added features in proposed authoring tool as

1. "Insert File into VRL" which used in laboratory experiments that require providing the student with a (file, lab network topology, lab circuit,..,etc). For example, in Labview, author can insert "student modulation Gui" using "Insert File into XFM" component and appear in student's view as a path, which may then the student can click on given path and begin to build the main circuit components using the given GUI.

Add Text Box	Open " student_modulation.vit" found in the below path "this will open a basic graphic user interface (GUI) "
Add "Insert File into VRL"	Select File > upload > Local Disk/ Public URL >

2. On the other side, in packet tracer, the author can insert the main network topology and configuration table using "Insert File into VRL" component, asking the student to configure network topology based on given network topology and configuration table

Add Text Box	Open IPV6 network devices network topology found in below path, this will open a network topology as Image below
Add "Insert file into VRL"	Select file> upload>local disk/ publick URL

Add Table					
	Device	**Interface**	**IPv6 Address**	**Prefix Length**	**Default Gateway**
	R1	G0/0/0	2001:db8:acad:a::1	64	N/A
		G0/0/1	2001:db8:acad:1::1	64	N/A
	S1	VLAN 1	2001:db8:acad:1::b	64	N/A
	PC-A	NIC	2001:db8:acad:1::3	64	fe80::1
	PC-B	NIC	2001:db8:acad:a::3	64	fe80::1

- **Results:**

A number of Electronics and Telecommunication Laboratory experiments learning tools that reflect different laboratory experiments requirements and how the added features in proposed authoring tool will ease the laboratory experiment creation process and fulfill each laboratory experiment requirements was prepared.

T8.3: Preparation of the laboratory evaluation and assessment contents for Electronics and Telecommunication experiments. (M6-M11)

- **Start Month: M6 – End Month: M11.**
- **Detailed results of this task are provided in the attached Appendix (17).**

- **Objectives:**

Prepare a different learning evaluation and assessment contents in electronics and telecommunication sector that exploit the added features in proposed authoring tool, considering different assessments types to consider different laboratory experiment requirement.

- **Methodology:**

Prepare a number of Electronics and Telecommunication Laboratory evaluation and assessments that considering all the added features in proposed authoring tool. Evaluation and assessments content can be created within the experiment, while the student performing the laboratory experiment, and also can be created after finishing the experiment, in the form of exam. The following assessments types can be chosen in either as assessment within experiment or as a exam after experiment.

- Assessments Types, author can add in the assessments part in selected laboratory experiment, different types of Assessments, from
    1. **open question**

Add Open Question	A. Define the Main function of BFSK Modulation

2. **Multiple Choice Question,**

Add Section	**Questions**
Add Multiple Choice Question	The distance between the constellation point of 16QAM is …… the value of 16PSK a) 1.6 b) 110 c) 1.20 d) 3

3. **True or False,**

Add True or false Question	1. Can the same link-local address, fe80::1, be assigned to both Ethernet interfaces on R1? True or false

4. **Submit file from VRL using "Submit file from VRL"**

Add Text Box	Build a VI that first accumulates an array of temperature values using the digital thermometer VI. Incorporate these items: • Set the array size with a control on the front panel. • Initialize an array using the initialize array function of the same size where all values are equal to 10. • Add the two arrays, calculate the size of the final array and extract the middle value from the final array. • Display the temperature array, initialized array, final array and mid value.
Add Text Box	Submit Array function File usinf "Submit file from VRL"
Add "Submit file from VRL"	**Allow student to Submit Array function Vi file from VRL**

5. **Table Question**

<table>
<tr><td>Add Table Question</td><td>

Step 1: Record the interface status for the following interfaces.

Interface	S1 Status	S1 Protocol	S2 Status	S2 Protocol
F0/1	Up	Up	Up	Up
F0/6	Up	Up	Down	Down
F0/18	Down	Down	Up	Up
VLAN 1	Up	Up	Up	Up

</td></tr>
</table>

- Assessment's settings
  a) Author can add assign added questions in assessments part to be graded or ungraded as shown below in figure#
  b) Authors can assign a max/min number of trails for student's submission
  c) Authors can add correct answer after student's assessment question submission

Add "Take snapshot from VRL"	Allow student to take snapshot from running VRL	Add grade
Add Text Box	Save Your LabView File .vi using "Take File from VRL"	
Add "Submit file from VRL"	Allow student to submit file from running VRL	Add Grade

Results:

Prepare different learning evaluation and assessment contents in each proposed laboratory learning content that exploit the added features in proposed authoring tool, considering different assessments types to consider different laboratory experiment requirement.

III: Salient and Tangible Achievements (one page maximum)

Publications	1. Ahmed M. Abd El-Haleem, Noha A. Elmosilhy, Abdullah I. Salama, Eman Serag El Din and Mahmoud M. Elmesalawy, “Efficient Collaborative and Cooperative Laboratory Experimentation System for Online Engineering, Science and Technology Education,” International Conference on Remote Engineering and Virtual Instrumentation (REV2022), Cairo, Egypt, 2022. 2. Ahmed F. Yousef, Ahmed M. Abd El-Haleem and Mahmoud M. Elmesalawy, “Identifying Success Criteria for Sustainable AI-based Online Laboratory Courseware System," *2022 IEEE Global Engineering Education Conference (EDUCON), Tunisia, 2022.* 3. Ayman Atia, Ahmed F. Yousef, Alaa Hamdy, Ahmed M. Abd El-Haleem and Mahmoud M. Elmesalawy, “Intelligent Virtual Tutor for Online Laboratory Experiments Based on Modelling the Student’s Mouse Interaction Behavior," *2021 IEEE 12th Annual Ubiquitous Computing, Electronics & Mobile Communication Conference (UEMCON)*, New York City, NY, USA, pp. 0154-0159, 2021. 4. Ahmed F. Yousef, Ayman Atia, Amira Youssef, Noha A. Saad Eldien, Alaa Hamdy, Ahmed M. Abd El-Haleem and Mahmoud M. Elmesalawy, “Automatic Identification of Student’s Cognitive Style from Online Laboratory Experimentation using Machine Learning Techniques," *2021 IEEE 12th Annual Ubiquitous Computing, Electronics & Mobile Communication Conference (UEMCON)*, New York City, NY, USA, pp. 0143-0149, 2021. 5. M. M. Elmesalawy et al., "AI-based Flexible Online Laboratory Learning System for Post-COVID-19 Era: Requirements and Design," 2021 International Mobile, Intelligent, and Ubiquitous Computing Conference (MIUCC), pp. 1-7, 2021. 6. Ahmed M. Abd El-Haleem, Mohamed Anany, Eman Serag El Din and Mahmoud M. Elmesalawy, “Matching Game-based Framework for Resources Management in Online Laboratory Learning Systems”, Ready for submission to IEEE Access Journal.
Patents (submitted /issued)	

Technological Development/Know How	
Technology Transfer and/or Localization	
Deepening Local Manufacturing (Name locally manufactured parts/spares)	National Developed Laboratory Learning System (LLS) for Science, Technology and Engineering Education.
Marketing/ Applications (Give names & places)	
Spinoff/Startups resulted from the project (give names)	
Return of Investment (ROI)	
Societal Impact	
Capacity building No. of participating M.Sc. & PhD students: No. of awarded degrees: Purchasing or upgrading equipments: Int. cooperation: Fund raising :	2 PhD students 1 M.Sc Student Purchased equipment: Server and licenses for educational software simulation in the field of Engineering.

Appendix (1)

Detailed Results of Task 2.3

T2.3 Design and development of users' authentication and authorization service.

The authentication in the proposed LLS prevents anonymous access to the controllers and actions. It's allowing only for user who's logged in and with the authorized role. Different design patterns were chosen in order to implement these services to assure one of the software engineering primitive principles. The singleton and object pool assure single instance of connections to the database for scalability and fast reusages of connections. The observer design pattern is used for notifications and allowing adding observers without changing code and structured as shown in Figure 1. The strategy design pattern was used for changing between different roles for execution. A web page for user authentication was deployed applying notifications and login functionality.

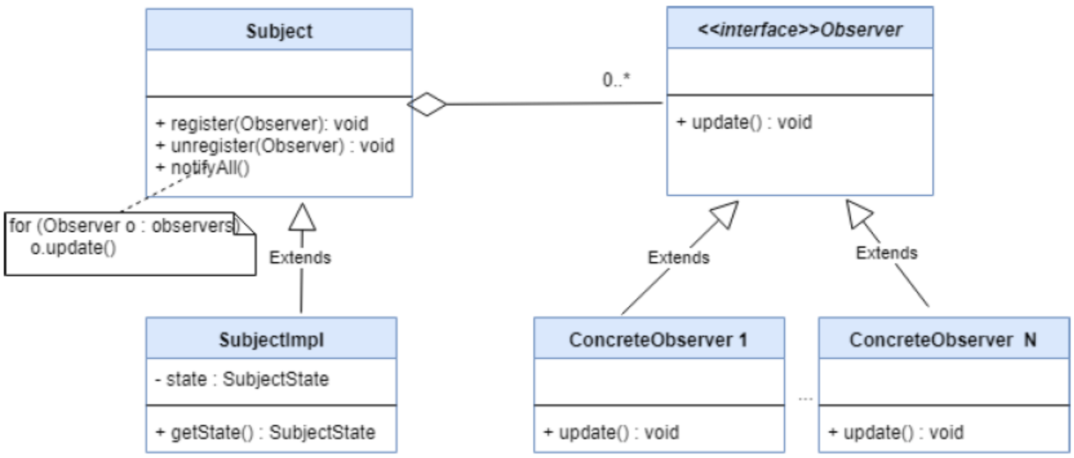


Figure 1: Observer design pattern diagram

First the user must log in by sending the username and the password, then the app has to check if the user exists in database, if so, the app creates a JWT token and sends it to the client to save it in the local storage to be used in another request, without the need to log in again. Each request must contain this token in the header to allow user to access the API Action.

JSON Web Token (JWT) is an open standard that defines a compact and self-contained way for securely transmitting information between parties as a JSON object. This information can be verified and trusted because it is digitally signed. JWTs can be signed using a secret (with the HMAC algorithm) or a public/private key pair using RSA or ECDSA.

Although JWTs can be encrypted to also provide secrecy between parties, we will focus on *signed* tokens. Signed tokens can verify the *integrity* of the claims contained within it, while encrypted tokens *hide* those claims from other parties.

When tokens are signed using public/private key pairs, the signature also certifies that only the party holding the private key is the one that signed it.

We choose to use the JWT for two reasons:

- **Authorization**: This is the most common scenario for using JWT. Once the user is logged in, each subsequent request will include the JWT, allowing the user to access routes, services, and resources that are permitted with that token. Single Sign On is a feature that widely uses JWT nowadays, because of its small overhead and its ability to be easily used across different domains.
- **Information Exchange**: JSON Web Tokens are a good way of securely transmitting information between parties. Because JWTs can be signed—for example, using public/private key pairs—you can be sure the senders are who they say they are. Additionally, as the signature is calculated using the header and the payload, you can also verify that the content hasn't been tampered with.

We used **`Microsoft.AspNetCore.Authentication.JwtBearer`** middleware that enables an application to receive an OpenID Connect bearer token. JWT structure is compacted, it consists of three parts separated by dots (.), which are:

- Header
- Payload
- Signature

Therefore, a JWT typically looks like the following:

eyJhbGciOiJIUzI1NiIsInR5cCI6IkpXVCJ9.eyJJZCI6IjU3M GNiNTRiLWFlOGYtNDk3ZC04NzY3LWY5YTE4OWYyYmY2ZCIsImh 0dHA6Ly9zY2hlbWFzLnhtbHNvYXAub3JnL3dzLzIwMDUvMDUva WRlbnRpdHkvY2xhaW1zL25hdHA6Ly9zY2hlbWFzLm1pY3Jvc29 mdC5jb20vd3MvMjAwOC8wNi9pZGVudGl0eS9jbGFpbXMvcm9sZ SI6WyJVc2VyIiwiVGVhY2hlciJdLCJleHAiOjE2NzI4Mzc0NTZ 9.B5v21M	Hx E7 3Z yR _Q e	xoI3j HIHgg Afu0v 6EaLP 7cB4

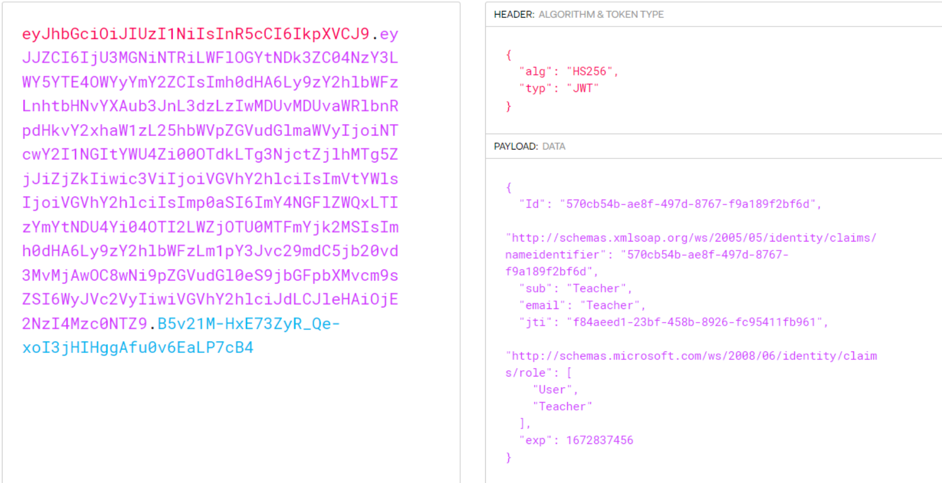


Figure 2: this figure shows the payload in the active JWT that is used in the main system using Jwt.io to decrypt the data inside the JWT

Authorization:

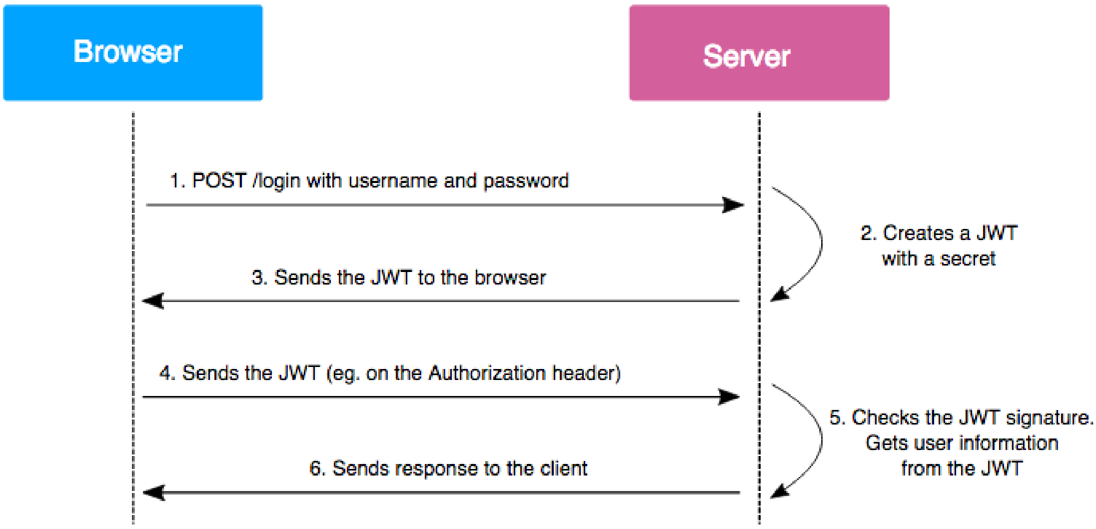


Figure 3: Using JWT for authorization sequence diagram

As for using JWT to retain the logged in user, we can't log out with only a JWT token. Since unlike a cookie or session there's nothing to kill or remove because JWT tokens are stateless.

JWTs are self-contained and there's nothing backing them but the data they contain. So, the server has no idea beyond the validity of the token and its expiration time whether its valid or not.

As for using HTML based applications as ours, we can use a cookie or some local storage to hold the Token and log out the user by removing it. We can clear the cookie or client-side API applications can remove the token from the client, and that effectively logs out the application. But even though these 'wrappers' may clear the token for the application, the actual token remains valid until expiration, if the token is somehow peeled out of the application wrapper or cookie.

Hence, we have chosen to use secondary layer to be able to log out, by wrapping a secondary layer around the JWT token in the token validation logic, by adding a record into the DB that holds the token and access status. When the token is validated, we also check for the access status in the DB. To 'log out' we can remove the record or mark it as logged out to disallow access even if the token has not expired. It's ugly and requires some stateful storage, which kind of defeats the whole idea of JWT Tokens in the first place, but it works.

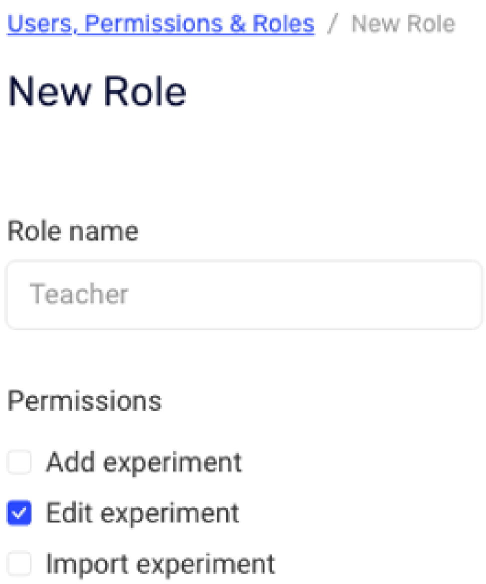


Figure 4: Example for the creation of a new role with specific permission

Appendix (2)
Detailed Results of Task 2.4

أكاديمية البحث العلمي والتكنولوجيا

T2.4: Design and development of laboratory assignment and scheduling services.

1) System Architecture

The proposed laboratory learning system consists of three main subsystems as shown in Figure 5:

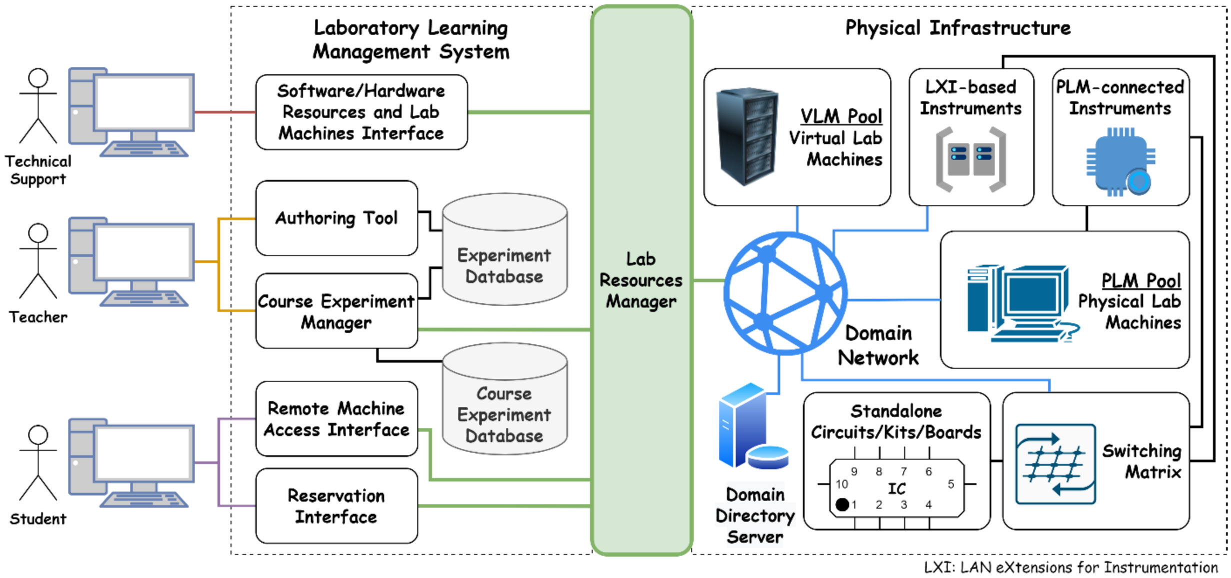


Figure 5 system architecture

1.1 The laboratory learning management subsystem.

Which is the management software helps teachers to create the Laboratory Learning Object (experiment) and manage the way of experiment execution, the interface between the student and the physical lab resources, and allow technical support to manage the hardware and software lab resources.

Course experiment manager.

- Allow teacher to access all the created experiment objects stored in the Experiment Database.
- The teacher can associate the created experiments LLOs to a course he/she is teaching.
- The teacher can assign the experiment to a cohort or a group of students and configure the experiment time duration, start and due date, and the maximum number of attempts.
- The relations between the experiment, course, and students' group are stored in the course experiment database.

Software/Hardware Resources and lab machine interface.

- Allow the technical support to install a new software and hardware control programs (resources) on the virtual and physical lab machines.
- Allow the technical support to configure installed software and connects hardware for each virtual/physical lab machine.
- Allow the technical support to configure the lab machines access times slots.
- All the information's about the lab machines and the software and hardware resources installed/connected to them are stored in the Software and hardware resources database and/or Lab Machines database (Machines Pool)

Reservation Interface.

- Allow student to reserve a time slot to execute his assigned experiment during the experiment active period (Which is done by the lab resources manager where all the required experiment resources are available)

Remote Machine Access Interface.

- The interface between students and lab machine resources used during the experiment execution to fulfill his experiment objectives.

1.2 The physical laboratory infrastructure.

It is consisting of all the hardware and software lab resources:

- Virtual Lab Machines
- Physical Lab Machines Pool
- PLM-connected Instruments
- LXI-based Instruments
- Standalone Circuits/Kits/Boards
- Switching Matrix.
- Domain Directory Server

1.3 The Laboratory Resource Manager.

One important functionality of the laboratory resource manager is to allocate resources (such as virtual machines, physical machines, laboratory softwares, and laboratory instruments) to the students according to their acquired experiments, in order to minimize the number of blocked timeslots, where a timeslot is blocked if there are no enough resources to be reserved for the acquired experiment by the student. In the following subsections, we present a mathematical formulation for the proposed system, and the resource allocation problem. Then, we solve the resource allocation problem using the matching game theory, and we used simulation to test and analyze the proposed solution.

2) System Model

In this section we propose a mathematical formulation for the resource allocation system. Let $\mathcal{M} = \{1,2, \dots, m, \dots, N^M\}$ be the set of available pool of laboratory virtual machines and physical machines, such that N^M is the total number of virtual and physical machines. Besides the virtual and physical machines, the laboratory available resources are comprised of different software and hardware instruments and can be denoted by the set $\mathcal{R} = \{1,2, \dots, r, \dots, N^R\}$, such that $N^R$is the number of available software and hardware resources, and $N_r^{\mathcal{M}}$is the number of physical and virtual machines that has resource r (e.g. a software that can be installed on different physical or virtual machines with licenses, or hardware replicas that is connected to different physical or virtual machines). Hence, the total number of resources in the system is $N_{total}^R = \sum_{r=1}^{N^R} N_r^{\mathcal{M}}$ Also, the set of available resources for each machine $m \in \mathcal{M}$ are denoted by $\mathrm{M}_m \subseteq \mathcal{R}$, and N_m^R denotes the number of available resources in machine m. Moreover, the created experiments are denoted by the set $\mathcal{E} = \{1,2, \dots, e, \dots N^E\}$, where N^E is the total number of created experiments. Each created experiment $e \in \mathcal{E}$ has a set of required resources $\mathrm{E}_e \subseteq \mathcal{R}$, such that there is at least a set $\mathrm{M}_m \supseteq \mathrm{E}_e$. Also, each experiment $e \in \mathcal{E}$ is assigned a duration time t_e from the set of available time durations $\mathcal{T} = \{1,2, \dots, t_d, \dots, N^T\}$, where N^T is the total number of available time durations. Besides, $N_e^{T_d}$ is the number of time durations that can be reserved by a student for experiment e. This number can be calculated by knowing the start scheduled time T_e^{start} and due scheduled time T_e^{due} of the experiment, the virtual and physical machines off time duration for physical and virtual machines t_m^{OFF}, and the duration time t_e, as follow:

$$N_e^{T_d} = \frac{(T_e^{due} - T_e^{start}) - t_m^{OFF}}{t_e} \qquad (1)$$

On the other hand, the set of students reserving experiments at time slot t are denoted by $\mathcal{S}_t = \{1,2, \dots, s_t, \dots N^{S_t}\}$, such that N^{S_t} is the total number of students reserving time slot t. an association matrix X_t^e at time slot t represents the association between the set of students $\mathcal{S}_t$ and the set of virtual and physical machines $\mathcal{M}$, such that X_t^e is an $N^{S_t} \times N^M$ matrix, and $N^M \geq N^{S_t}$. An element of the matrix X_t^e has the value of $x_{s_t m}^e \in \{0,1\}$, where $x_{s_t m}^e = 1$ represents the reservation of student s_t to machine m for experiment e, while $x_{s_t m}^e = 0$ means that machine m is not reserved by student s_t for experiment e, this can be formulated mathematically as follow:

$$x_{s_t m}^{e} = \begin{cases} 1, & \mathrm{E}_e \subseteq \mathrm{M}_m, and \sum_{s_t} x_{s_t m}^{e} = 0 \\ 0, & \mathrm{E}_e \neq \mathrm{E}_e \cap \mathrm{M}_m, or \sum_{s_t} x_{s_t m}^{e} = 1 \end{cases} \quad (2)$$

A student acquiring experiment e at time slot t that needs a duration time t_e is denoted by s_t^e, such that $s_t^e \notin \mathcal{S}_t$ and $s_t^e = N^{S_t} + 1$. The availability of time slot t for experiment e to be reserved by student s_t^e is denoted by a_t^e, and can be represented as follow:

$$a_t^e = \begin{cases} 1, & \sum_{s_t} \sum_m x_{s_t m} = N^{S_t} + 1 \\ 0, & \sum_{s_t} \sum_m x_{s_t m} < N^{S_t} + 1 \end{cases} \quad (3)$$

Where $a_t^e = 1$ if all the reserved students $\mathcal{S}_t$ and the acquiring student s_t^e for experiment e at time slot t are associated to machines from the machines pool $\mathcal{M}$. While $a_t^e = 0$ if only some of the acquiring and reserved students are associated to machines from the machine pool $\mathcal{M}$.

The availability matrix A^e for any student acquiring experiment e is an $N_e^{T_d} \times 1$ matrix, that contains the elements a_t^e where $t = [1, N_e^{T_d}]$. The number of available time slots $N_{s^e}^{A}$ for student s^e is equal to:

$$N_{s^e}^{A} = \sum_{t=1}^{N_e^{T_d}} a_t^e \quad (4)$$

While the number of blocked time slots $N_{s_t^e}^{B}$ for student s^e can be calculated as follow:

$$N_{s^e}^{B} = N_e^{T_d} - N_{s^e}^{A} \quad (5)$$

1.1 Problem Formulation

In this work, our problem is to minimize the blocking rate which is defined as the number of blocked time slots per acquiring student, by optimizing the association matrix X^e between all the reserved students and the available physical and virtual machines at different time slots, where $\mathrm{X}^e = \{\mathrm{X}_1^e, \mathrm{X}_2^e, \dots, \mathrm{X}_t^e, \dots, \mathrm{X}_{N_e^{T_d}}^e\}$. This problem can be formulated as follow:

$$\mathbf{OPT:}\ \min_{X^e} N_{s^e}^{B} \qquad (6)$$

s.t.

$$x_{s_t m}^{e} \in \{0,1\}, \qquad (7)$$

$$x_{s_t m}^{e} = 1 : \mathrm{E}_e \subseteq \mathrm{M}_m, and \sum_{s_t} x_{s_t m}^{e} = 0, \qquad (8)$$

$$x_{s_t m}^{e} = 0 : \mathrm{E}_e \neq \mathrm{E}_e \cap \mathrm{M}_m, or \sum_{s_t} x_{s_t m}^{e} = 1, \qquad (9)$$

$$\sum_{m} x_{s_t m} \leq 1, \qquad (10)$$

$$N^{S_t} \leq \sum_{m} \sum_{s_t} x_{s_t m} \leq N^{S_t} + 1, \qquad (11)$$

In optimization problem OPT, constraint (7) ensures that the association index $x_{s_t m}^{e}$ is equal only to 0 or 1; and, constraint (8) and (9) ensures that a student is associated with a specific physical or virtual machine m, if only the machine can provide the experiment's required resources E_e, and no student is associated with this machine; Also, constrain (10) ensures that a student cannot associate with more than one machine; Moreover, constraint (11) ensures that at least all the reserved students in a specific time slot t are associated to physical or virtual machines.

3) <u>Matching game-based framework For students – Laboratory Resources association</u>

The aforementioned formulated problem OPT can be posed as a matching problem, where students should be matched optimally to the physical and virtual machines according to their available resources and each student's experiment required resources. It can be considered as a one-to-one matching problem, where only one student is matched to one physical or virtual machine. The matching theory is a Nobel prize winning framework that provide mathematical tractable solutions for combinatorial matching problems.

In order to solve this problem, we propose a framework based on matching game algorithm, where the optimization problem OPT is divided into $N_e^{T_d}$ matching sub problems. For a student acquiring an experiment e, the matching sub problems should be solved to determine the availability of each specific timeslot t. If a stable matching between the students (the acquiring student, and the reserving students at time slot t) occurs, then this timeslot is considered available, if not, then the timeslot is considered unavailable. Solving the matching sub problem is applied on each of the available timeslots for this student.

1.1 Matching game definition for students' association

The basic solution concept of a matching problem is defined as the two-sided stable matching. The two-sided stable matching occurs only if there are no blocking pairs. A pair (s'_t, m') is defined as a blocking pair if student s'_t prefers to be matched to machine m' instead of its currently matched machine m, and machine m' prefers to be matched to student s'_t instead of its matched student s_t.

The a matching game algorithm that can find a stable matching between two sets, which is called the differed acceptance matching algorithm. In this algorithm each student ranks the physical and virtual machines based on a utility function in order to obtain their preference relation, on the other side, each physical and virtual machine should also rank the students based on a utility function to obtain their preference relations.

The one-to-one matching game can be formulated by the tuple $(\mathcal{S}_t, \mathcal{M}, \succ_{\mathcal{S}_t}, \succ_{\mathcal{M}})$, where the first players set is the students set $\mathcal{S}_t$, the second players set is the physical and virtual machines set $\mathcal{M}$, while $\succ_{\mathcal{S}_t}$,and $\succ_m$ are the preference relations of the students' set and the machines set, respectively, such that $\succ_{\mathcal{S}_t} = \{\succ_{s_t}\}_{s_t \in \mathcal{S}_t}$, and $\succ_{\mathcal{M}} = \{\succ_m\}_{m \in \mathcal{M}}$. A matching between the students and the machines is denoted by $\mu: \mathcal{S}_t \to \mathcal{M}$, where μ is the matching game student's association outcome. Moreover, a utility function for each student is denoted by $U_{s_t}(m)$, which is used by the students to rank the physical and virtual machines, in order to build the preference relations $\succ_{s_t}$. On the other hand, the utility function for the physical and virtual machines are denoted by $U_m(s_t)$, which is used by the physical and virtual machines to rank the students, in order to build the preference relations $\succ_m$. The utility functions are described in the following subsections.

1.2 Students' utility function

In order to minimize the blockage rate $N^B_{s^e}$ in the optimization problem OPT, we designed a utility function for the students' that aims at maximizing the utilization of the available resources $\mathrm{M}_m$for each machine m. The utility function $U_{s_t}(m)$ is formulated as follow:

$$U_{s_t}(m) = \min(N_r^{\mathcal{M}}: r \in M_m) - N_m^R, \forall m \in \mathcal{M} \quad (12)$$

In this utility function, the first term $(\min(N_r^{\mathcal{M}}: r \in M_m))$ is the minimum of the number of physical and virtual machines that has resource r, for all the resources on machine m. In other words, for each machine m, we find the minimum number $N_r^{\mathcal{M}}$ for all the resources on that particular machine. The aim of finding this minimum number $N_r^{\mathcal{M}}$ is that it reflects the most rarely resource r in machine m, and a student is preferred to be matched with a machine that have a higher rare value, instead of matching with a machine with a rare resource, which could block other students.

On the other hand, the second term (N_m^R) is the number of resources on physical or virtual machine m. This number reflects resources occupancy of machine m. A student is preferred to be matched with a machine that has the lowest resources occupancy, in order to leave the highest possible number of resources available for other students. This will provide a better utilization to the available resources.

1.3 Physical and virtual machines utility function

In this subsection we design an efficient physical and virtual machine utility function that serves the matching game algorithm in solving the optimization problem OPT. The utility function $U_m(s_t)$ is formulated as follow:

$$U_m(s_t) = -\min(N_r^{\mathcal{M}}: r \in \mathrm{E}_e, e \to s_t), \forall s_t \in \mathcal{S}_t \quad (13)$$

A physical and virtual machine m rank the students based on the resources required by the experiments in which the students are mapped to. For a particular resource r required by experiment e that student s_t should perform, the number $N_r^{\mathcal{M}}$ is the number of physical and virtual machines that has resource r. Thus, for a student s_t, if an experiment e require multiple resources, machine m will consider the resource that has the minimum number $N_r^{\mathcal{M}}$, which indicates the rarity of that resource. The utility function $U_m(s_t)$ implies that machine m will prefer matching with the student that needs the rarest resource, which decrease the probability that this student is blocked, and will provide a better utilization to the available resources.

1.4 Proposed matching game algorithm

Algorithm 1 presents the details of the proposed matching game algorithm. After initialization, each student s_t use the utility function $U_{s_t}(m)$ in (12) to construct its preference relation $\succ_{s_t}$ (step 1). Then it sends a bed request $b_{s_t \to m}$ to machine m that has the maximum $U_{s_t}(m)$ value (steps 2-5). On the other side, the physical and virtual machines update the requesting students set $\mathcal{S}_m^{req}$ according to the bidding received (step 6-7). Then, each machine constructs its preference relations $\succ_m$ based on (13), and accepts the student with the highest $U_m(s_t)$ value (step 8-9). After that, each machine sends a rejection to the not accepted bidding students according to the rejection list $\mathcal{S}_m^{rej}$ (step 10). Finally, for each student received a rejection from machine m, he should remove machine m from his preference relation $\succ_{s_t}$. This process (step 2-12) is repeated until there is no bidding request left.

Algorithm 1 **One-to-One Matching Game for Students Association**

Initialization: $\mathcal{S}_t, \mathcal{M}$.

Discovery and utility function computation:

1: Every student s_t construct $\succ_{s_t}$ using $U_{s_t}(m)$

Find stable Matching:

2: **While** $\sum_{\forall s_t, m} b_{s_t \to m} \neq 0$ **do:**

3: *For each unassociated student:*

4: Find $m = \arg \max_{m \in \succ_{s_t}} U_{s_t}(m)$.

5: Send a request $b_{s_t \to m} = 1$ to machine m.

6: *For all machines ($m \in \mathcal{M}$):*

7: Update $\mathcal{S}_m^{req} \leftarrow \{s_t : b_{s_t \to n} = 1, s_t \in \mathcal{S}_t\}$.

8: Construct $\succ_m$ based on $U_m(s_t)$.

9: Accept $s_t = \arg \max_{s_t \in \succ_m} U_m(s_t)$.

10: Update $\mathcal{S}_m^{rej} \leftarrow \{\mathcal{S}_m^{req} \backslash \mathcal{S}_m\}$.

11: Remove machines $m \in \succ_{s_t}, \forall s_t \in \mathcal{S}_m^{rej}$

12: **end while**

13: **Result**: A stable matching μ^*.

---

4) Performance evaluation

In this section, we evaluate the performance of the proposed laboratory management system. We begin with the simulation setup, followed by a detailed description of how the resources are mapped to machines and its effect, then we end by the simulation results.

1.1 Simulation Setup

In order to evaluate the performance of the proposed laboratory management system, a simulation setup is used where 5 experiments are created, and each experiment is assigned a unique resource randomly from the set of available resources. The students are randomly assigned one experiment from the created experiments in each iteration. In, each simulation run, 1000 iterations are conducted, and average values of the iterations are calculated.

Moreover, two performance metrics are adopted to show the effectiveness of the proposed laboratory management system under different parameters changes. The first performance metric is the average percentage of blocked timeslots $\frac{N_{se}^{B}}{N_{e}^{Td}}$, which is the ratio of the number of blocked timeslots to the total number of available timeslots, where $0 \leq \frac{N_{se}^{B}}{N_{e}^{Td}} \leq 1$. The lower the percentage of blocked timeslots, the better the resource management scheme is. The second performance metric is the average resource utilization efficiency, which is the ratio of the maximum number of students that can reserve in a specific timeslot to the total number of physical and virtual machines. Note that this performance metric also has a minimum of 0 and a maximum of 1. Whenever this ratio increases, this indicates the effectiveness of the used resource management scheme in utilizing the available resources.

In this context, and in order to evaluate the average percentage of blocking while increasing the number of students, we consider fixing the following parameters, number of physical and virtual machines, total number of timeslots, and the total number of resources in the system. On the other hand, in order to evaluate the average percentage of blocking while increasing the number of machines, we consider fixing the total number of students, total number of timeslots, and the total number of resources in the system parameters. Furthermore, to evaluate the average resource utilization efficiency while increasing the number of physical and virtual machines, we consider fixing the total number of timeslots, and the total number of resources in the system parameters. In addition, we fix the number of physical and virtual machines, and the total number of timeslots parameters in evaluating the average resource utilization efficiency while increasing the total number of resources in the system. Moreover, a detailed explanation of how each physical and virtual machine is assigned its resources is described in the next subsection.

Table 1 Parameters values for different simulation runs.

Simulation Parameter	**Value**
Number of experiments N^E	5
Number of resources needed for an experiment $\lvert E_e \rvert$	1
Percentage of blocking vs number of students	
Number of machines N^M	5, 15
Number of timeslots $N_e^{T_d}$	10
Total number of resources in the system N_{total}^R	25
Percentage of blocking vs number of machines	
Number of students N^S	40, 80
Number of timeslots $N_e^{T_d}$	10
Total number of resources in the system N_{total}^R	25
Resource utilization efficiency vs number of machines	
Number of timeslots $N_e^{T_d}$	1
Total number of resources in the system N_{total}^R	25
Resource utilization efficiency vs total number of resources in the system	
Number of machines N^M	5, 15
Number of timeslots $N_e^{T_d}$	1

1.2 Resources to physical and virtual machines mapping

An important parameter that directly affects the performance of the laboratory managements system and represents different case scenarios is the number of available physical and virtual machines, and how the total available resources in the system are mapped to it. In order to distribute and map the available resources to a specific number of the available virtual and physical machines N^M, the total number of available resources N_{total}^R should be given. In each iteration, the number of resources $N_r^{\mathcal{M}}$ for each resource type r is assigned randomly, such that $\sum_{r=1}^{N^R} N_r^{\mathcal{M}} = N_{total}^R$. Then, the resources of each resource type r is mapped randomly to the available physical and virtual machines, under the condition that each machine should assigned at least one resource from the different resource types, and considering that there is always at least one combination where each resource type is mapped to a different machine, to reflect the possibility of conducting all the available experiments at the same timeslot.

It should be noticed that the total number of available resources N_{total}^R should always be greater than or equal the number of virtual and physical machines N^M, in order to make sure that every machine is mapped at least to one resource. Besides, the total number of available resources N_{total}^R should not exceed the number of virtual and physical machines N^M multiplied by the number of available resource types N^R, to ensure that there are no extra resources wasted and not assigned to a machine. Thus, the following inequality must be satisfied:

$$N^M \leq N_{total}^R \leq N^M \times N^R \qquad (14)$$

For illustration, Figure 6 shows three resources to physical and virtual machines mapping tables with different number of machines in each table. Note that, the values in each cell of the table is binary, to indicate whether a resource r is mapped to machine m or not, where 1 indicates a mapping between resource r to machine m, and 0 otherwise. The reason that the cell value should be binary, and does not has values more than 1, is that a resource can only be installed once on a physical or virtual machine (i.e. it is not logical to have more than one license for a specific software on a physical or virtual machine). In this figure, the total number of resources in the system N_{total}^R is fixed, and is equal to 25. Also, the number of available resource types N^R is fixed, and is equal to 5. Moreover, the number of resources $N_r^{\mathcal{M}}$ for each resource type r is fixed, and is equal to 5, such that $\sum_{r=1}^{N^R} N_r^{\mathcal{M}} = N_{total}^R = 25$. The highlighted cells in each table show that there is always at least one combination where each resource type is mapped to a different machine, to ensure that there is at least one way to work all the experiments at the same time, and this condition must be considered while randomly assigning the number of resources for each resource type to the physical and virtual machines.

		Resources ($N^R=5$)					
		$N_1^M=5$	$N_2^M=5$	$N_3^M=5$	$N_4^M=5$	$N_5^M=5$	N_m^R
Machines ($N^M=5$)	m=1	1	1	1	1	1	5
	m=2	1	1	1	1	1	5
	m=3	1	1	1	1	1	5
	m=4	1	1	1	1	1	5
	m=5	1	1	1	1	1	5
Total resources in the system N^R_{total}							25

(a)

		Resources ($N^R=5$)					
		$N_1^M=5$	$N_2^M=5$	$N_3^M=5$	$N_4^M=5$	$N_5^M=5$	N_m^R
Machines ($N^M=15$)	m=1	1	1	0	0	0	2
	m=2	1	0	0	1	0	2
	m=3	0	1	0	0	1	2
	m=4	0	0	0	1	1	2
	m=5	0	0	1	0	1	2
	⋮	⋮	⋮	⋮	⋮	⋮	⋮
	m=15	1	0	0	0	0	1
Total resources in the system N^R_{total}							25

(b)

		Resources (N^R=5)					
		N_1^M=5	N_2^M=5	N_3^M=5	N_4^M=5	N_5^M=5	N_m^R
Machines (N^M=25)	m=1	0	1	0	0	0	1
	m=2	1	0	0	0	0	1
	m=3	0	0	0	1	0	1
	m=4	0	0	1	0	0	1
	m=5	0	0	0	0	1	1
	. . .	. . .	. . .	. . .	. . .	. . .	. . .
	m=25	0	0	1	0	0	1
Total resources in the system N^R_{total}							25

(c)

Figure 6 Resources to physical and virtual machines mapping. In (a), the total number of physical and virtual machines is $\boldsymbol{N^M} = \mathbf{5}$. In (b), the total number of physical and virtual machines is $\boldsymbol{N^M} = \mathbf{15}$. In (c), the total number of physical and virtual machines is $\boldsymbol{N^M} = \mathbf{25}$. Note that, the total resources in the system $\boldsymbol{N^R_{total}} = \mathbf{25}$, and the number of different resource types $\boldsymbol{N^R} = \mathbf{5}$, and the number of resources used in each resource type $\boldsymbol{N_r^{\mathcal{M}}}$, are fixed in (a), (b), and (c).

In Figure 6-a, the number of physical and virtual machines N^M is 5. This table represents the extreme scenario of (14) where $N^R_{total} = N^M \times N^R$. This scenario is the most cost-efficient scenario where all the physical and virtual machines are fully utilized, and each machine is mapped to all the available resource types. However, only 5 students, requiring any of the available experiments, can be associated to the available machines in one timeslot. By increasing the number of physical and virtual machines N^M to be equal to 15 as shown in Figure 6-b, the number of resources for each resource type is mapped randomly to the available physical and virtual machines. Thus, each physical or virtual machine is assigned some of the available resource types. Although the number of machines increased, and accordingly the number of students that can be associated to machines in one timeslot increased, the resource types availability per machine decreases, hence, all the students cannot acquire the same experiment at the same timeslot. On the other side, increasing the number of machines increases the laboratory cost as well. By increasing the number of physical and virtual machines to the maximum to be $N^M = N^R_{total} = 25$ satisfying (14) as shown in Figure 6-c, the number of resources for each resource type is mapped randomly to the available physical and virtual machines, while considering that each machine should be mapped to at least one resource of the available resource types. Thus, each machine will be mapped to only one resource type. In this scenario, the number of machines is maximized, hence, the number of students that can be associated with the available machines is also maximized, and this is considered the ideal scenario in terms of the associated number of students. However, the laboratory cost is also maximized, and the resource types availability per machine is decreased.to the minimum. These different scenarios show the tradeoff between cost, and the resource types availability per machine, which if exploited by a well-designed management scheme, it can offer a significant performance enhancement.

1.3 Simulation Results

In this subsection, we evaluate the performance of the proposed remote laboratory management system without the matching game framework, where a student's reservation to a physical or virtual machine for specific experiment is fixed (i.e. the student will be always associated to the same reserved machine until working the experiment). Then we will compare it with proposed remote laboratory management system while applying the matching game framework, where a student's reservation to a physical or virtual machine for specific experiment is dynamic (i.e. the student will be associated to any machine that is mapped to the needed resources for his experiment). Both the proposed remote laboratory management system with and without the matching game framework are compared to a third remote laboratory where each physical and virtual machine is assigned only one experiment, such that all the experiments are mapped to physical and virtual machines. In order to ease the comparing between the three remote laboratory management systems, the proposed remote laboratory management system without the matching game framework, which indicates a Fixed Student to Machine Reservation, will be denoted by (FSMR). The proposed remote laboratory management system with matching game framework, which indicates a Matching Game based Resource Association, will be denoted by (MGRA). While the remote laboratory system where each physical and virtual machine is assigned only one experiment, which indicates a Fixed Resource to Machine Assignment, will be denoted by (FRMA).

In Figure 7, a comparison between the different remote laboratory management schemes in terms of the average resource utilization efficiency while changing the total number of resources in the system is presented. As shown, the proposed MGRA and FSMR management schemes outperform the FRMA scheme at N^M = 5 and N^M = 15. Also, it can be shown that the proposed MGRA has higher average resource utilization efficiency compared to the proposed

FSMR management scheme at N^M = 5 and N^M = 15. This is because the FRMA scheme has a fixed physical and virtual machine to experiment assignment, thus, if the number of students acquiring an experiment is greater than the physical and virtual machines assigned to that experiment, only some of the students (equal to the number of machines assigned to that experiment) will be associated to the physical and virtual machines, while others will remain unassociated. On the other hand, the proposed MGRA and FSMR management schemes looks for the needed resources of the acquired experiment by a student on all the available machines, thus, they are not bounded by a number of physical or virtual machines that are assigned to that experiment, they are bounded by the number of resources on all the machines that are acquired by the experiment.

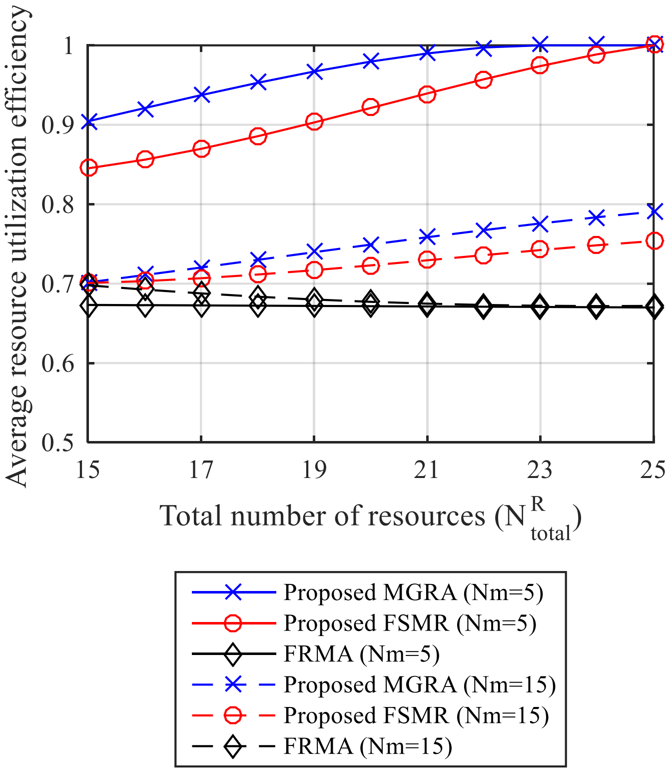


Figure 7 Average resource utilization efficiency for different remote laboratory management schemes with the change in the total number of resources at number of machines = 5 and number of machines =15.

Moreover, the proposed MGRA scheme outperforms the FSMR scheme because the MGRA scheme manages the students to machines association dynamically according to the experiments acquired by the students (i.e. it looks for the best association combination to fit all the students), while in the FSMR scheme, the student that comes first chooses the machine to be associated with, according to the machine's available resources and the needed resources by the experiment, and this association remains fixed.

Furthermore, it can be noticed that the FRMA scheme's average resource utilization efficiency does not change with the change in the total number of resources, and has almost similar values at different number of physical and virtual machines. This because increasing the total number of resources will increase the available resource types per machine, despite that, the FRMA scheme will assign a permeant experiment to a machine, and the available resource types per machine will not be useful in the students to machine association. On the other side, it can be noticed that the proposed MGRA and FSMR management schemes increase with the increasing total number of resources. This is because increasing the total number of resources will increase the available resource types per machine, and the proposed schemes exploit the number of available resource types per machine, as it will increase resource types availability per machine, which in turn can handle a diverse students' experiments.

Figure 8 illustrates the effect of increasing the number of physical and virtual machines for the different schemes in terms of average resource utilization efficiency. It can be shown that the both the proposed MGRA and FSMR management schemes outperform the FRMA scheme. This is because both schemes exploit the number of available resource types per machines, while the FRMA scheme has a fixed machine to experiment assignment, thus, wasting the number of available resource types per machine. Moreover, it can be noticed that the FRMA scheme has an almost constant average resource utilization efficiency, this is because increasing the number of machines does not affect the resource utilization efficiency, since the number of students that should be associated increases as well. Also, it can be noticed that both the proposed MGRA and FSMR management schemes decreases with the increase of the number of machines, this because the total number of resources is constant and is equal to 25, and by increasing the number of machines, the resource type availability per machine decreases, until reaching the ideal scenario shown in Figure 6-c (when the number of machines reaches 25), at which all the schemes will achieve the same average resource utilization efficiency, as each machine will be assigned only on resource. Furthermore, the proposed MGRA scheme outperforms the proposed FSMR scheme because of the dynamic management of the students to physical and virtual machines association according to the required resources needed for the acquired experiment.

An interesting observation is that both the proposed MGRA and FSMR management schemes achieves the same and the highest average resource utilization efficiency when the number of machines is equal to 5. This is because the total number of resources is 25, and the number of resource types is 5, thus, each machine will have all the resource types available for it, as shown in Figure 6-a. At this situation the resource type availability per machine is at its maximum, thus, both schemes have an average resource utilization efficiency equal to 1.

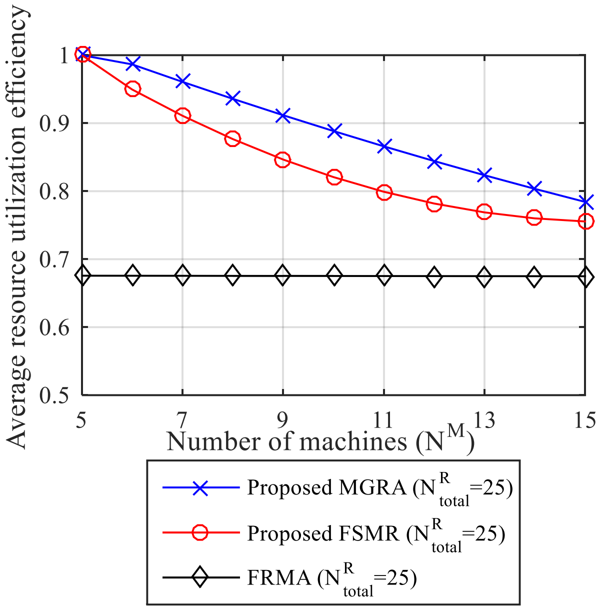


Figure 8 The effect of changing the number of physical and virtual machines for the different management schemes in terms of average resource utilization efficiency.

In order to study the effect of increasing the number of students on the remote laboratory management schemes, Figure 9 shows the performance of the different management schemes in terms of average percentage of blocked timeslots at different number of machines while changing the number of students in the system. It is noteworthy that the total number of resources in the system is fixed at 25 for this simulation run. This figure shows that both the proposed MGRA and FSMR scheme outperform the FRMA scheme at the different number of machines. This is because of the dynamic experiment to machine assignment according to the needed resources by the experiment in the FSRMA, and the dynamic student to machine association according to the needed resources by the experiments acquired by all the students reserving the same timeslot in the MGRA scheme, compared to a static and fixed experiment to machine assignment in the FRMA scheme. At number of machines equal to 5, and since the number of timeslots is 10, all the schemes reach a percentage of 100% at number of students equal to 50, since all the machines in all the timeslots are reserved. The same happens when the number of machines is 15, and the number of students reaches 150.

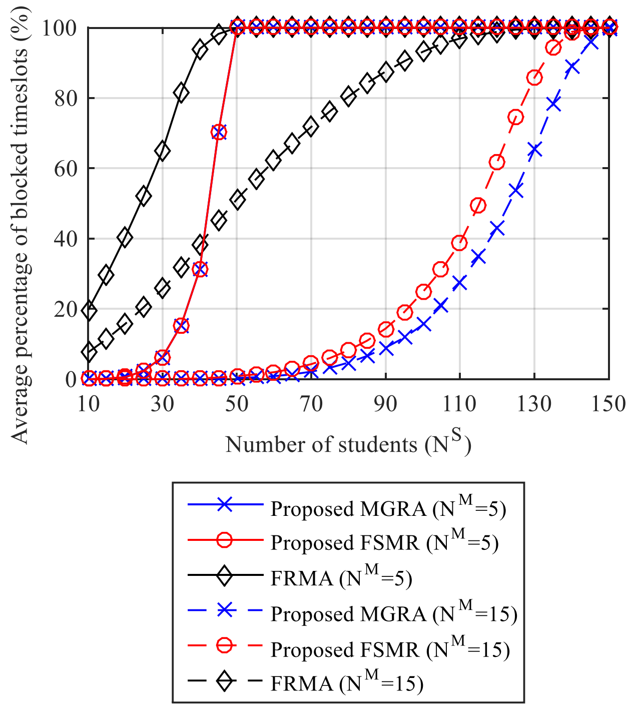


Figure 9 Average percentage of blocked timeslots for laboratory management schemes at different number of machines while changing the number of students.

Also, it can be noticed that both the proposed MGRA and FSMR management schemes have the same average percentage of blocked timeslots at number of machines equals to 5, while increasing the number of students. This is because of the case scenario discussed in Figure 6-a, where the resource type availability per machine is at its maximum, and al the resource types are available for each machine, thus both the proposed schemes achieve the same performance. At number of machines equal to 15, the proposed MGRA achieves better performance compared to the proposed FSMR, where the resource type availability per machine decreases, hence, the students to machines association optimization done in the MGRA scheme shows significant performance improvement.

Furthermore, the effect of increasing the number of machines on the performance of the different remote laboratory management schemes in terms of average percentage of blocked timeslots at different number of students in the system is studied in Figure 10. It is noteworthy to know that the total number of resources in the system is 25 in this simulation run. Generally, it can be shown that by increasing the number of machines the average percentage of blocked timeslots decreases for all the remote laboratory management schemes, since the machines avaialbility increases, hence increasing the capacity of students to machine association at one timeslot. Also, it can be noticed that that the proposed MGRA scheme achieves better perormance at number of students equals to 40 and 80, this is because of the students to machines association optimization used in the MGRA scheme to minimize the number of blocked timeslots.

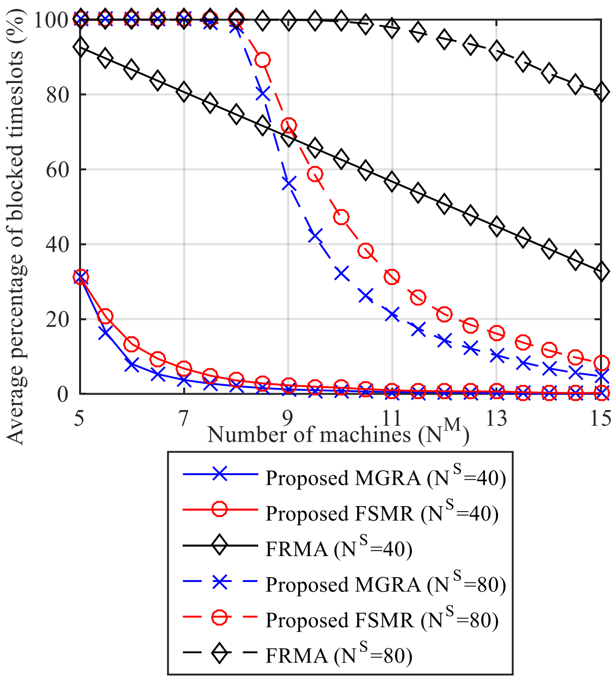


Figure 10 Average percentage of blocked timeslots for laboratory management schemes at different number of students while changing the number of machines.

Moreover, it can be noticed that both the proposed MGRA and FSMR schemes achieves the same performance at number of machines equals to 5, this is due to the scenario described in Figure 6-a, where the resource type availability per machine is at its maximum. It can also be shown that all the schemes achieve an average percentage of blocked timeslots equal to 100%, when the number of students is 80, until the number of machines reach 8. This is because when the number of machines is less than 8, the total number of machines available for reservation in all the 10 available timeslots is less than the number of students in the system, therefore, there will always be no timeslots available.

Appendix (3)
Detailed Results of Task 2.5

T2.5: Design and development of laboratory synchronous and asynchronous communication services.

The system implements a five-tier business model: the system users' layer, the experiment sharing and control runtime engine layer, the group-based experiment service layer, the laboratory learning management system (LLMS) layer, and the infrastructure layer, as shown in Figure 11.

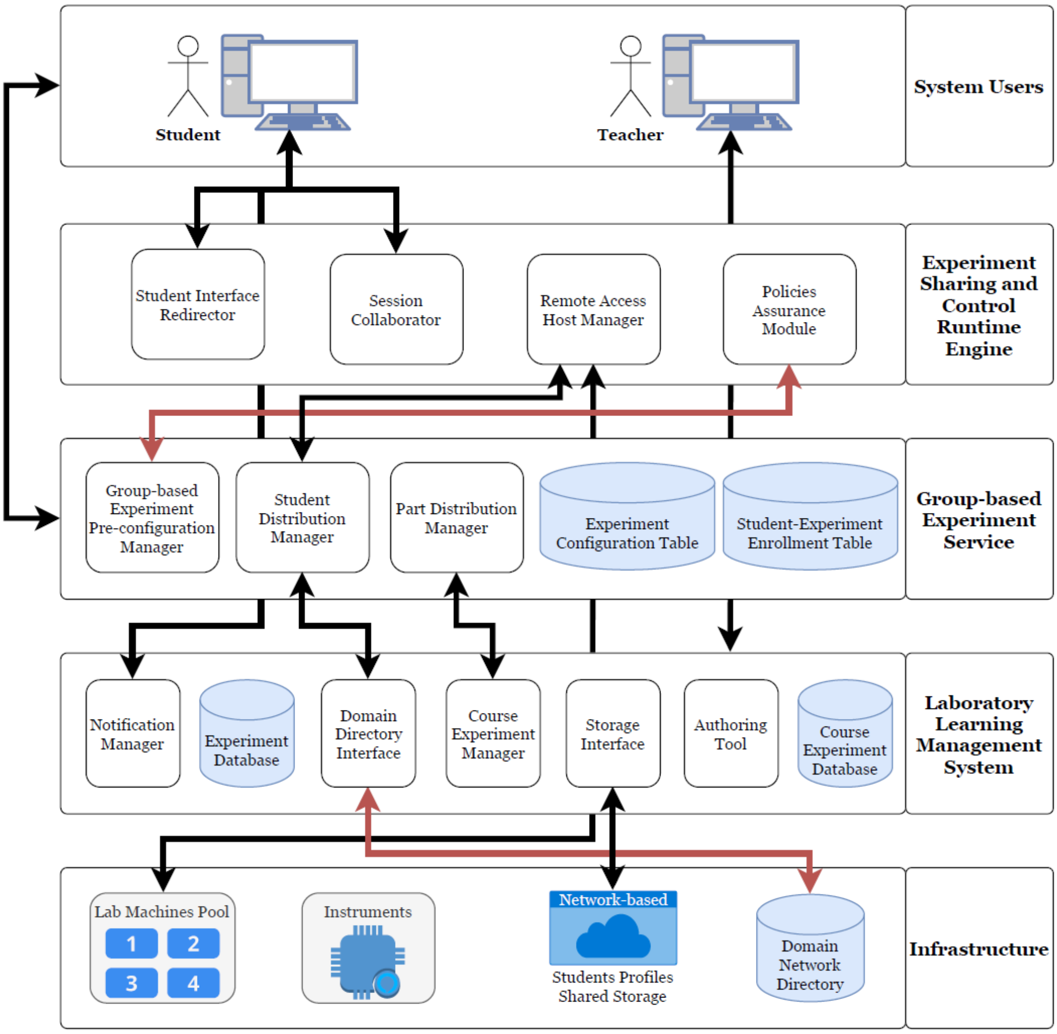


Figure 11. Layered architecture of the proposed Collaborative and Cooperative laboratory learning management system

The system users layer represents the student and the teacher roles. The student receives audio, video, and text from his group colleagues, and is able to remotely access the lab machine from the infrastructure layer via the run-time engine layer.

The experiment sharing and control run-time engine layer consists of the applications responsible for managing and maintaining the running concurrent sessions and control the remote lab machines which are accessed through a web browser. The run-time engine provides remote access host manager which hosts the lab machine remote access and have two types of shares. The lab machine granted control share type is sent to the master student who is in control, and the lab machine screen-only share type is sent to the students not in control. These two share types are made possible via the student interface redirector, which is responsible for the machine screen area shown in Figure 14. A recommended implementation for the remote access host manager is Myrtille built using .NET framework via C# language, where the average session uses about 200 KB/s of bandwidth.

This layer is also responsible for the audio, video and text chat between the group student members, which is done by means of the session collaborator. A good implementation that supports multi-participants, video stream, audio stream, and text chat is Conference Call built using PHP Web socket (Ratchet). Another implementation for it is built using socket.io and NodeJS, but is ideal for not more than 4 students in one group.

The running experiment have certain policies that ensures evenly contribution between the same group members within the experiment. This contribution can be calculated by means of experiment parts finished or time. Policies assurance module is responsible for that via direct control on the student interface redirector if needed.

The group-based experiment service layer consists of the applications responsible for configuring experiments, students′ distribution and student-to-part distribution managers. The process of assigning students to the same group is the responsibility of the student distribution manager, whether this distribution is manual by means of the teacher choice or by means of the students′ desires, or automatic by means of specific criteria determined by the teacher. Each experiment is fragmented into multiple parts, these parts can be assigned to specific students via the part distribution manager. The student distribution and part distribution managers results are saved in student-experiment enrollment database table. The experiment is configured via the group-based experiment pre-configuration manager, and saved in the experiment configuration database table.

The LLMS layer consists of the core modules, managers and interfaces with external systems. The teacher is able to create new experiments via the customized authoring tool, and the LLO is saved in the experiment database.

Adding a created experiment to course, teacher is responsible of, is possible via the course experiment manager, where a copy of the experiment LLO is added to the course and saved in the course experiment database. New added experiments to courses are notified to the students via the notification manager.

The system is able to access the domain network directory via the domain directory interface, and access the network-based students′ profiles shared storage via the storage interface. The infrastructure layer consists of all of the hardware resources such as physical and virtual lab machines, instruments such as experimental boards and devices, the students′ profiles shared storage, and the domain network directory. A web service is used as a gateway between all layers to allow the system users modules and system modules and services to access the database. This approach was preferred as it allows the separation of the system users and system modules and services from the data storage process.

Group-based Laboratory Experiment Interaction Types and Student User Interface

Group-based laboratory experiment defines two ways of student′s interaction types based on the experiment requirements, the sequential interaction between the same group students, and the concurrent interaction, as well as the student user interface while performing the experiment, as defined in the following subsections. For each interaction type, each group should reserve a time-slot to perform experiment to guarantee available software/hardware resources within the selected time-slot.

1. Sequential Interaction

In sequential interaction, known as cooperative interaction, as shown in Figure 12, only one student (master) can instantly remotely access and control lab machine to perform his assigned part using remote access host module, While other students in group can co-operate and share the master student′s activities using session sharing module. Session sharing module allow screen, audio, text and video sharing. Students in turns can switch interface and control the lab machine to finish assigned parts using students interface switch module. When a student finish his assigned part, the results will be saved in lab machine under student profile in a group shared folder.

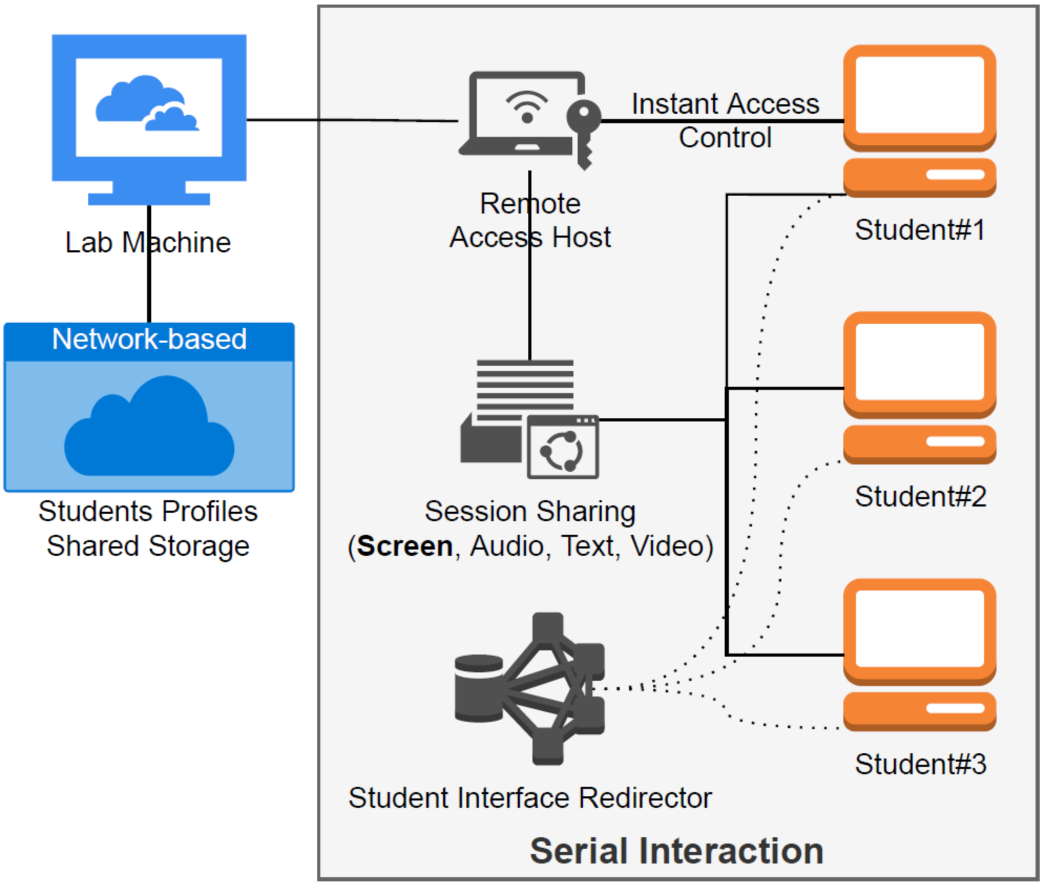


Figure 12. Group-based laboratory sequential interaction

2. Concurrent Interaction

In the concurrent interaction, known as collaborative interaction, as shown in Figure 13, group of students can mutually engage in a coordination way to perform experiment objectives efficiently. In concurrent interaction, each student can access his own lab machine using remote access host module, and use session sharing module to collaborate with his colleagues within the group by means of audio, video, and text. Each student can share his activity using the shared storage module.

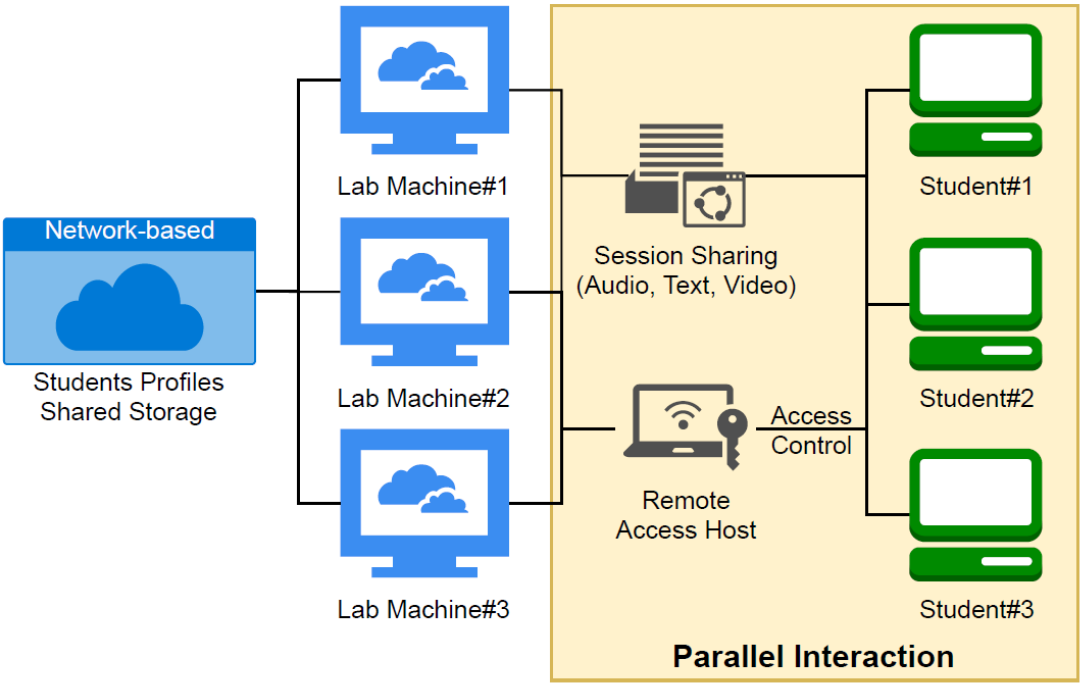


Figure 13. Group-based laboratory Concurrent interaction

3. Student Graphical User Interface

Figure 14 shows run-time experiment student's web-based graphical user interface design. The design is divided into six parts. Left-hand side shows the experiment content and assessments, which added by the instructor through the authoring tool. The experiment content may consist of text, images, tables, etc. to reflect the experiment objectives, procedures, expected results, etc., while the assessments include number of different types of questions, such as multiple-choice, true/false, matching, etc., to measure the student progress and evaluate his performance.

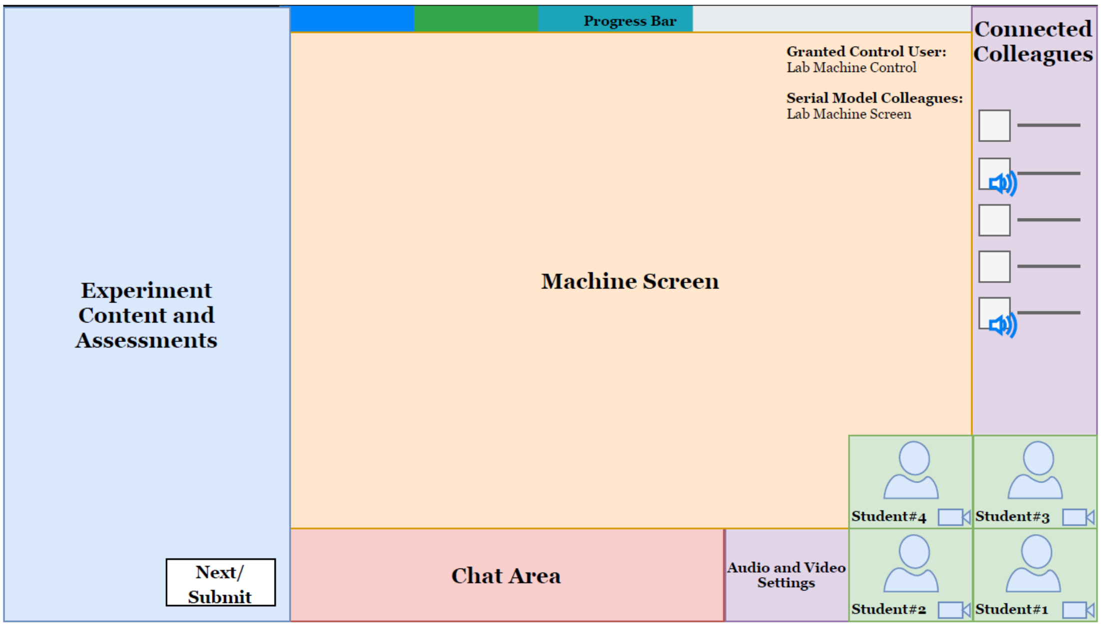


Figure 14 Runtime experiment student's web-based graphical user interface

The center of the student's graphical user interface shows the remotely connected lab machine screen whether controlled by the student (master) or it's just a shared-screen of the master's screen in case of sequential interaction. The right-hand side of the screen shows the info of the student's group connected colleagues. The progress of each student is shown in a bar located at the top of the web screen.

The bottom of the web screen contains the chat area, the student's audio settings to mute/unmute and change volume, and video settings to switch camera on/off, and the multi-video conference area showing the video coming from each participant student.

Appendix (4)
Detailed Results of Task 2.6

T2.6: Design and development of LLS users and learning database.

<u>First phase:</u> in this phase, we created the following entities and its relations:

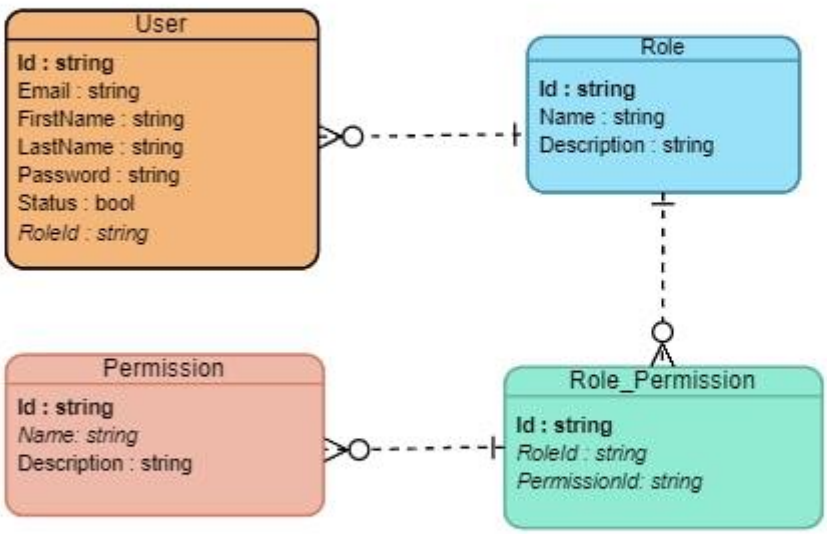
- User
- Role
- Permission

The User has one role and each role have zero or more than one Permission, so we have the relations:

1- User - Role => One-to-Many Relation

2- Role - Permission => Many -to-Many Relation

So according to requirement the ERD will be:



PostgreSQL is the relational database management system emphasizing extensibility and SQL compliance, also free and open source, chosen to be used in our proposed LLMS. As by using the .NET core framework, we worked with the Entity Framework Core, which is a modern object-database mapper for .NET. It supports LINQ queries, change tracking, updates, and schema migrations, as well as its ability to work with PostgreSQL. We made the process of running a PostgreSQL container along with a pgAdmin container. After that, we connected to the database instance using the pgAdmin portal to run the customized queries. We used this as a simple setup for our development purposes with SQL, as part of our proposed LLMS.

The following shows the test performed on each API using the postman API testing application:

1. User Controller

- Get-All-Users
- Get-User-By-Id
- Create-User-By-Admin
- Update-User
- Delete-User

2. Role Controller

- Get-All-Users-Roles
- Add-Role
- Get-User-Roles
- Delete-Role

1. <u>User Controller</u>

This Controller has all the actions required to manage the user

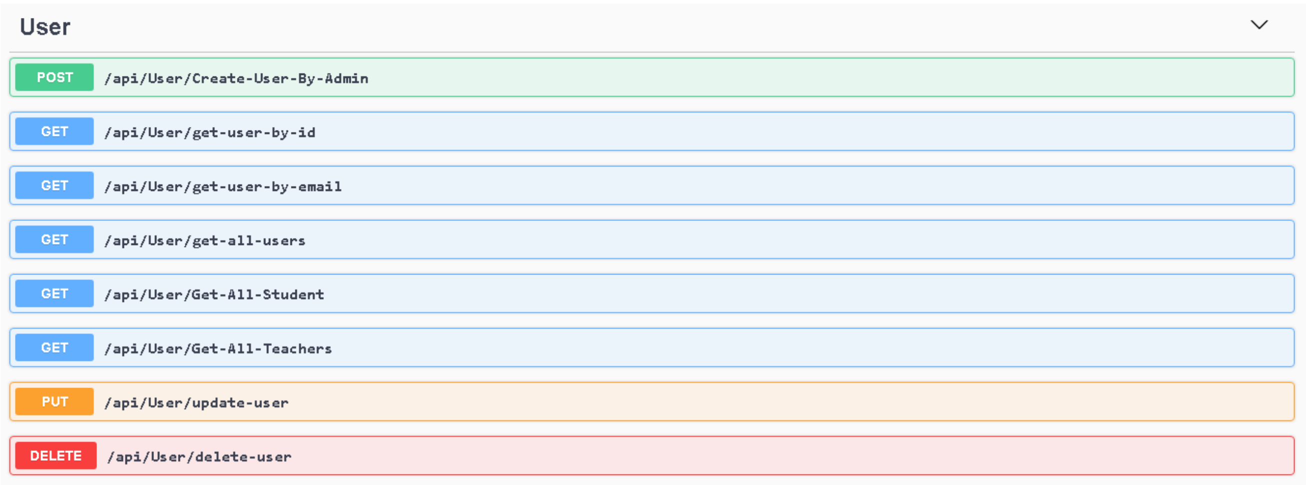


Figure 15: Snapshot of developed API endpoints in user controller previewed in swagger

- **Get-All-Users**

  This endpoint returns the data of all users in Database

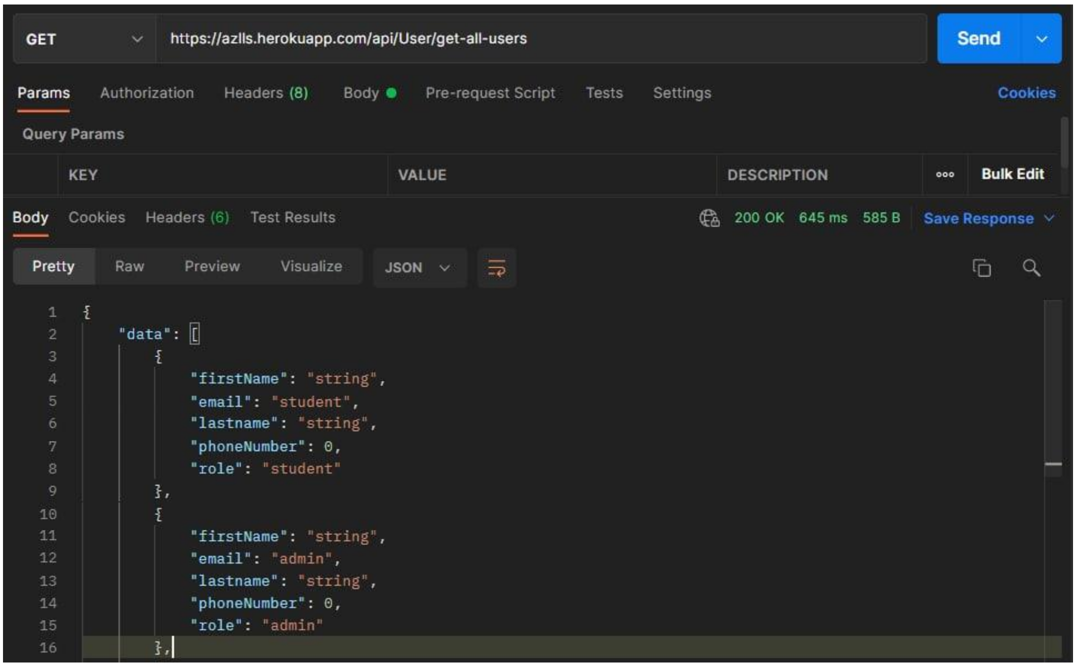


Figure 16: Snapshot of postman preview of API used for getting all users stored in the LLS database

- **Get-User-By-Id**

The frontend developer has to send an object with id of a user and this endpoint will return all of his data.

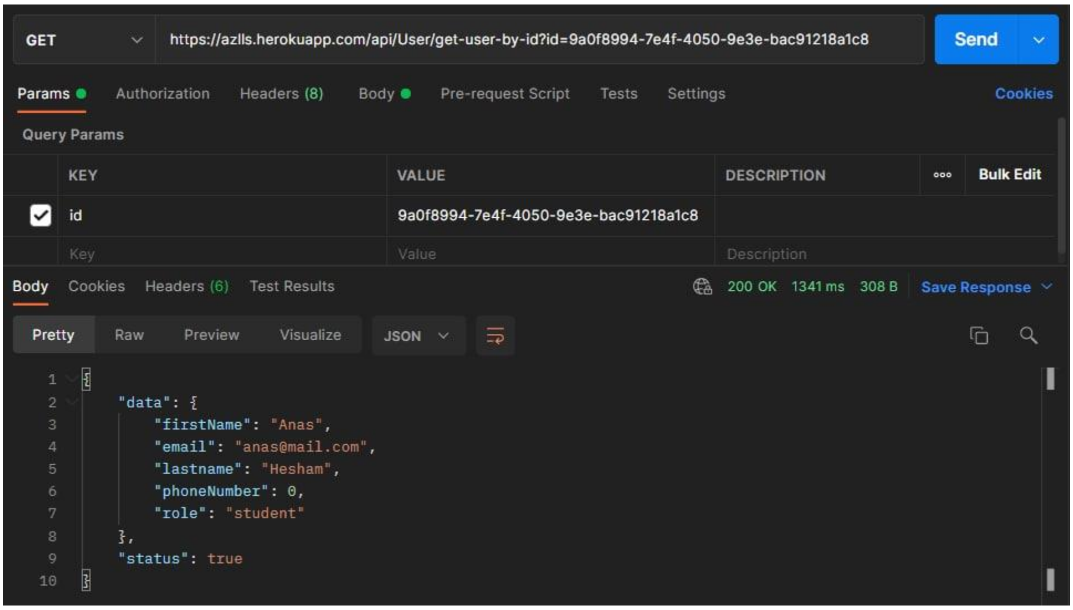


Figure 17: Snapshot of postman preview of API used for getting a user with specific id stored in the LLS database

- **Get User-By-Email**

  The frontend developer has to send an object with email of a user and this endpoint will return all of his data.

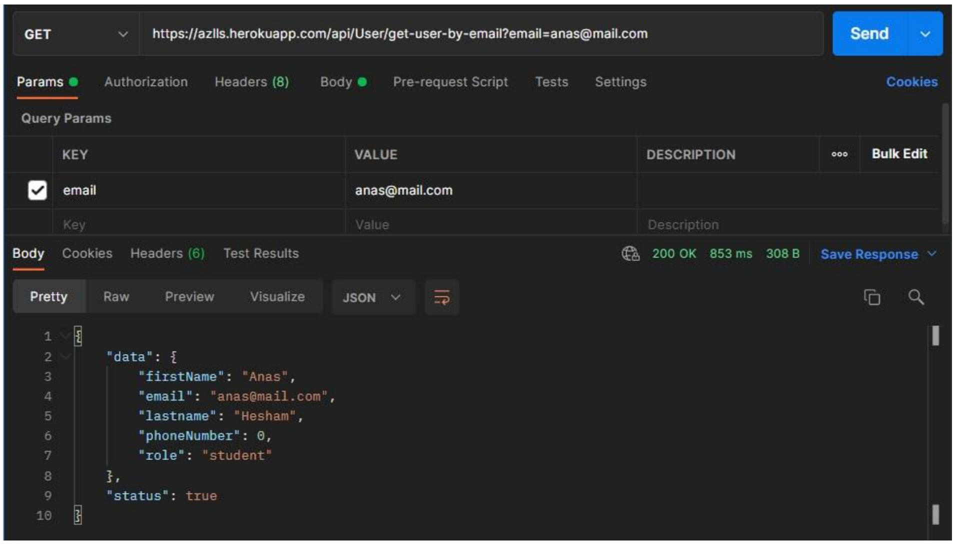


Figure 18: Snapshot of postman preview of API used for getting a user with specific Email stored in the LLS database

- **Create-User-By-Admin**

  This endpoint creates a user and save it in database, we need to send a user object with the data which we want to save in database

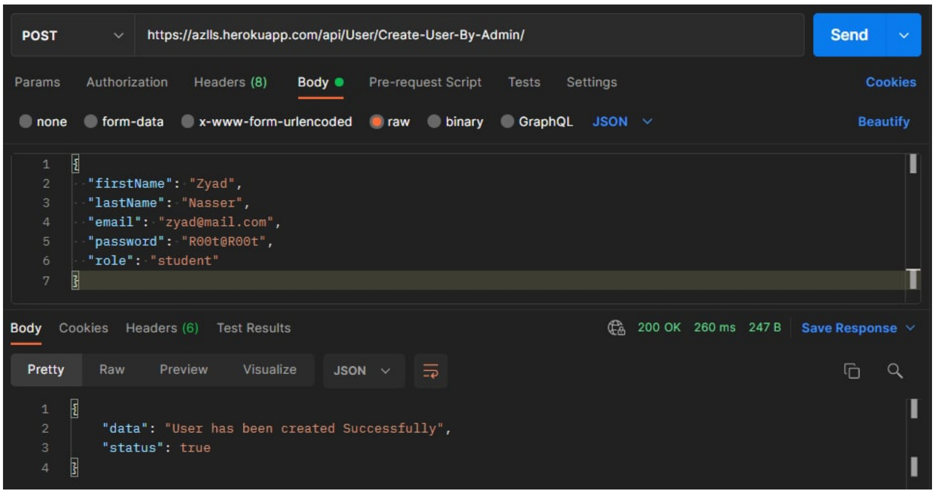


Figure 19: Snapshot of postman preview of API used for creating a user to be stored in the LLS database

- **Update-User**

This endpoint takes a user object with the new data and will bring the old user and edit its data then save it in database again.

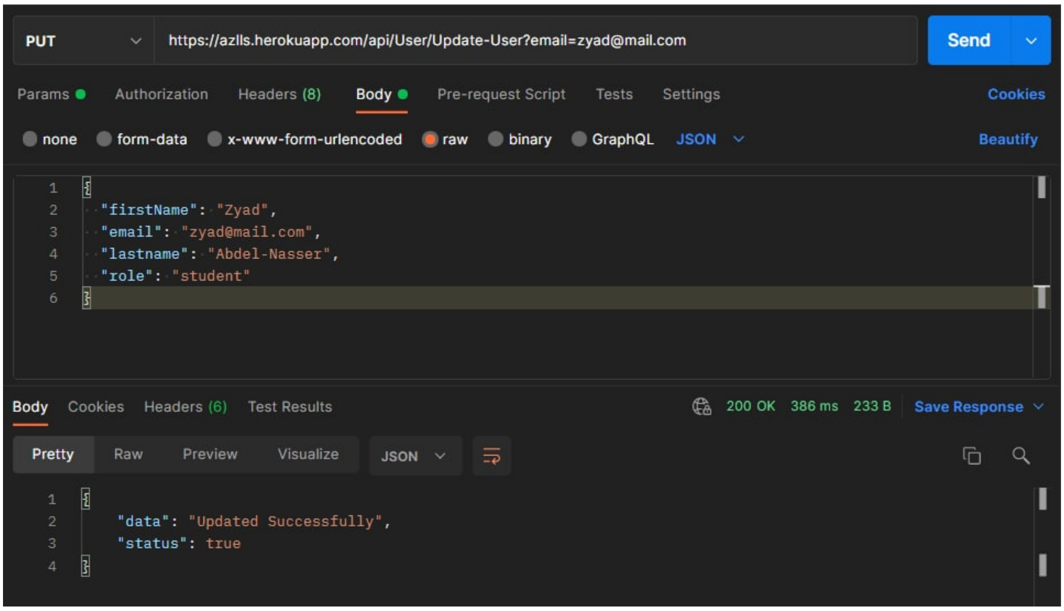


Figure 20: Snapshot of postman preview of API used to edit a user stored in the LLS database

- **Delete-User**

The frontend developer has to send an object with email of this user and this endpoint will delete him from database.

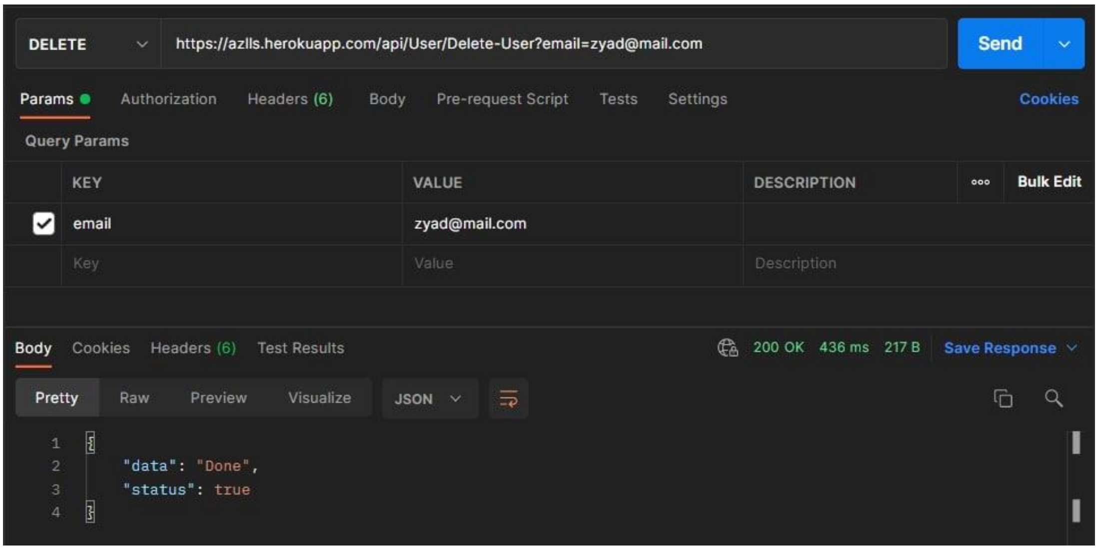


Figure 21: Snapshot of postman preview of API used to delete a stored user in the LLS database

2. Role Controller

- **Get-All-Roles**

This endpoint returns data of all roles in Database

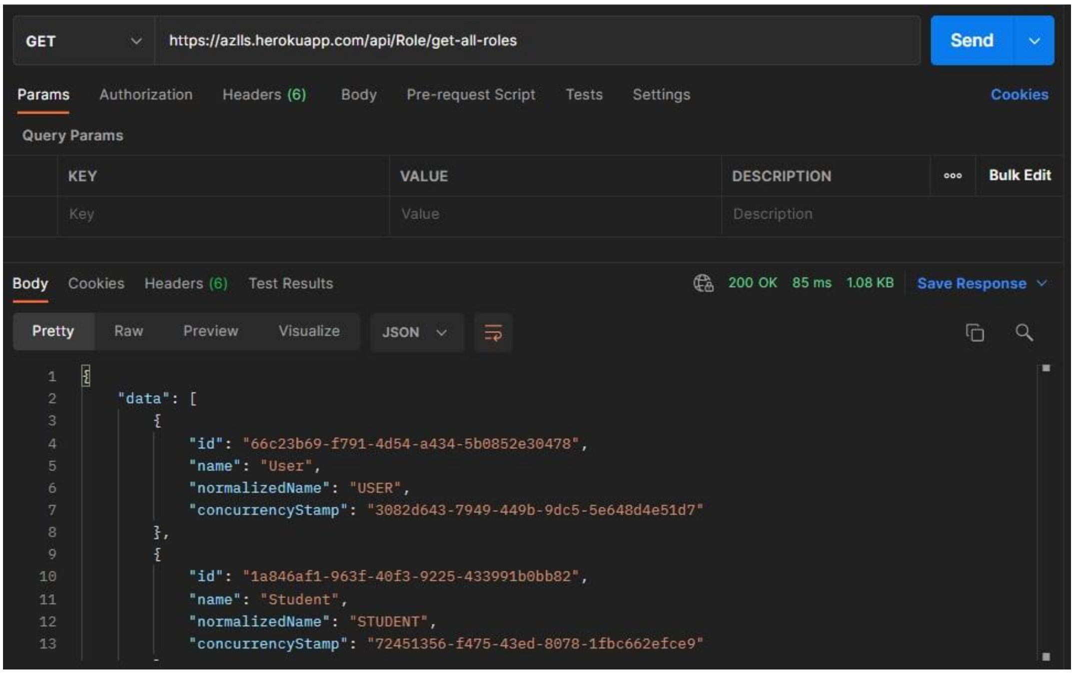


Figure 22: Snapshot of postman preview of API used to fetch all roles stored in the LLS database

- **Add-Role**

This endpoint creates a role and save it in database

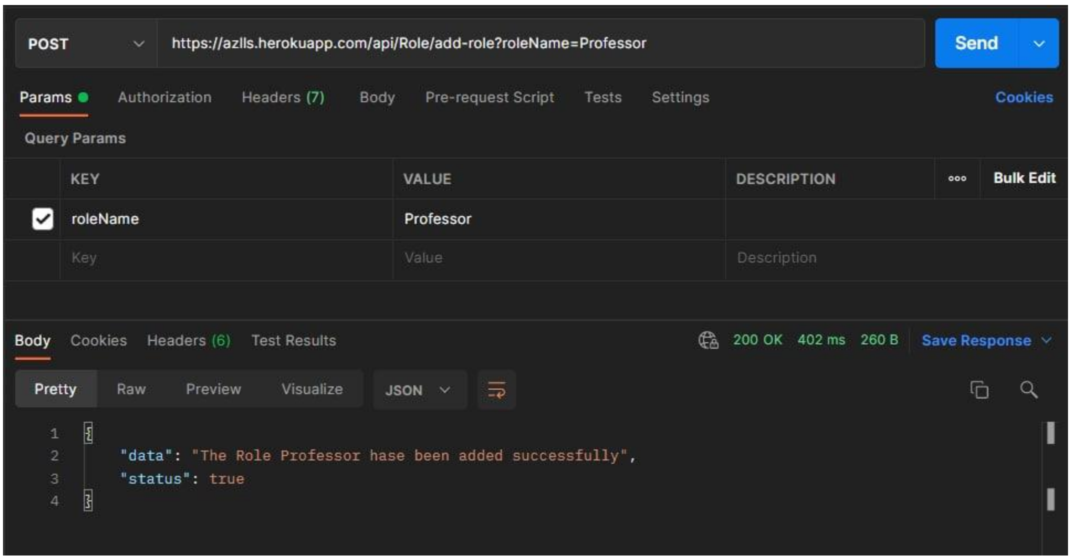


Figure 23: Snapshot of postman preview of API used to create a new role to be stored in the LLS database

- **Get-User-Roles**

  This endpoint receives a user's email and returns the list of roles assigned to this user

  Note: any created user in the system does have the role "user" by default

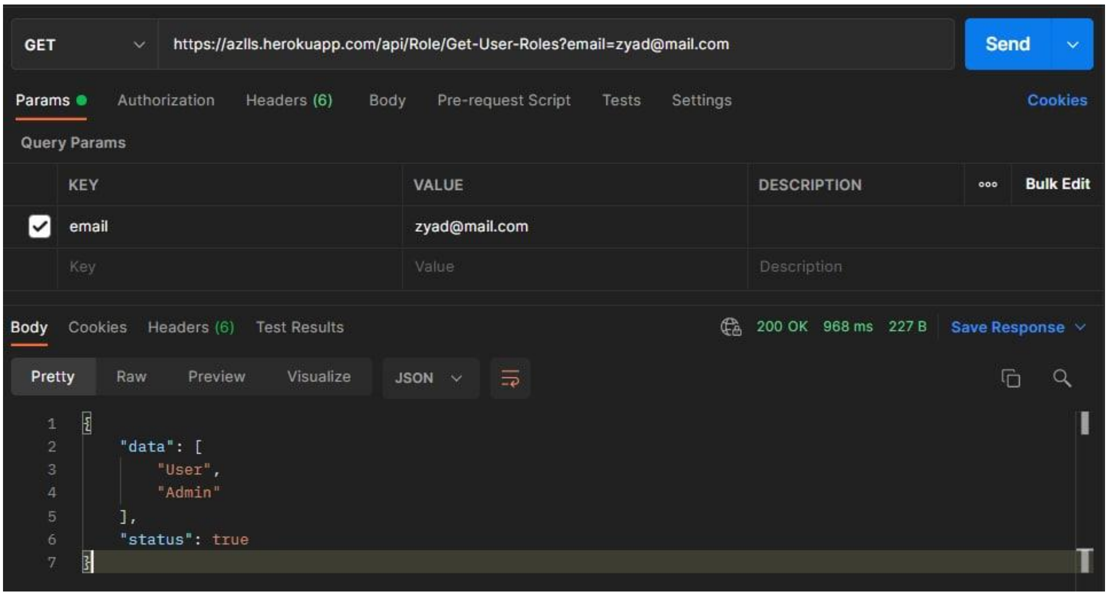


Figure 24: Snapshot of postman preview of API used to get all the user's assigned roles

- **Delete-Role**

  The frontend developer has to send an object with email of this role and this endpoint will delete it from database

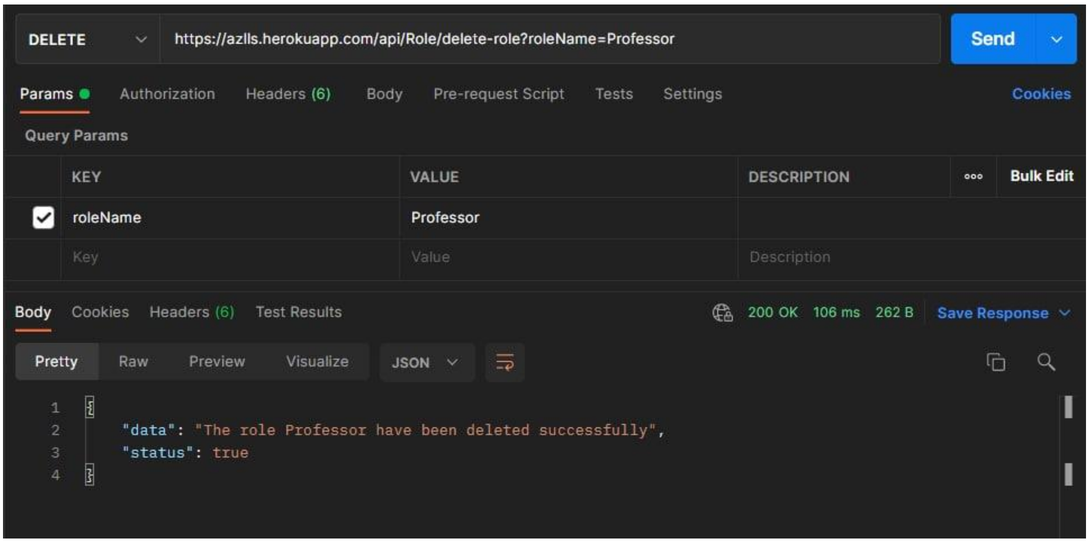


Figure 25: Snapshot of postman preview of API used to delete a role stored in the LLS databas

<u>Second Phase:</u> in this phase, we created the following entities and its relations:

- Course
- Experiment

The Course has one or more than one teacher, student and experiment and each experiment have one author

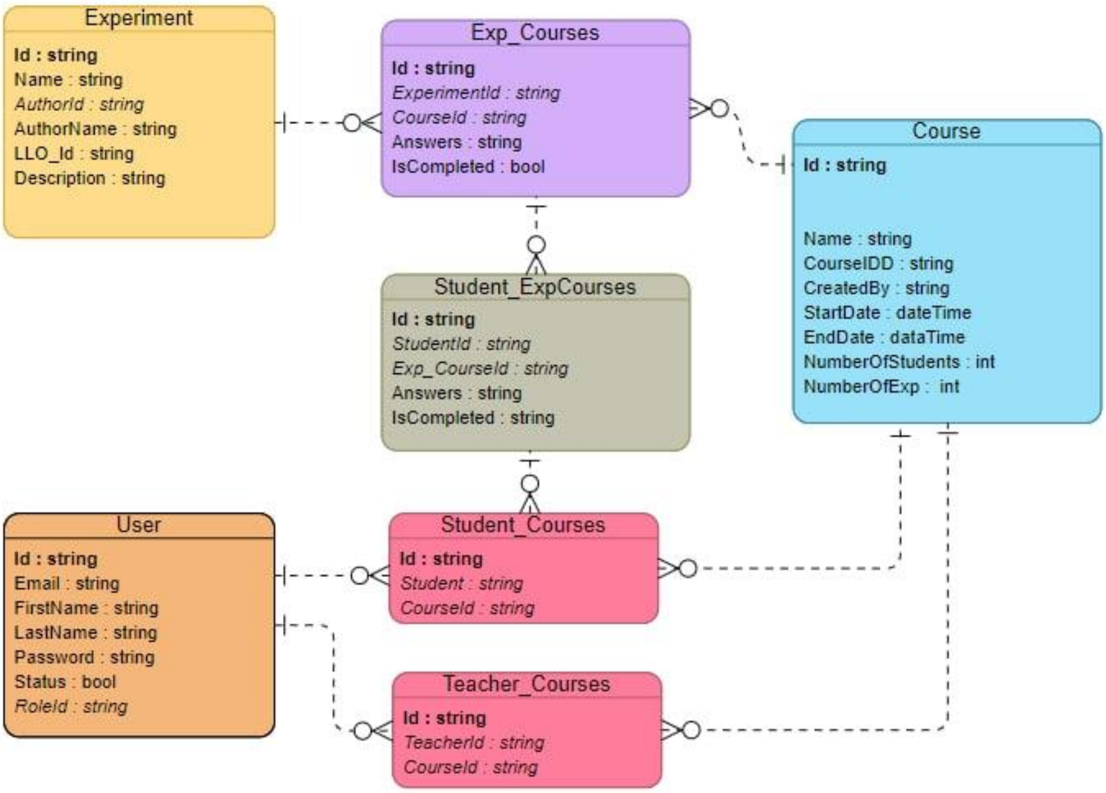
1- Course – Experiment => Many-to-Many Relation

2- Course – User (Teacher) => Many-to-Many Relation

3- Course – User (Student) => Many-to-Many Relation

4- User (Author) – Experiment => One-to-Many Relation

5- All the students assigned in a course have a many-to-many relation with the experiments within this course



The following shows the test performed on each API using the postman API testing application:

1. **Experiment Controller**
   - Add-New-Exp
   - Get-All-Exp

- Get-Experiment-By-Name
- Delete-Experiment
- Edit-Exp

2. **Course Controller**
   - Create-Course
   - Get-List-Of-Courses
   - Get-Course-By-Name
   - Assign-Teacher
   - Assign-Student
3. **Student Controller**
   - Get-Assigned-Exp-For-Student-In-Course
   - Get-All-Assigned-Exp-For-Student
   - Get-All-Assigned-Exp-For-Student-Now

1. <u>Experiment Controller</u>

This Controller has all actions required to manage the course

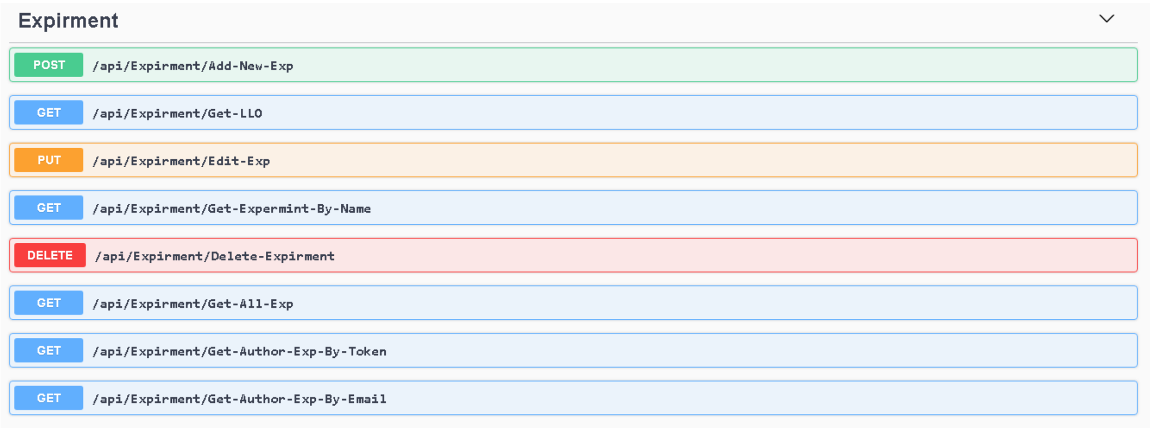


Figure 26: Snapshot of developed API endpoints in Experiment controller previewed in swagger

- **Add-New-Exp**

  This endpoint creates an experiment and save it in database, we need to send an Experiment object with the data which we want to save in database

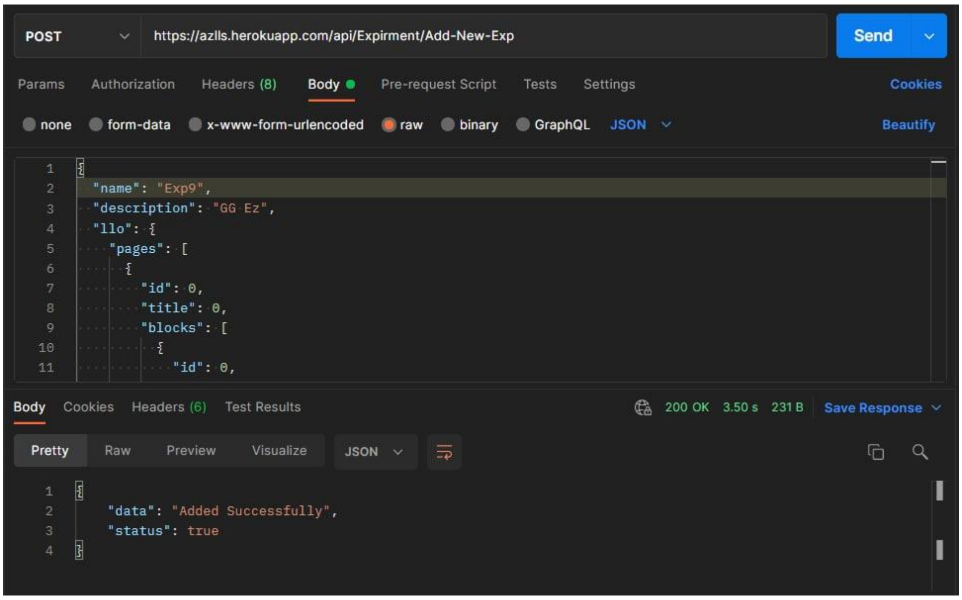


Figure 27: Snapshot of postman preview of API used for creating an Experiment to be stored in the LLS database

- **Get-All-Exp**

  This endpoint returns the data of all Experiments in Database

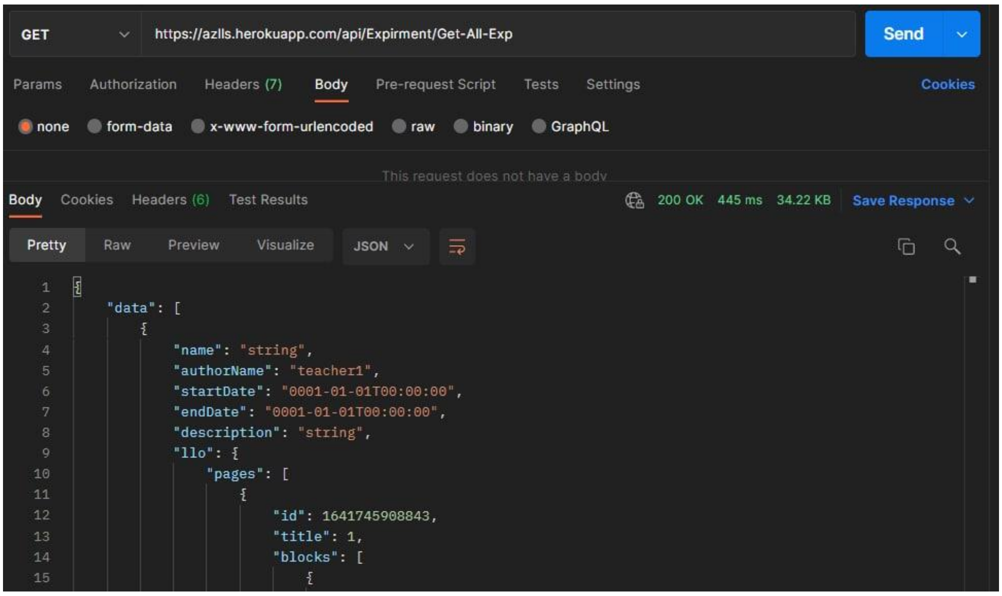


Figure 28: Snapshot of postman preview of API used for getting all Experiments stored in the LLS database

- **Get-Experiment-By-Name**

  The frontend developer has to send an object with the name of an experiment and this endpoint will return all of its data

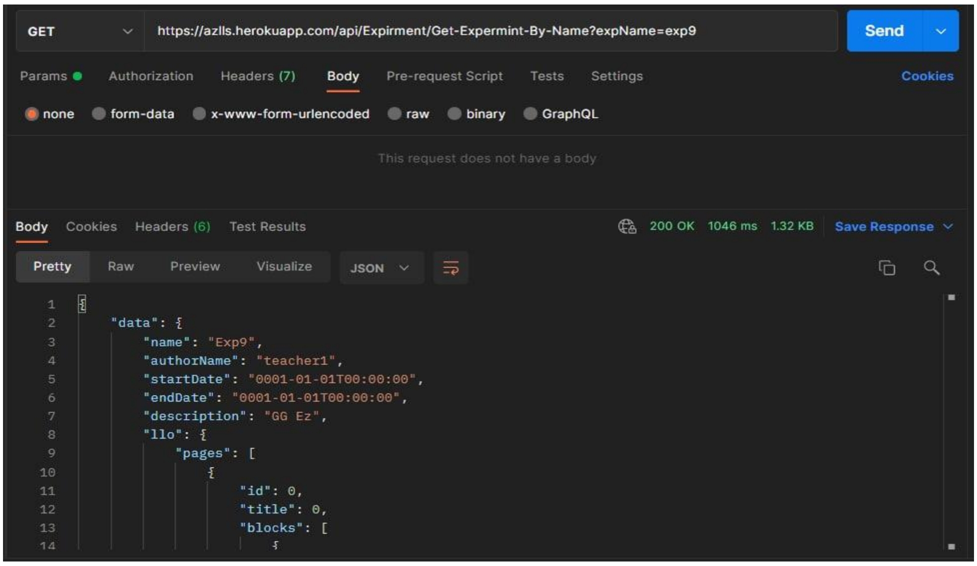


Figure 29: Snapshot of postman preview of API used for getting an experiment with specific name stored in the LLS database

- **Delete Experiment**

  The frontend developer has to send an object with Name of this Experiment and this endpoint will delete it from database

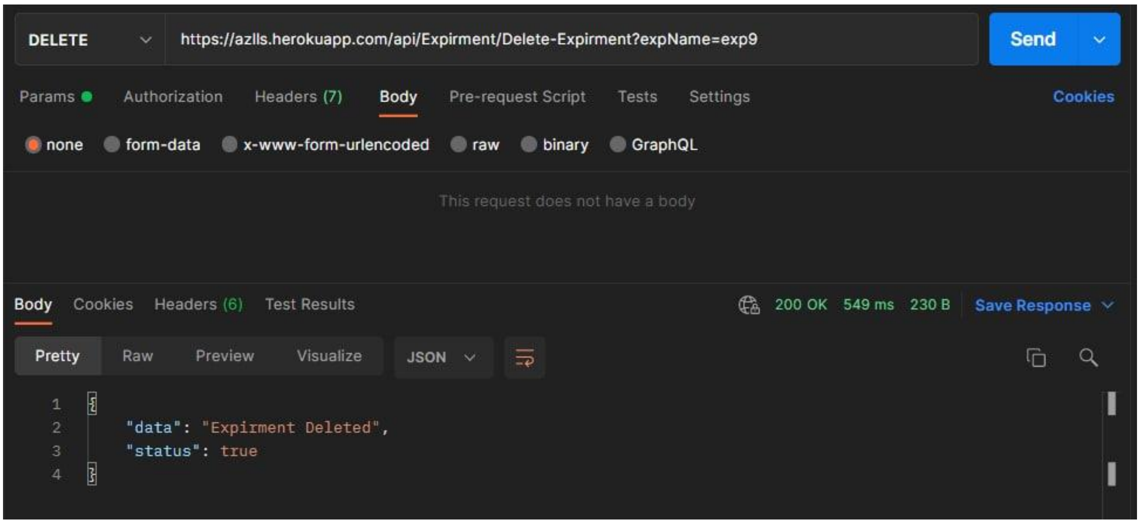


Figure 30: Snapshot of postman preview of API used to delete a stored Experiment in the LLS database

2. Course Controller

Figure 31: Snapshot of developed API endpoints in course controller previewed in swagger

- ### Create Course

This endpoint creates a course and save it in database, we need to send a course object with data which we want to be saved in database

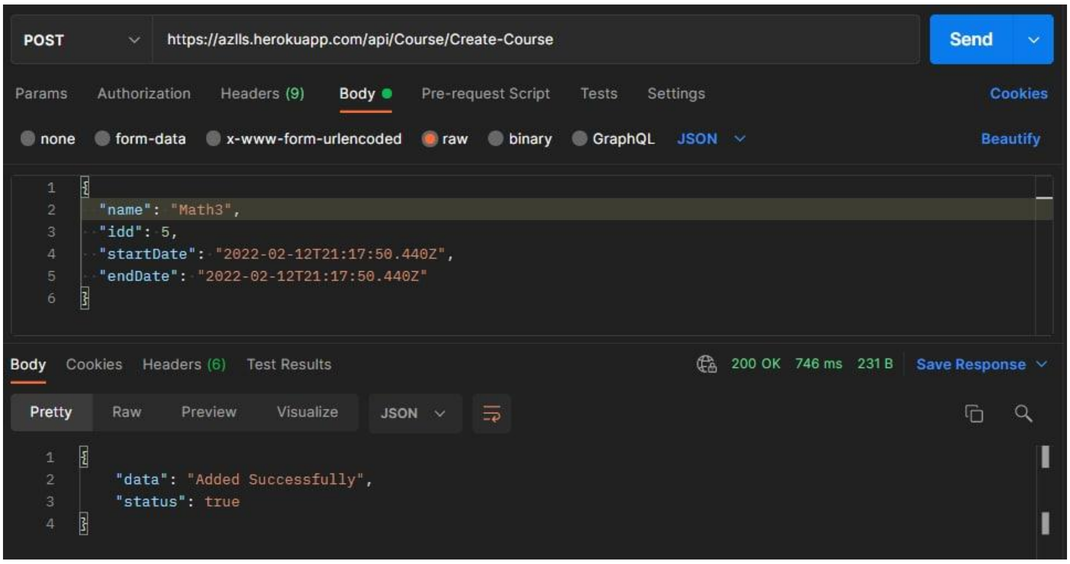


Figure 32: Snapshot of postman preview of API used for creating a course to be stored in the LLS database

- **Get-List-Of-Courses**

This Endpoint returns the data of all courses in database

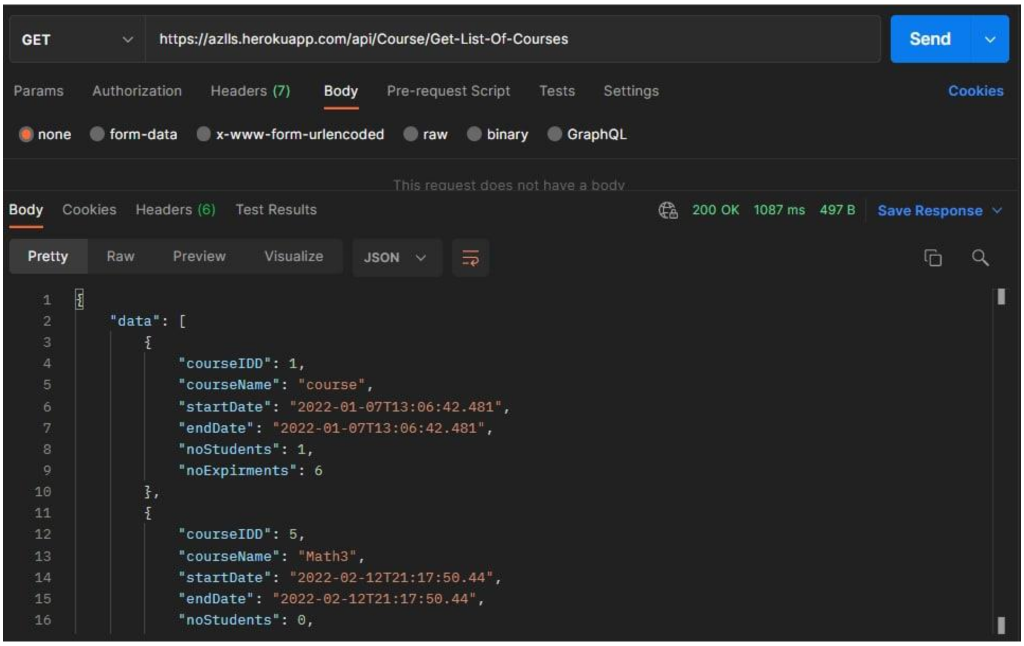


Figure 33: Snapshot of postman preview of API used for getting all courses stored in the LLS database

- **Get-Course-By-Name**

The frontend developer has to send an object with Name of a course and this endpoint will return all of its data

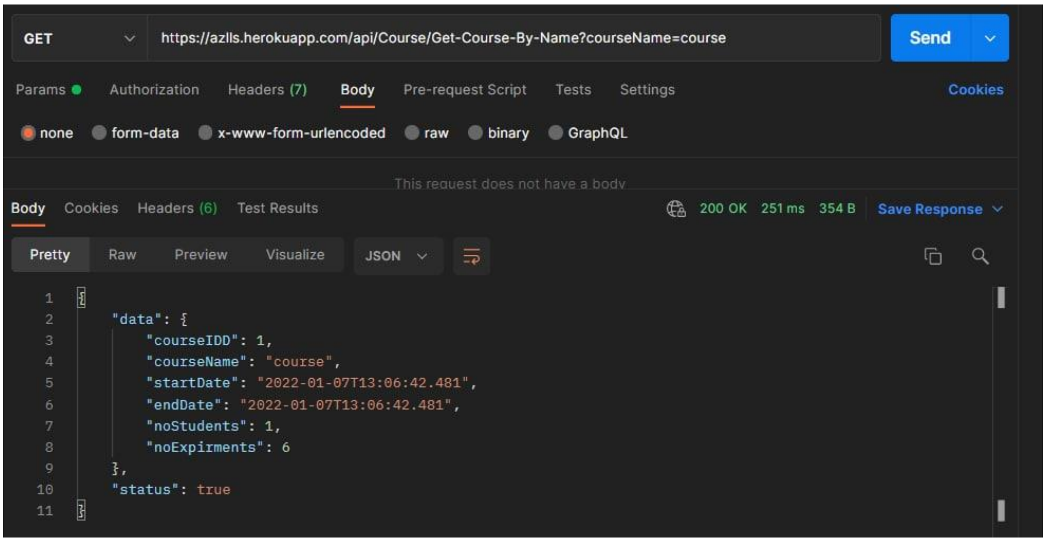


Figure 34: Snapshot of postman preview of API used for getting a course with specific name stored in the LLS database

- **Assign-Teacher**

This endpoint is used to assign a teacher to a course given the teacher's name and course name by the frontend

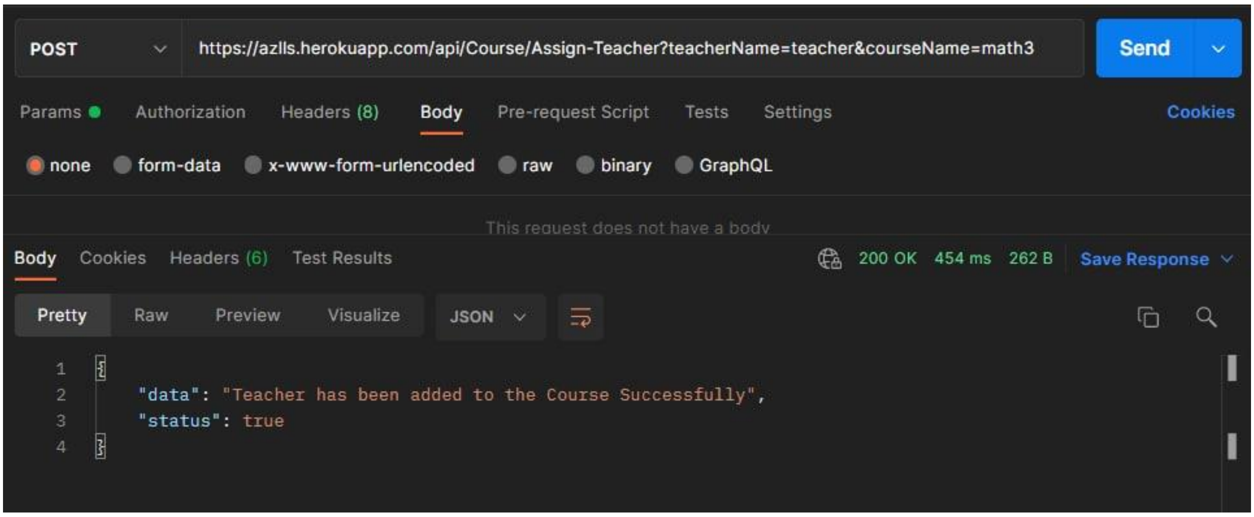


Figure 35: Snapshot of postman preview of API used for assigning a teacher with specific name to a course with specific name stored in the LLS database

- **Assign-Student**

This endpoint is used to assign a student to a course given the student's name and course name by the frontend

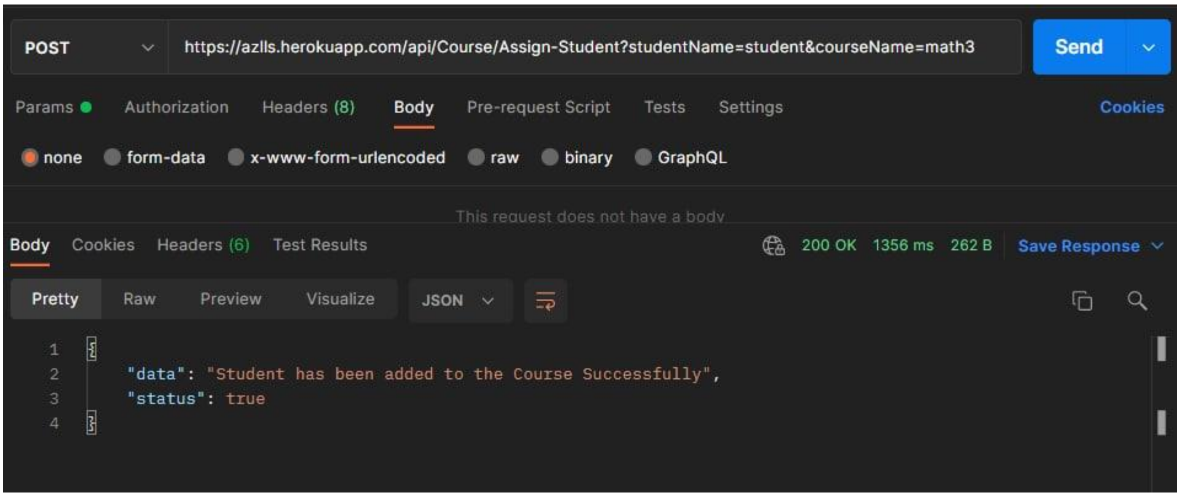


Figure 36: Snapshot of postman preview of API used for assigning a student with specific name to a course with specific name stored in the LLS database

- **Get-Assigned-Students**

This endpoint is used to get a list of the students assigned to a course given its name by the frontend

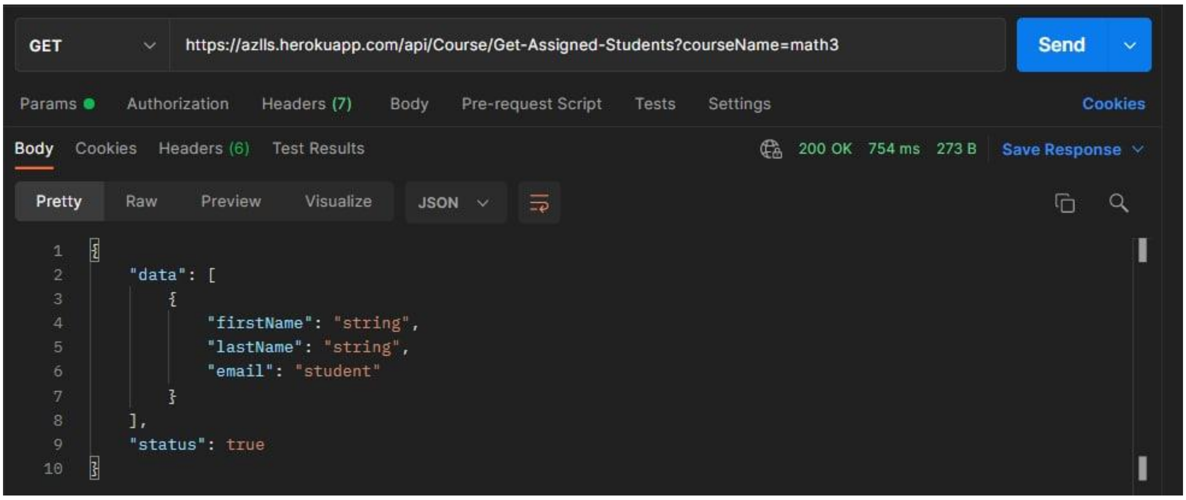


Figure 37: Snapshot of postman preview of API used for getting all students assigned in course with a specific name stored in the LLS database

- **Get-Assigned-Teachers**

This endpoint is used to get a list of the teachers assigned to a course given its name by the frontend

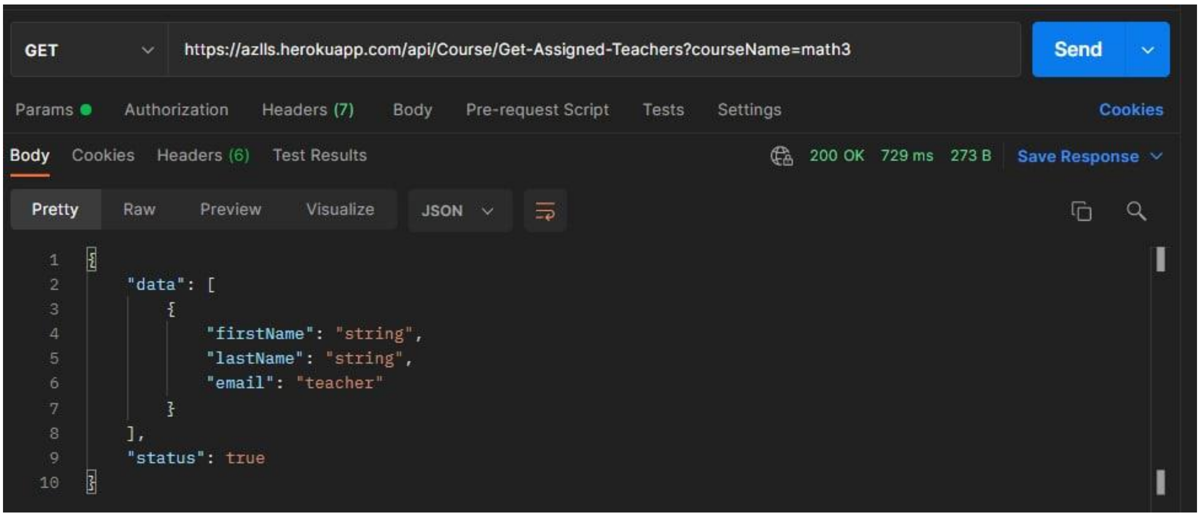


Figure 38: Snapshot of postman preview of API used for getting all teachers assigned in course with a specific name stored in the LLS database

3. Student Controller

The following shows the test performed on each API using the postman API testing application:

1. Get-Assigned-Exp-For-Student-In-Course
2. Get-All-Assigned-Exp-For-Student
3. Get-All-Assigned-Exp-For-Student-Now

This Controller has all the actions required to manage the student:

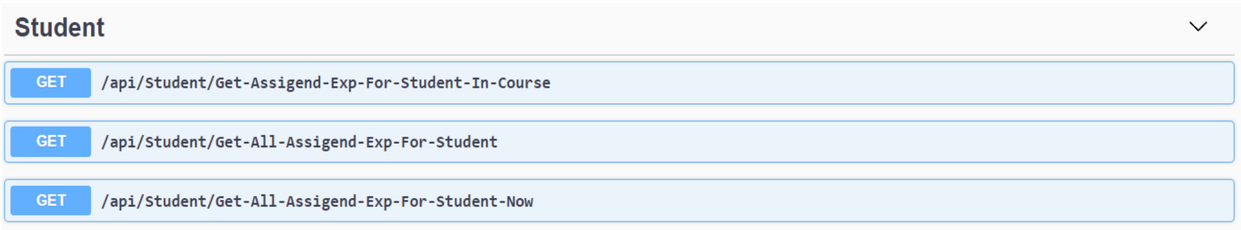


Figure 39: Snapshot of developed API endpoints in user controller previewed in swagger

- **Get-Assigned-Exp-For-Student-In-Course**

  The purpose of this request is to Get all the assigned experiment assigned to the student in a specific course given the course name by the frontend.

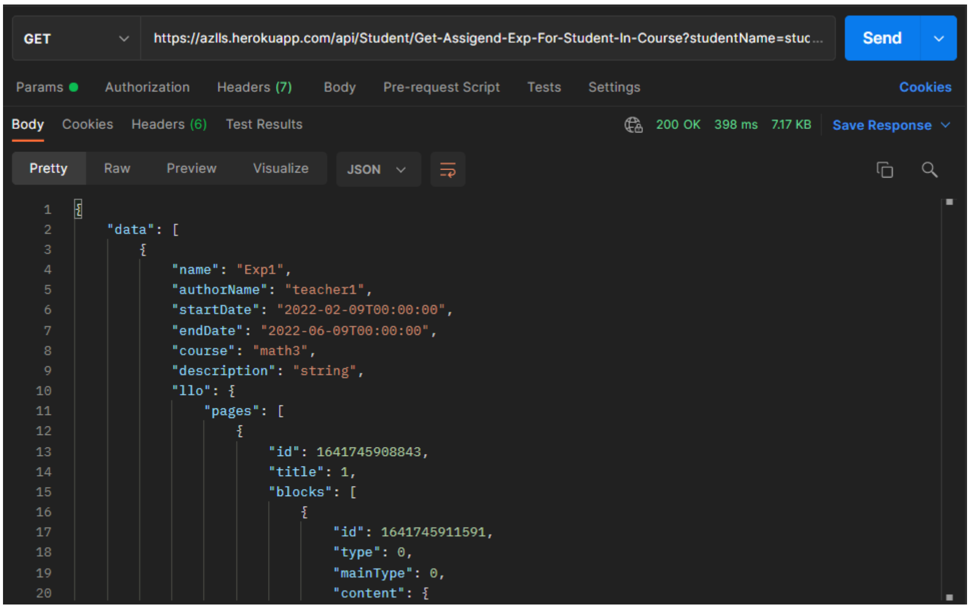


Figure 40: Snapshot of postman preview of API used for getting all experiments assigned to student with a specific name stored in the LLS database

- **Get-All-Assigned-Exp-For-Student**

  The purpose of this request is to Get all the assigned experiment assigned to the student in general of all courses, given the student's name by the frontend.

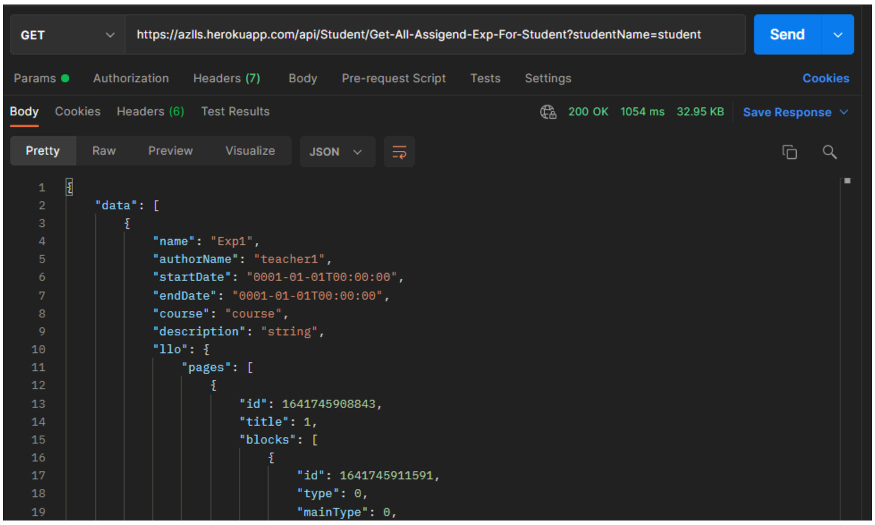


Figure 41: Snapshot of postman preview of API used for getting all experiments assigned to student with a specific name stored in the LLS database

- **Get-All-Assigned-Exp-For-Student-Now**

  The purpose of this request is to Get all the assigned experiment assigned to the student in general of all courses that available to complete now, given the student's name by the frontend.

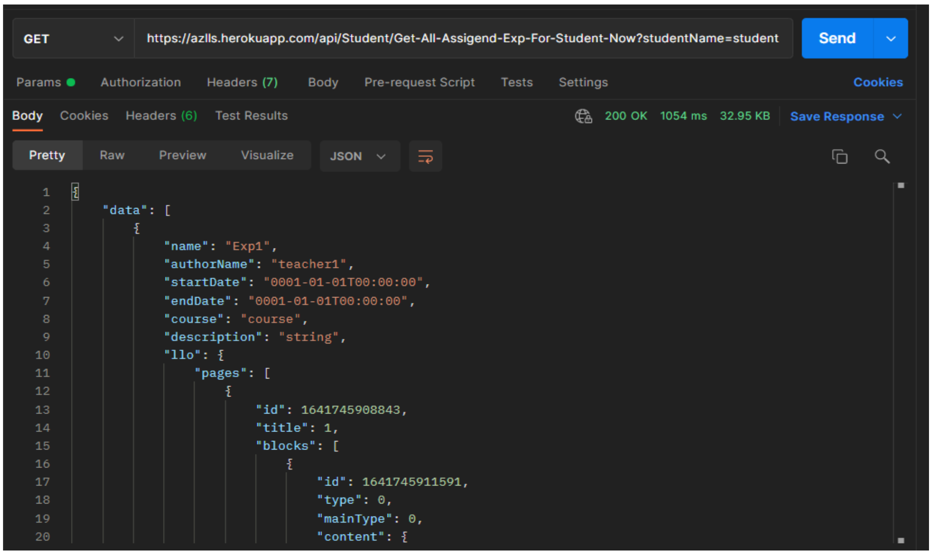


Figure 42: Snapshot of postman preview of API used for getting all experiments assigned to student with a specific name stored in the LLS database

Appendix (5)
Detailed Results of Task 3.4

T3.4: Develop an embedded laboratory experiment authoring tool in the LLS.

Design a high-level architecture design for the laboratory experiment-authoring tool, by designing new authoring modules that help the operation of creating laboratory experiments for those unaware to develop web pages. We start by dividing the experiment into multiple pages; each page consists of more steps, where each step is composed of draggrable components. Which can be content such as text, image, table, etc., and/ or assessment such as multiple choice, fill-in-blanks, matching, etc., and also VRL-related component as previously discussed. We also add experiment settings, content component settings and assessment settings as shown below in Table. The help option within component settings includes upload feature that allows attaching images, videos, and documents, as well as plain text, to fit according to the student's learning cognitive style.

We study the full cycle after creating a new experiment via instructor through authoring tool, until student start to perform assigned experiment. Starting by creation process, registration process, reservation of a schedule time-slot to perform assigned laboratory experiment including all needed software and hardware to fulfill the laboratory experiment requirements. Ended by the assessment grading process

Table 2 content component & assessment settings

	Content Component	**Assessment Component**
Settings	Time Help	Grade Answer time Help Correct answer/s Self/Manual grading Min/Max number of trials Show correct answer after submission

The proposed design succeed to include added features that allow sufficient transition of real laboratory experiment to be held remotely. The following figure illustrates the modules that comes out of the box with the authoring tool. Components are the smallest building unit in the experiment. Pre-built-in assets are available within our proposed authoring tool within the three categories: content, assessment, and VRL-specific. Settings per component and for the whole experiment can be customized through the authoring tool, with an option to preview student's view. The authoring tool is well integrated with the Laboratory Library Mapping module that interfaces with the Laboratory

Library Manager responsible for managing the storage. The authoring tool stores the experiment in a JSON package called the Laboratory Learning Object (LLO).

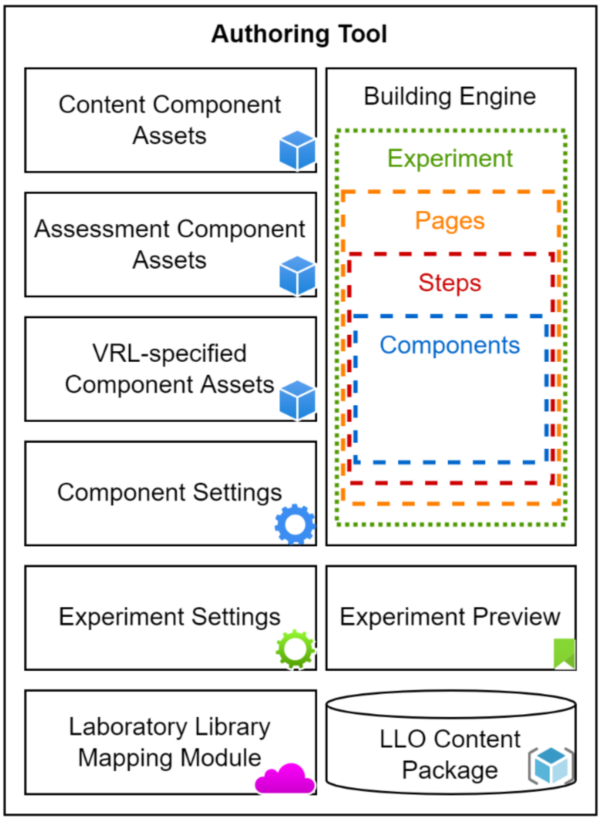


Figure 43. Authoring tool modules

As shown in the following figures that illustrates the produced LLO cycle within the LLS system after the experiment is added to a course where students are registered and then scheduled within a specific week during the academic year where the students are then allowed to reserve a specific time slot to start the experiment and benefit from the system, the Experiment Control Runtime Engine (ECRE) is the module that maintains the student session during his reserved timeslot. ECRE is integrated with the LRM discussed at section 2.4 to deliver the student's reserved VRL session such that any needed hardware and software can be accessed by the student to fulfill his experiment needs.

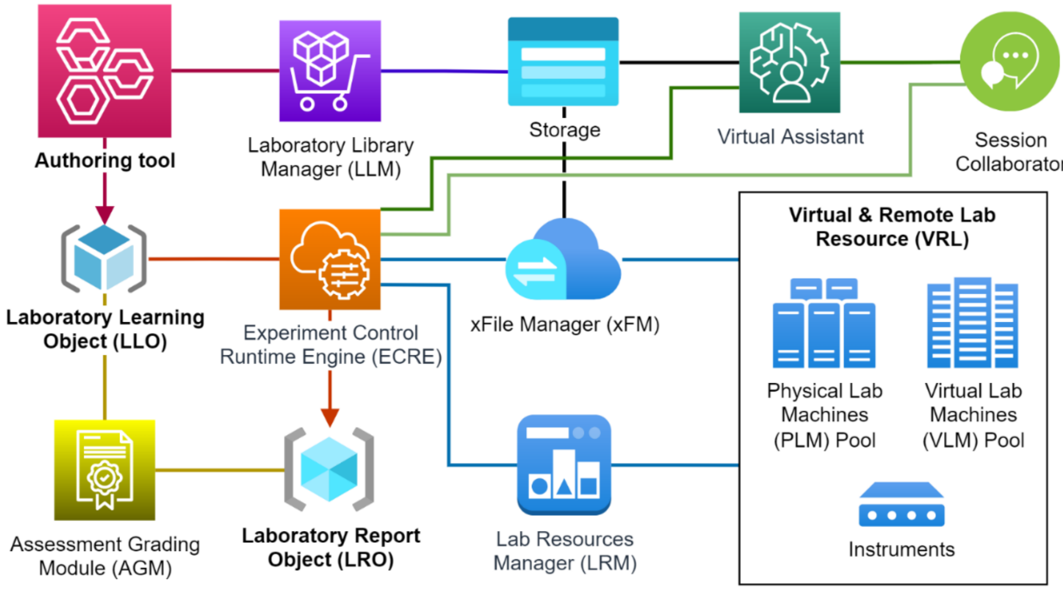


Figure 44: Authoring tool produced LLO modular cycle

The following three assessment components (1. Take snapshot from VRL / 2. Submit file from VRL / 3. Insert file to VRL) are made possible through xFile Manager (xFM) module as discussed below.

1. The "Take snapshot from VRL" component is used to allow the student to submit a snapshot from his reserved VRL to fulfill an experiment requirement. The VRL will be captured on the student's browser using iframe2image to convert iframe to image / base64, and html2canvas to save the image data in the memory, then xFM to upload the image to the assessment API customized as follow:

Course ID → Experiment ID → Assessment ID → Student ID → Session ID

2. The "Submit file from VRL" component is used to allow the student to submit a file from his reserved VRL to fulfill an experiment requirement. The xFM will run Windows PowerShell remoting commands using .NET Framework v4. As shown in figure 45, PowerShell's generic Remoting architecture consists of numerous different, interrelated components and elements.

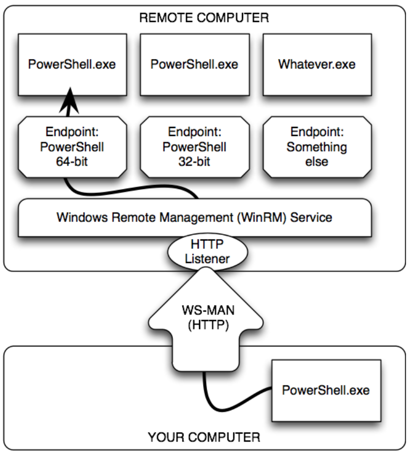


Figure 45: The elements and components of PowerShell Remoting

xFM will pend student to insert the required file name and type in the specified directory path, then the student will confirm the file is ready by pressing a button, then xFM will run PowerShell command to pull the file and push it towards the storage, then showing the student the success of this process.

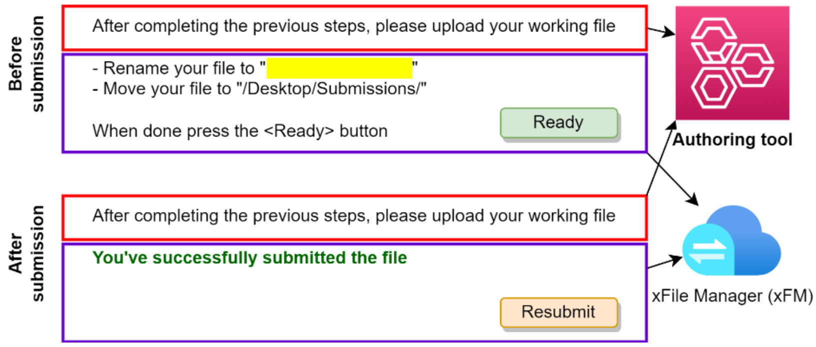


Figure 46: "Submit file from VRL" component student's preview

3. The “Insert file into VRL” component is used to allow the instructor to insert a file to the student’s reserved VRL. This component uses the same technology as the previous component. It pulls the file from the storage and inserts it to the VRL using PowerShell commands, and shows the path where the file will be found to the student.

Also, during the experiment the student may struggle while proceeding, the VA will detect such condition and begins showing help that fits the student’s learning cognitive style. If the student still can’t proceed, session collaborator will launch to connect the student with a TA to assist him.

After the student finishes the experiment, ECRE produces Laboratory Report Object (LRO), a JSON-structured file that contains student’s answers. After that Assessment Grading Module (AGM) will compare predefined answers as per experiment’s LLO with student’s LRO to auto grade the assessments and save the grades in the student’s LRO.

The following part shows proposed authoring tool components and their relations with each module:

		LLM	AGM	xFM	LRM	ECRE
Content components	Text					
	Image	✓				
	Table					
	Document	✓				
	Equation					
	Code					
	On-spot	✓				
	Media	✓				
	Iframe					
Assessment components	Open question		✓			
	Single choice		✓			
	Multiple choice		✓			
	Single image choice	✓	✓			
	Multiple image choice	✓	✓			
	Fill-in-blanks		✓			
	Text matching		✓			
	True/False		✓			
	Ranking		✓			
	Table question		✓			
	Drag and drop text		✓			
	Take snapshot from VRL		✓	✓		
	Submit file from VRL		✓	✓		
VRL specified	Add tool/s				✓	
	Insert file into VRL			✓		
Content component settings	Time					✓
	Add VA component help	✓				
Assessment component settings	Grade		✓			
	Answer time					✓
	Correct answer/s		✓			
	Un/Graded		✓			
	Number of trials					✓
	View correct answer after submit					✓
	Add VA component help	✓				
Experiment settings	Show progress bar					✓
	Add coauthor					
	Page theme					

Once author start to create a new experiment by creating a new page, then author start to create a learning content based on laboratory experiment requirement. Our proposed authoring tool, ease the learning content creation process by adding the following features in which the author can use to create laboratory experiment content.

- **Text:** By selecting this tab, the author will be able to write a text and the editing text bar will be shown automatically. The editing text bar will give the author multiple options to edit the written text, as type of text, bold, italic, direction of text, bullet option, adding table with selecting the number of rows/columns and also can attach a file or add link. The author can divide the written text into multiple columns.
- **Image:** By selecting this tab, the author will be able to add an image or image with text and then the image editing bar shows automatically. The image-editing bar gives the facility to change the direction of the image with text, crop and add more images. The new image can be uploaded locally from PC or a pre-created library.
- **Table:** By selecting this tab, the author will be able to insert a table, selecting the number of rows and columns needed. Once the author selects the number of rows and columns, the table editing bar will show automatically, which includes adding table header, add more rows, add more columns, change the inserted table style, delete cell, change per cell color, adding vertical or horizontal align and change the cell style.
- **Document:** By selecting this tab, the author will be able to add a document, uploaded from the PC or chosen from the pre-created library.
- **Equation:** By selecting this tab, the author will be able to add an equation, equation with text or equation with media. The list of symbols will automatically show gives all the required symbols to successfully write an equation.
- **Code:** By selecting this tab, the author will be able to write a code the editing text bar will be shown automatically. The editing text bar will give the author multiple options to edit the written code, as type of text, bold, italic, direction of text, adding comment and other option to successfully write a code.
- **On spot:** By selecting this tab, the author will be able to add hotspot images or add HTML blocks. The hotspot image, gives the author the option to insert an image and asked the student to comment on specific spot in the image.
- **Media:** By selecting this tab, the author will be able to add Video, Audio or Video with text. The video editing bar shows automatically, given the option to change the Video and text location and add more videos.
- **Iframe:** By selecting this tab, the author will be able to add iframe object with customizable link, width and height.

VRL specified settings, in our proposed authoring tool, a virtual remote lab (VRL) feature is added, which allow the chosen remote/ virtual tool to be open in student's VM based on laboratory experiment requirement. The VRL specified settings can be classified as follow:

- **"Add VRL":** author can add virtual/remote lab tool using " Add VRL" and select the needed VRL tool from VRL tool list, for example (MATLAB, LabView, Packet tracer, etc..) to be opened once student start laboratory experiment on student's VM screen
- **"Take snapshot from VRL":** author can add to allow Student to take snapshot from student's results or progress based on experiment requirement
- **"Submit File into VRL":** which allow student to submit his work/lab progress from VRL

Assessment and evaluation

In our proposed authoring tool, different assessment and evaluation types has been added, to fulfill different laboratory experiments requirements. The assessment and evaluation process can be taken:

- ❖ within the experiment as the author can add different type of question through experiment
- ❖ after the experiment, in the form of exam

The assessments types can be classified into:

- **Open question:** Starts with writing the question title. The author can add voice with question title and add question instructions. The author also will be able to create a response for each student's answer. Add content box, gives the author the option to add a content with the question.
- **Single choice Question:** Starts by writing the question title with the option to add voice and add question instructions. In the answer option field, the author will add the choice answer with the option to add explanation for each answer. The author also will be able to create a response for each student's answer. Add content box, gives the author the option to add a content with the question.
- **Multiple choice Question:** Starts by writing the question title with the option to add voice and add question instructions. In the answer option field, the author will add the choice answer with the option to add explanation for each answer. The author also will be able to create a response for each student's answer. Add content box, gives the author the option to add a content with the question.

- **Single/ Multiple image Question:** Starts by writing the question title with the option to add voice and add question instructions. In the answer option field, the author will make the image choices. The author also will be able to create a response for each student's answer. Add content box, gives the author the option to add a content with the question.
- **Fill in blanks Question:** Starts by writing the question title with the option to add voice. The author will start to add content including blanks and dropdowns. The author also will be able to create a response for each student's answer. Add content box, gives the author the option to add a content with the question.
- **Text matching Question:** Starts by writing the question title with the option to add voice and question instructions. The author will start to add item content and matching content. The author also will be able to create a response for each student's answer. Add content box, gives the author the option to add a content with the question
- **True or false Question:** Starts by writing the question title with the option to add voice and question instructions. The author will type the true statement and false statement with the option to add more statements. The author also will be able to create a response for each student's answer. Add content box, gives the author the option to add a content with the question.
- **Table Question:** Starts by writing the question title with the option to insert a table, add voice and question instructions. In the answer option field, the author will add an option for students to upload tables and an option also to add a comment. The author also will be able to create a response for each student's answer. Add content box, gives the author the option to add a content with the question.
- **Drag and Drop Question:** Starts by writing the question title with the option to add voice and question instructions. In the answer option field, the author will allow students to upload files and Drag and Drop files. The author also will be able to create a response for each student's answer. Add content box, gives the author the option to add a content with the question.
- **Take Snap Shot from VRL:** Starts by asking the student's to Take snapshot from a required results, code, circuit, …, etc. in the answer option field, the author will allow students to take snapshot which automatically will be saved and show under the author' question using xFile manager (XFM). Add content box, gives the author the option to add a content with the question
- **Submit File from VRL:** Starts by asking the student has to submit file of final student's results. in the answer option field, the author will allow students to submit file which automatically will be saved and show under the author' question using

XFM. Add content box, gives the author the option to add a content with the question

Appendix (6)
Detailed Results of Task 4.1

T4.1: Survey and investigate different standard integration technologies and models for LMSs.

In the past few years, and since the COVID-19 pandemic has come, each and every way of our life are affected. This pandemic preventing students from attending their classes and posing a demanding challenge for the whole education process. Also, after reopening the social distancing control measures is applied, which force universities and educational organizations to reduce the number of students in classes and laboratories to its minimum and depend mainly on e-learning concepts. In the case of distance learning in the fields of Engineering, Science and Technology Education, it is necessary to deliver both theoretical and practical knowledge to the students. To achieve this double goal and riches the learning experience the organization Learning Management System (LMS) must be integrated with the Laboratory Learning System (LLS). Based on [1] there are two main integration aspects must be considered:

- ***Location*.** Lab software can be located inside or outside the LMS as a learning resource. Labs located in the LMS have some advantages over that located outside, for example, the LLS does not need to deal with authentication and authorization: only students with access permissions can run the experiments. Another important advantage is that LMS can be configured to allow access to the lab only to learners who have satisfactorily completed prerequisite tasks.

- ***Interaction*.** Lab software can exchange information with the LMS. Labs obtain some benefit by establishing LMS-LLS communications such as exchanging learner credentials, allowing student authentication through the LMS. Furthermore, student results can be stored in the LMS grading book, which can use the information to control access to other resources in the LMS.

The integration of LMS with a LLS can be classified according to the lab location and interaction, as shown in Figure 47, into:

1) ***Outside and No Interaction*** (No integration). The lab is referenced through a link in the LMS, and the lab GUI is hosted in a web page in some other location, here the LLS is completely independently of the LMS. In this scenario the LLS built as new learning systems having the full functionalities of LMS plus a new functionality related to the remote and virtual lab services. Applying this scenario is therefore spending money and time and using resources over and over again in doing the same thing.

2) ***Inside and No Interaction*** (minimal integration). The LLS is accessed through the LMS, but the LMS merely acts as a host for the lab. There is no communication between the LMS and the lab software, which is executed completely independently of the LMS. This integration level can

identify users who access the LLS after they have been identified in the LMS.

3) ***Outside and Interaction***. The LLS is located outside the LMS, outside the LMS environment, but the lab establishes communications with the LMS.

4) ***Inside and Interaction.*** The LLS is located within the LMS. This type of lab software can interact with the LMS and can be related to other resources located in the LMS. This scenario (fully integrated laboratory) has the most advanced integration with the LMS.

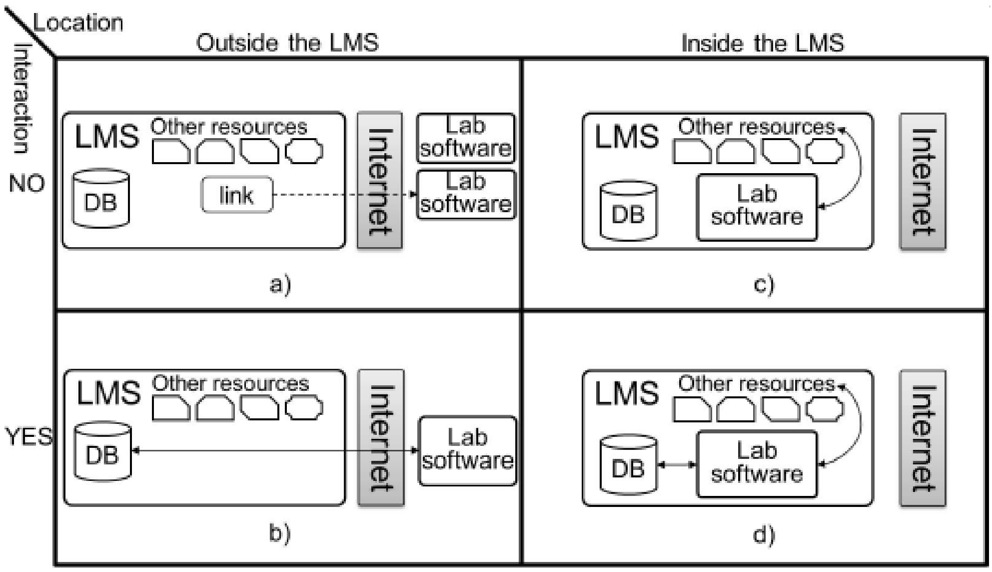


Figure 47: LMS-Lab software scenarios based on location and interaction.

In Scenarios 3 and 4 the LLS is integrated with LMS. It can be implemented in the LMS using either ad hoc development or using one of the e-learning standards such as the Shared Content Object Reference Model (SCORM), eXperience API (xAPI), Learning Tool Interoperability (LTI), Computer-Managed Instruction 5 (cmi5), Inquiry Learning Spaces (ILS), Massive Open Online Labs (MOOL) or IEEE1876 -IEEE Standard for Networked Smart Learning Objects for Online Laboratories. This integration level not only supports identification of students accessing the lab but can also use this identification to customize lab execution based on the individual student; the work carried out by each student can be controlled; and self-evaluations can be performed, and their results registered in the LMS.

From the student perspective, the laboratory integration into educational system will be high quality if it is imperceptible – seamless [2]. The quality of integration can be evaluated according to various criteria, such as by **visual aspects**, **binding strength** or support of lab session bookings/sharing.

- ***Visual aspects***
  1) The lowest level of lab visual integration is the using of a simple hyperlink within the LMS system, which opens the LLS on an external website in a new browser tab. This behavior usually means for user a disruption of impression integrity and it considered as a low-quality integration scenario.
  2) Another option is to insert a LLS function and services into the graphical layout of the LMS, using appropriate html element (e.g. iframe, object, applet or embed). This method is less noticeable for users and easily implemented by developers, which makes this option general popular and categorized as a high-quality integration scenario. The disadvantage of this solution is the fixed height of the inserted element and this problem should be then resolved within the graphical layout satisfactorily.
  3) In addition, there exists alternative method of integration, namely direct insertion of HTML code that was generated by the LLS application into the web pages of the educational system. Using this variant, there is no problem with the fixed height of the inserted element – it can be a visually perfect integration solution for users.

- ***Binding strength***
  Interaction ability of the LLS with the LMS is the second quality aspect of integration. Therefore, the strength of integration binding may be weak, when both LLS and LMS does not interact at all, or it can reach different levels of strength according to a variety of functions in their communication interface.

To integrate our proposed LLS with an LMS, a fundamental requirement is to establish communication between them. At the most basic level, this communication should allow the LMS to send the student ID and receive information regarding the work of the student in the lab experiments. This information should be stored in a database accessible to both the student and appropriate instructor. This communication between the LLS and the LMS can be implemented in four ways [3]:

1. Using an LMS extension that provides a communication interface that can be used by the LLS to access and manipulate the elements in the LMS. Due to the heterogeneity of the LMSs the extensions are usually not generic; they must be developed specifically for each LMS, so the lab experiments developed for use with a specific extension cannot be used

with a different one. This limits LLS to use only with the LMS for which they were originally designed.

2. Packing the virtual and remote laboratories within content packages that comply with e-learning standards such as Sharable Content Object Reference Model (SCORM). The main problem with the current e-learning standards is that they were developed for packing static content and do not support interactive code that provides the communication between remote labs and the physical instruments. This approach also presents some limitations because data interchange is limited to the SCORM data model.

3. Using a standard supported by the LMS that allows LLS-LMS remote interaction. These standards can be implemented in any programming language and executed on any type of device, even mobile phones; it is not required to be located inside the LMS. There are several possibilities for implementation such as using the LTI specifications, xAPI, cmi5 or OpenSocial.
   LTI is not in widespread use except in some academic environments. It requires the proper use of LMS-compatible APIs during LLS development. The xAPI is more popular. The required implementation approach is similar to LTI, although xAPI requires using an LRS (Learning Record System) that must be integrated with the LMS. cmi5 is a promising alternative for the near future, as it has been developed based on both SCORM and xAPI and will overcome some of the drawbacks of each (solves that: learners don't have to be in the same location to take a course – they don't even have to be online). The Open Social standard, backed by the World Wide Web Consortium (W3C), would also allow LMS-lab data exchange, however, it is designed for more general social network communications; therefore, using an e-learning-specific standard seems more appropriate. Still, several works discuss using OpenSocial with labs.

4. Creating a specific module to integrate the LLS within a specific LMS. The main drawback is that this module is an ad hoc solution for a specific industrial remote laboratory.

The most popular and widespread standards related to interactivity and architecture that allow or facilitate the integration of online laboratory-type educational content in learning platforms are SCORM, xAPI and LTI [4].

Appendix (7)
Detailed Results of Task 4.2

T4.2: Study the basic operation of LTI and xAPIs integration technologies.

1) Learning Tools Interoperability (LTI)

LTI is a standard developed by the IMS Global Learning Consortium (IMS) [5] whose objective is the integration among learning applications enriched with learning platforms. It specifies a method for a learning system to invoke and to communicate with external systems. Essentially, the LTI standard enables a secure exchange of information between LMS and any external learning tool. The information exchanged between the LMS and the external learning tool includes course information and user identity which helps ensure that learners can navigate seamlessly from one learning tool to the other without having to log into each one.

Through LTI, external learning tools can also securely send back information or feedback into the LMS, for example, the results of learners activity did in the external tool.

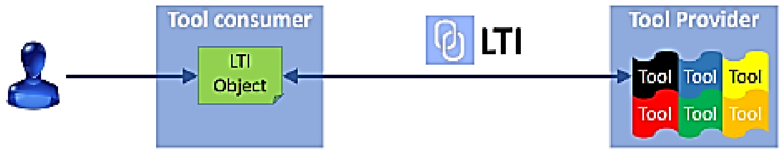


Figure 48: Example of the use of LTI standard

The most common use of LTI occurs when an LMS (Tool Consumer) uses it to offer users external content to the platform in the form of content that is apparently located in the LMS, as shown in Figure 48. When a student accesses an LTI element of the LMS, the LMS uses the LTI standard to launch a tool (Tool) located on an external server (Tool Provider) that can be used by the student.

Objectives

The objectives of the LTI standard are:

- To provide a simple mash-up style deployment model consisting of a URL, key, and secret which the LMS administrator or the course instructor can enter into the LMS.
- To define a protocol for launching an external application from an LMS in a way that supports single-sign-on and which preserves the learning context and user roles within that context.
- To make links to external applications portable by defining data elements that can be embedded in IMS Common Cartridges.

Key Concepts

The basic workflow for using LTI starts when the Instructor or LMS administrator gains access to an externally hosted learning tool. The tool's administrator provides the administrator or instructor a URL, key, and secret for the Tool.

After adding an LTI tool into their course structure as a resource link, instructor enters the URL, secret, and key into as meta data for the resource link using the LMS control panel. When students select the tool, the LMS uses the URL, secret, and key information to seamlessly launch the student into the remote tool in an iframe or new browser window.

For the Administrator use case, they generally add a "virtual tool" to the LMS, entering the URL, secret and key. Once this is done, Instructors simply see the newly configured LTI tool as another tool or activity to be placed as a resource link in their course structure. The Instructors and students simply select and use the tool and they not even be aware that the tool they are using is running outside of the LMS.

In both cases, the LLS receives a Launch request that includes user identity, course/experiment information, role information, and the key and signature. The launch information is sent using an HTTP form generated in the user's browser with the LTI data elements in hidden form fields and automatically submitted to the LLS using JavaScript. The data in the HTTP form is signed using the OAuth (www.oauth.net) security standard so the LLS can be assured that the launch data was not modified between time the LMS generated and signed the data and the time that the Tool received the data.

Once the launch request is received, the tool may choose to redirect the user's browser to some other URL, or it may render the requested user interface straight-away.

LTI Data Elements

The following is a subset of the information that the Tool Consumer (TC) sends to the Tool Provider (TP).

`resource_link_id=2191-e1939-bb3856`
This is an opaque unique identifier that the TC guarantees will be unique within the TC for every placement of the resource link
`resource_link_title=Week One Experiment`
A title for the resource. This is the clickable text that appears in the link.
`user_id=0ae8c6b9-7fc06f-66acf45`
Uniquely identifies the user. This should not contain any identifying information for the user. Best practice is that this field should be a TC-generated longterm “primary key” to the user record – not the “logical key". This parameter is recommended.

```
user_image=http://....
```
This image is suitable for use as a "profile picture" or an avatar representing the user.

```
roles=Teacher
```
This attribute is comma-separated list of one or more roles. Instructor and Learner are the most commonly used roles.

```
lis_person_name_given=Ahmed
lis_person_name_family=Haleem
lis_person_name_full=Ahmed M. Haleem
lis_person_contact_email_primary=ahmed_haleem@helwan.edu.eg
```
These fields contain identifying information about the user account that is performing this launch. These parameters are recommended unless they are suppressed because of privacy settings in the TC.

```
context_id=82-006f-6783c545
```
This is an opaque identifier that uniquely identifies the context that contains the link being launched.

```
context_title=Design of AM Modulator
context_label=AM182
```
A title of the context – it should be about the length of a line. The label for the context is intended to fit in a column.

```
oauth_consumer_key=llsng.helwan.edu
oauth_signature=Xddn2gaKxCdcc%3D
```
These and other OAuth fields are used to properly sign and secure the contents of the launch data. The oauth_consumer_key is the key that was originally issued by the Tool Provider and entered into the Tool Consumer by the administrator or instructor as shown in the sample launch form at the end of this document.

LTI V1.3

The new core LTI version 1.3 and a package of high-value services align LTI with industry-best security and provides a clear path forward for existing services and new services to pursue the rich integration available between learning platforms and tools. Here is a quick look at what's new in LTI 1.3:

1- Introduction of the IMS Security Framework specification prescribing improved security based on OAuth2 and JSON Web Tokens
2- Improved documentation and migration guidance to help move the market from the benefits of basic launch to the full suite of LTI possibilities
3- Alignment with the LTI Advantage set of services that enable a fully integrated and innovative digital ecosystem.

LTI 1.3 Advantage

LTI 1.3 is a package of three essential end-user services that build on LTI 1.3. Together, these standards implement features that support key teaching and learning activities, such as the provisioning of usernames and roles so a tool can intelligently address the learner on launch, and the exchange of assignments from a platform to an assessment tool and the subsequent scores back to a central gradebook. Figure 49 shows the LTI advantage new services which are:

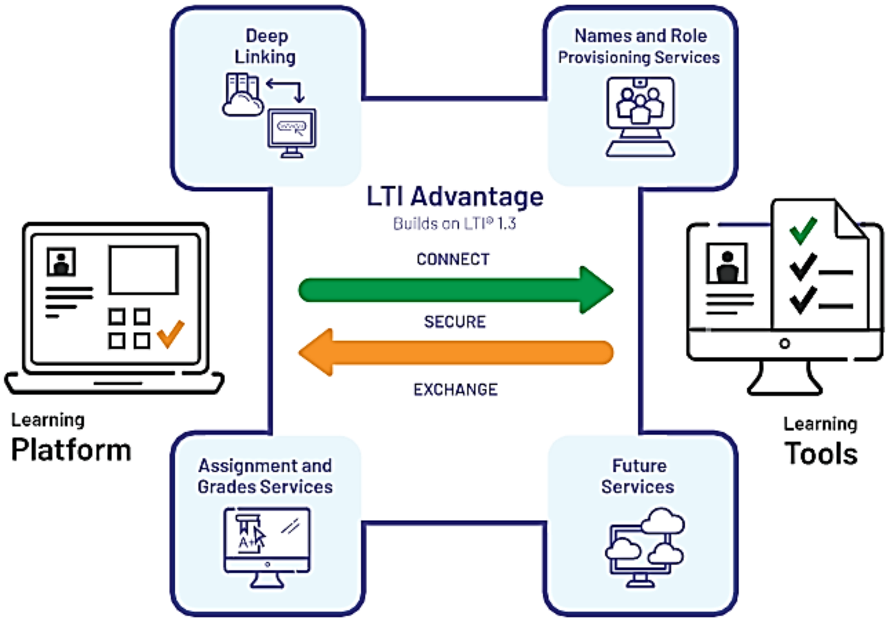


Figure 49: LTI Advantage architecture

1- **Names and Role Provisioning Services:** enables sending a list of course participants and faculty defined groups to learning tools. With **Names and Role Provisioning Services,** you can:
   a. Exchange a list of users and their roles
   b. Learn who has not yet accessed a tool
   c. Enable communications among users without sharing contact information.

2- **Assignment and Grade Services:** Enables passing of assignment results from the tool back to the LMS. With Assignment and Grade Services, you can:
   a. Gradable assignments shared with a tool
   b. Numeric scores returned to LMS grade book
   c. Assessor's comments returned if provided
   d. Multiple results supported in a single exchange
   e. Instructor override and history of attempts allowed.

3- **Deep Linking:** enables a more intuitive way to add content and links to a platform from a learning toll. With Deep Linking, you can:
   a. Select and add course content in a few clicks
   b. Add playlists and tables of content
   c. Enable links and other HTML content
   d. Add pre-registered tools with a few clicks

2) Experience API (xAPI)

The Experience API standard, also called xAPI or Tin Can API is a specification also managed by Advanced Distributed Learning (ADL) [6] that emerged as an evolution of SCORM. The goal was to solve some of SCORM's own problems. xAPI is a standard that enables two-way communications to be established between learning content and learning platforms to record and monitor all types of learning experiences.

Experience Application Programming Interface "xAPI", where 'x' stands for experience, because xAPI enables detailed recording and transfer of "learning experience" data, whether those data come from an eLearning experience, a simulation-based training experience, a tablet-based educational experience, or even an operational (on-the-job) experience. So, it will allow the LLS learning analytic module to track any learners' behaviors and performance (i.e., formal, informal, or operational). xAPI can track reading an article or watching a training video, chatting with a mentor, quiz scores, and answer history by question. And it follows standardized transportation rules to move those data to a data store or between applications.

According to a more recent definition (retrieved April 2019), the "Experience API (xAPI) is a technical specification that aims to facilitate the documentation and communication of learning experiences. It specifies a structure to describe learning experiences and defines how these descriptions can be exchanged electronically." [6]. In more simple terms, the xAPI allows tracking of online student activities in various environments, and stores the data in database called Learning Record Store - from which it then can be retrieved for various purposes, e.g. student monitoring or institutional learning analytics.

xAPI can be implemented in any digital environment, including mobile learning, simulations, virtual worlds, serious games, real-world activities, mobile and wearable devices, experiential learning, and more. It can be used to track and store data on any imaginable activity, as in Figure 50 such as:

- Reading an article or interacting with an eBook
- Watching a training video, stopping and starting it
- Training progress data from a simulation

- Performance in a mobile app
- Chatting with a mentor
- Physiological measures, such as heart-rate data
- Micro-interactions with e-learning content
- Team performance in a multi-player serious game
- Quiz scores and answer history by question
- Real-world performance in an operational context

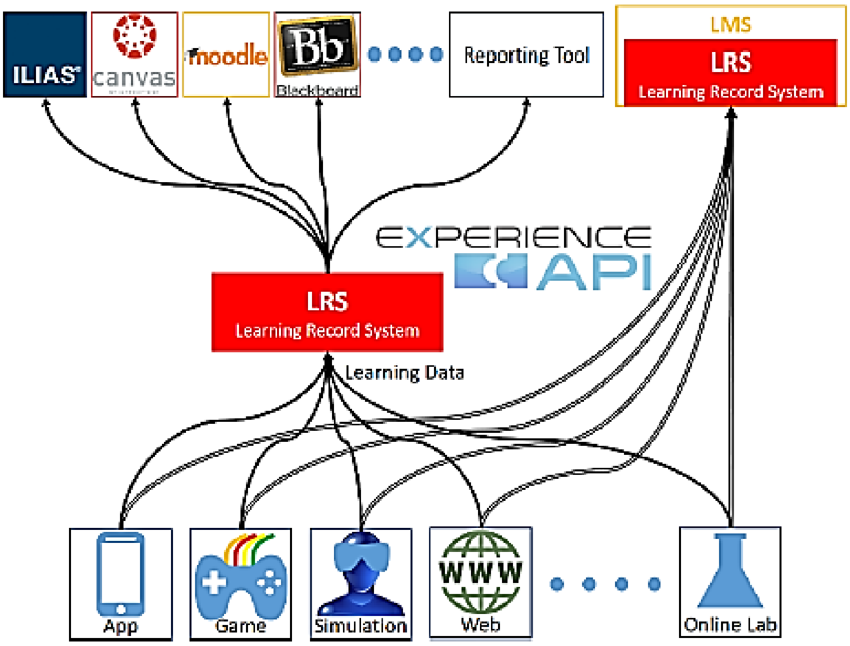


Figure 50: xAPI functionality

Experience API Operation

1. When an activity needs to be recorded, the application sends secure statements in the form of “Noun, verb, object” or “I did this” to a Learning Record Store (LRS) [7].
2. Learning Record Stores record all of the statements made. An LRS can share these statements with other LRSs. An LRS can exist on its own, or inside an LMS.
3. A learner has a learning experience. This experience could take place in an online course or online experiment, it could be on the job or it could be part of recreation. This experience is tracked, on the learner’s behalf, by a trusted Learning Record Provider (LRP). The Learning Record Provider can also be responsible for the trusted relationship between the experience and the learner. This might even include launching content for the learner and managing digital rights associated with the content.

4. The Learning Record Provider creates Learning Records and sends them to one or more Learning Record Stores (LRSs). The LRS stores the Learning Records and makes them available to any authorized Client. A Learning Record Consumer (LRC) is a type of Client that accesses Learning Records and makes use of them.

Statement Object Model

xAPI statements are the structured data about a learning experience. An xAPI statement includes data about the ***actor*** (e.g., learner), ***verb*** (e.g., watched, passed), and ***object*** (e.g., video, quiz) as well as contextual information such as the ***timestamp*** and issuing ***authority***, and also optional information such as ***results***, other informational ***attachments***, and *context* details.

The xAPI standard also defines requirements for the storage and retrieval of xAPI statements. All xAPI statements are validated and stored by an LRS. These data stores may be part of an LMS or LLS, or they can be standalone applications.

More precisely, an LRS is the implementation of the server-side requirements associated with xAPI. LRSs are responsible for storing, accessing, and often visualizing the data about learning experiences, activities, and performance. LRSs also validate the format of the statements, ensuring that only conformant statements are accepted and retained.

xAPI uses a distributed implementation architecture. In other words, rather than use a single LRS for all data, xAPI is best implemented with many distributed LRSs that can communicate with each other. Each LRS can be public, private, or a combination of the two (i.e., private but sharing limited data with public).

LRS Conformance

Because an xAPI LRS validates each xAPI statement it receives, LRSs are the linchpin of a functional xAPI implementation. Organizations seeking to build or buy an LRS should procure one that meets xAPI conformance standards, i.e., that has demonstrated it adherence to the xAPI standard via a Conformance Test Suite. The ADL Initiative hosts a publicly available LRS Conformance Test Suite [8] designed for use by DoD organizations and their vendors.

3) LTI Vs. xAPI

LTI and xAPI have similarities and differences. The most important similarity is that learning content does not have to be within the LMS but can also reside on a content server.

Table 3: Comparison between LTI and xAPI standards

LTI	xAPI
Standard, extendable way of integrating rich learning application	Experience tracking integration utilizing activity streams
Applications and content are web-based, extremally hosted	Can support online or offline activity–session-less communication
Grade and outcome data can be returned to the LMS	Content can exist in any system (i.e. outside of the LMS)

As shown in Table **3**: Comparison between LTI and xAPI standardsTable 3 The LTI solution standard is an extendable way of integrating rich web-based learning applications with LMSs and other educational environments, where grades and outcome data can be returned to the LMS. On the other hand, the xAPI is an experience tracking integration standard, which utilizing activity streams and can support online or offline activity - session-less communication where content can exist in any system (i.e. outside of the LMS)

LTI integration with LMS

1- Required a plugin external tool.
2- The external tool can be written in any coding language as long as it is web-based (no support for non-web-based activities).
3- LTI generates a simple data report contains a limited number of activities that can be stored by the LMS in the Gradebook.
4- Detailed reporting or analytics are provided within the external tool and not constrained by LMS or static data model

xAPI integration with LMS

1- Required a plugin external tool.
2- External content can contain any activity which lets LLS system record and analyze different learning experiences.
3- Allow LLS share data and transcripts across the system's modules.
4- Detailed reporting or learning analytics are provided within the LRS.

Appendix (8)
Detailed Results of Task 4.3

T4.3: Design of an efficient integration model between LLS and LMSs.

1) Integration example of online laboratory with LMS platform using LTI

Go-Lab project [2] main objectives of the project include creating an international federation of online lab providers, encouraging cooperation between these providers, creating an online lab gallery available to public and providing a single integration and communication interface.

Go-Lab integration interface is called Smart Gateway “gateway4labs” it aims to gain external systems access to labs from the gallery and to simplify adding new laboratories into the gallery on the other hand. It includes integration plugins for LMS MOODLE and CMS Joomla, as illustrated on the architecture diagram in Figure 51.

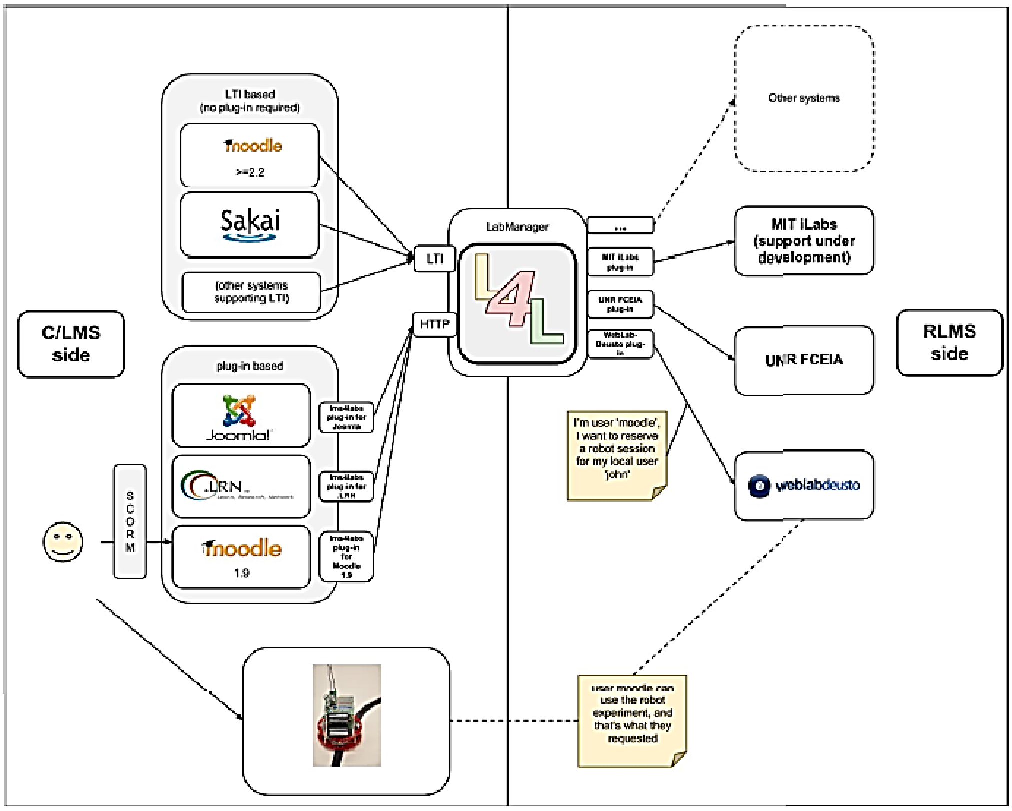


Figure 51: Go-Lab integration interface known as Smart Gateway “gateway4labs”

As described in the figure above, there are three main components involved:

1. The LMS/CMS/PLE (left side). If it supports IMS LTI, it will use it and no code will be required in the LMS/CMS/PLE. If it does not support it, it will have a small plug-in that communicates with the LabManager.

2. The LabManager, which will receive requests from multiple, different LMSs and it will understand the protocols of different RLMSs. It does not have any LMS dependent code, but it has RLMS dependent plug-ins.
3. The RLMS, which will support a federation protocol to process requests from the LabManager. The federation protocol from one RLMS to other will be different. It should not require anything special for being supported by the LabManager.

This way, if a new LMS/CMS/PLE is aimed, if it supports IMS LTI the support is automatic. If it does not support it, a new plug-in for that LMS is required in the LMS, but it has no impact on the rest of the RLMSs neither on the LabManager. If a new RLMS is aimed, a new plug-in for that RLMS is required in the LabManager, but it has no impact on the LMSs/CMSs/PLEs.

2) <u>Integration example of online laboratory with LMS platform using both LTI and xAPI standards</u>

Autor of Remote Laboratory Management System (RLMS) [9] proposed an integration of RLMS to Learning Management System (LMS) through the use of standard technologies such as Learning Tools Interoperability (LTI) or through the implementation of web services as shown in Figure 52.

LTI module provides session information to the session manager and allows the correct visualization of user laboratory interface inside the VLE. The experience API (xAPI) module is responsible to inform about the user interaction in the system and to report information to the Learning Analytics module. Reliability module detects failures and report them to the lab manager.

The Forging Online Education through FIRE (Future *Internet* Research *and* Experimentation) FORGE initiative provides educators and learners in higher education with access to world-class FIRE testbed infrastructure. This framework offers the methodology, environment, tools and resources to support the creation of HTML-based online educational material capable accessing virtualized and physical FIRE testbed infrastructure easily.

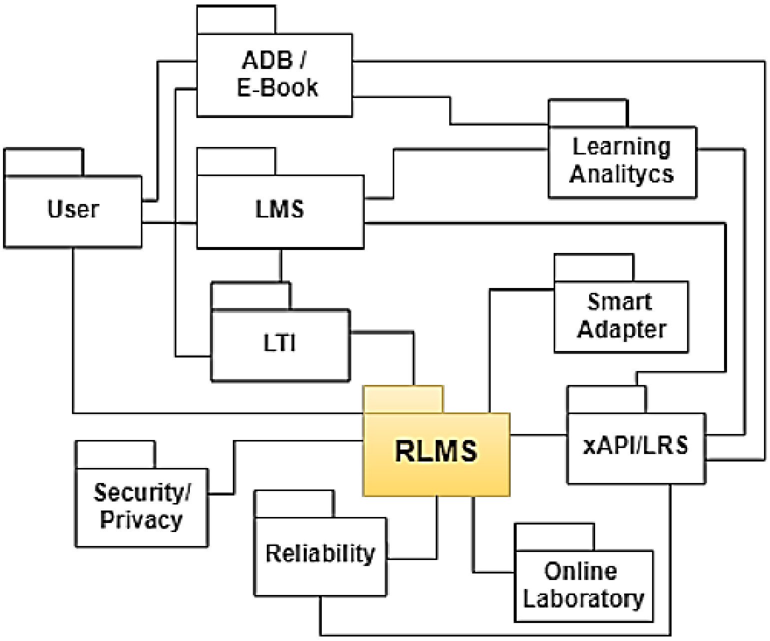


Figure 52: Remote Laboratory Management System (RLMS)

FORGE support interoperability with existing LMSs and VLEs, FORGEBox uses eLearning technologies such as the Learning Tools Interoperability (LTI) standard and SCORM. Additionally, FORGEBox captures valuable quantitative and qualitative learning analytic information based on the Experience API (xAPI) specification. This information can help optimize and support student learning and assist with course evaluation and future adaptation. seamlessly integrate VLE/LMS with FORGE artefacts using well known eLearning technologies. they investigated solutions of exploiting these eLearning technologies in two areas: interoperability and means to study user behaviour while learning on top of FIRE. These technologies are the Learning Tools Interoperability (LTI) standard, SCORM and the Experience API (xAPI), commonly known as the Tin Can API. LTI adoption provides better integration between FORGE technology and existing LMSs and VLEs. LTI provides a seamless experience for learners while interacting both with the LMS/VLE content and the remote FIRE resource. Consequently, LTI makes it much easier for organizations to adopt and use the FORGE technologies and integrate them with their own already deployed learning systems. xAPI on the other hand allows instructors to study learners’ behavior while interacting with a facility.

3) The proposed integration model design objectives

The Proposed LLS system is designed to be used as a standalone Lab management system as well as to integrate with any standard Learning Management System. So, the integration type will be Outside and Interaction, where the LLS is located outside the LMS environment, but the LLS establishes communications with the LMS.

The proposed integration model needs to provide information exchanged between the LMS and the LLS including all course information and user identity, which ensures that users can easily navigate from the LMS to the LLS without having to log in to each system separately and without having multiple credentials. Also, to provide secure send of information or feedback back to the LMS, for example, the results of the activity that students have done in the LLS. Finally, the conclusion is that our target is to create smooth and consistent learning and teaching experience through the proposed integration model.

Integration model design

The proposed integration model will be implemented using the eXperience API (xAPI), and the Learning Tool Interoperability (LTI) as shown in Figure 53, to supports not only for seamless authentication of Students, Administrator, and Instructor accessing the LLS through the LMS but also to customize lab execution based on the individual student; assist the students during the experiment execution using the AI-based virtual assistant; evaluate the work carried out by each student and registered their results in the LMS.

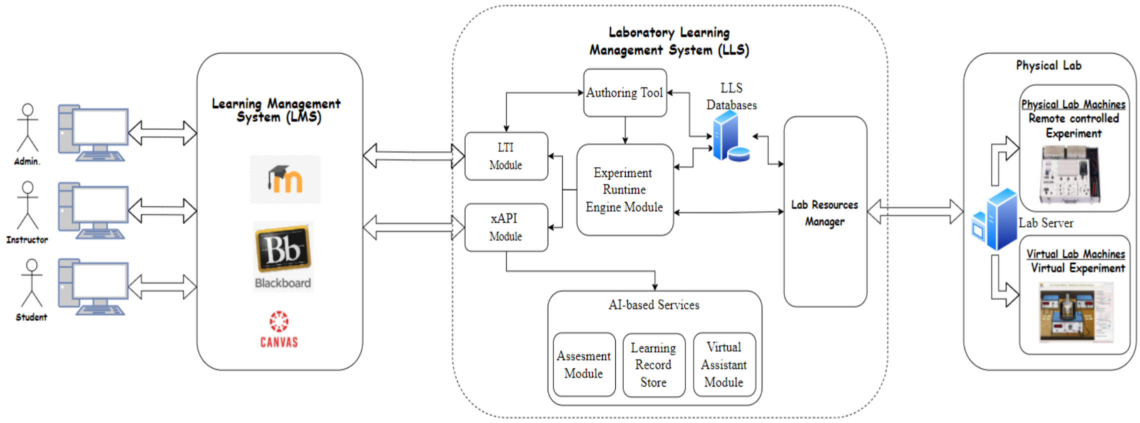


Figure 53: Proposed LMS and LLS integration

LTI will provides a seamless experience for students while interacting both with the LMS content and the remote LLS resources. Consequently, LTI makes it much easier for organizations to adopt and use the LLS system and integrate it with their own already deployed learning systems. xAPI on the other hand allows instructors to study students' behavior while interacting with the lab, also, it allows the AI-based services to collect all the required student activity while interacting with the lab.

The proposed integration model will allow the administrators to seamlessly login to the LLS through the LMS (using LTI Module) to configure the lab resources and manage the access privileges of the different users and do all the required tasks for their role. In similar way the instructors can login seamlessly and create and edit experiments/ assignments /quizzes (using Authoring tool), add experiment to course, assign and schedule different experiments for their students, mark the unmarked experiments/ assignments /quizzes, see the student finished experiments.

The LLS database is used to provide data storing and management services, which contains different data related to the students and the learning process. The LTI module allows students to access the LLS system seamlessly from their LMS course web page to book any assigned experiment, run the experiment during the scheduled time slot, see the final grading and feedback. During the experiment execution, the xAPI module collects all students' activities from the experiment runtime engine and sends them to the AI-based services subsystem to analyze the student activity (Mouse action, and keyboard strokes), evaluate the students' performance, assist students facing difficulties, and store the result in the learning record store.

Appendix (9)
Detailed Results of Task 5.1

T5.1: Survey and investigate existing techniques for virtual laboratory assistant.

The aim with this comparative study is to attain a deeper understanding of common problems related to design, development and implementation of virtual laboratories.

Building a virtual laboratory for teaching and learning is a highly complex process, incorporating diverse areas such as interaction design, visualization, and pedagogy. This study focuses on the production and implementation issues that were found in the comparison of different virtual laboratory projects and discuss which design considerations can be drawn from these observations. Two web-based virtual laboratories - the Gas Laboratory and the Virtual Color Laboratory - were developed independently of each other within two different content areas. The laboratories share considerable overlaps in goals and production circumstances. Through a comparison of production and outcome, similar problems related to design, development and implementation were observed. The research uses a mixed method approach combining quantitative pre- and post-tests for assessments, qualitative surveys, and qualitative, ethnographic observations and interviews. By comparing the background material, five design challenges for developing virtual laboratories are identified:

1. how to balance ambitions with available resources;
2. how to balance intended levels of user interaction with exploratory freedom;
3. how to find appropriate levels of realism depending on target group;
4. how to choose between mimicking real world appearance and enhanced features;
5. how to find the best learning situation for the virtual laboratory.

To meet these challenges, the following design considerations are proposed: Guide the design work with a clear understanding of purpose and context; select appropriate technology to ensure efficient design and media usage; select level of realism considering purpose and end users; and provide learning guides before and after the virtual lab session.

1) <u>How virtual labs can facilitate learning</u>

A virtual laboratory is considered to be an interactive environment in which simulated experiments can be carried out. A laboratory can be characterized as “a playground for experimentation” [10] providing tools that can be used to manipulate objects relevant to a specific scientific domain (such as chemicals in a chemistry lab). This playground for experimentation concept is relevant both for virtual laboratories and conventional hands-on laboratories. However, there is an important distinction in terminology. A conventional laboratory is an open playground where “the user can expand the laboratory by adding new objects, creating new experiments”, while due to technical limitations a virtual laboratory usually do not have that flexibility. A virtual laboratory is often custom-built to perform a limited set of experiments.

Virtual laboratories have become increasingly common as a form of teaching aid in different learning situations [11], [12], [13]. Creating a virtual laboratory for teaching and learning is, however, highly complex, incorporating skills in diverse areas such as interaction design, visualization, and pedagogy. It involves design and production of texts, images, 3D environments and interactivity, and the production requires programming and animation. The development of a virtual laboratory as well as implementing it as a laboratory exercise for learning requires knowledge in the three domains outlined by the TPACK model [14], [15], i.e. technology, pedagogy, and content knowledge. A laboratory exercise is here defined as a confined, scripted set of experiment procedures intended to be used for teaching purposes. An exercise is performed by the learner herself, while a demonstration is here considered to be performed by the teacher, albeit these two can involve essentially similar laboratory procedures.

To add even more complexity, the notion of virtuality is ontologically and conceptually multifaceted [16][17], [18], [19]. The virtual is often characterized as being almost as if something actual [18]. A virtual laboratory is virtual in the sense that its components - glass bottles, chemicals, burners and so on - partially behave as if they were physical, while being simulations based on a model of the actual reality. On the other hand, a virtual laboratory is a learning environment where students can perform learning activities, and from that viewpoint it is not more virtual than a book or a documentary movie. Such ambiguities sometimes lead to confusing arguments concerning the underlying concept for the design work. As illustrated in this article, the complexity of constructing a virtual laboratory often leads to difficulties in reaching the desired goals regarding clarity, usability, technology and design.

Standard arguments in favor of using virtual laboratories include accessibility (it is available online, and can be reached from anywhere anytime), resource economy (there is no physical setting, and no physical supplies), and demonstration possibilities (it can show things that normally cannot be seen, or are difficult to explain) [20][21]. A virtual laboratory is furthermore claimed to facilitate an enhanced learning experience, health and safety concerns, or ethical and legislative issues [21]. A thorough understanding of scientific theories is difficult to obtain with traditional teaching methodologies [12], [13] showed that learning was improved when students could use virtual labs prior to physical ones. Studies also show that students' learning outcome is equal, or higher, in non-traditional laboratories, such as virtual laboratories, compared to traditional laboratory environments [22]. However, despite these potentials, a virtual laboratory is not unproblematic to design, develop and finally integrate in a learning situation.

The rapid increase of students' use of online resources over recent decades requires schools to take an expert role and to positively shape students' exposure to digital technology [13][23], [24]. In this undertaking, it is imperative that online learning resources should involve a relationship between the technology used and the subject area and/or grade level at which it is applied [25]. Like all educational tools, digital learning materials involve certain problems, and educational gains from technical innovations cannot be taken for granted. Furthermore, research on instructional technologies often produces results that are not readily adopted by the school system and not easily transformed into education. Reasons for the scarce use of research results for teaching practice could include the fact that several of the findings emanate from short-term interventions or experimental studies, which are problematic to apply in school activities [26][27]. Analyzing students' scientific reasoning in their work with discovering scientific concepts in long term, design-based and comparative studies might be a way of unravelling the learning process engendered by digital technologies.

2) <u>Interactive learning environments and computer simulations</u>

The usage of interactive computer simulations in science education has been subjected to several studies (e.g., [28][29], [30][31][32]. In a large-scale study [32] made use of computer simulation in biology laboratory work. The interactive learning environment produced concentration profiles of enzyme-substrate complex and plotted these at a graphic user interface to control reaction parameters. Students had to learn how to use, and control altered reaction parameters in this computer simulated biology lab. The result showed that the computer simulation improved conceptual understanding of the reaction type under study. Higher gains for students using computer simulations than for those only using hands-on activities was also shown in a study of learning physics concepts [30]. In this study, a computer simulation where used where the users could create, see and interact with analytical, analogous and graphical representations of the physical concepts of weight and mass. The simulation also allowed multiple representations to be seen simultaneously. Results indicated that the simulation facilitated the development of students´ scientific understandings about the concepts of weight and mass by allowing students to explore and test predictions. Moreover, [30] found that the total gains obtained depended to a great deal on the teachers' pedagogy when using the computer simulation to teach the concepts of weight and mass.

Besides, both the above-mentioned studies by [30] and [32] indicated that combining computer simulations with hands-on experimentation was as effective, or even more effective for learning conceptual understanding of the topic under study, than using physical experimentation only. Other studies have similarly demonstrated that a combination of computer simulated and physical experiments can enhance students' conceptual understanding of scientific phenomena more than the use of simulated or physical experiments alone [28][29]. This claim is supported by evidence suggesting that interactive learning environments in which multiple representations are presented promote students understanding of scientific concepts (e.g. [33], [34]).

In a literature review [35] concluded that literature provides robust evidence that computer simulations can enhance traditional instruction, especially as far as laboratory activities are concerned. Contrasting the value of using physical and simulated experimentation in science education, in another literature review, [36] concluded that simulated experiments can sometimes be more appropriate than hands-on activities, while physical tests are more apt on other occasions.

Furthermore, [31] showed that carefully designed computer simulations have the potential to result in more favorable attitudes towards science among students. The usefulness of simulated experimentation appears to be a complex matter and dependent on several factors, such as teacher support [30], [37], [38] or integration of physical and virtual practices [28][29][30], [32]. Studying student-teacher interaction in computer-supported lab work, [38] found that a main concern for teachers was to direct the learners attention to coexisting conceptual perspectives. In a similar study, [37] acknowledged the importance of teachers' support with practical advice about how to solve assignments provided in interactive learning environment. The findings of these studies emphasize that conceptually oriented issues and procedural challenges have consequences for instruction and design of computer simulated interactive learning environments.

3) Conveying information in 3D models and virtual environments

The production of virtual media is highly influenced by the digital tools by which it is created. Depending on the possibilities of the tool itself, and the user competence of the designer, this can either create more opportunities or limit the design choices. [39] observe that physical objects rather than the spatial experience are emphasized in common digital communication tools for visualization. In current rendering technologies great achievements are made in representational similarity through increased photorealism. Accordingly, the challenge lies in the experimental concordance with a corresponding real space and how to find the appropriate level of realism and detailing to use for a specific purpose [39]. Visualizations have to be able to interpret some issues exactly [40], while merely sketching others [41]. In some cases, a small to modest amount of detail is sufficient for obtaining the level of realism needed [42]. If the information is too complex, contains too many parameters, or is too abstract, it will be difficult to grasp [43], [44], [45].

Interactivity has been a major feature in the debate on how to advance learning technologies. The degree of interactivity ranges from low to high depending on the type of control available to the users. There is a general assumption – often referred to as the interactivity effect – that the higher the interactive level, the greater the degree to which learning should increase when students engage in multimedia technologies [46]. In line with the proposed interactivity effect – that is, that interactivity can help learners overcome difficulties of perception and comprehension during the learning process –[47] examined the impact of animation interactivity on students' learning and found that increased interactivity significantly improved student achievement. A variety of interactive learning packages for instructional purposes in science education are accessible online calling upon research results explaining how they function in classroom practice.

4) How to choose between mimicking real-world appearance and adding enhanced features

One way to build a virtual laboratory is to see it as a real-world hands-on laboratory, but in digital format. This is what we choose to call a cloned virtual laboratory. Another option is to add extra features to the laboratory that could not be part of a real-world laboratory. This is what we choose to call an enhanced virtual laboratory. In this latter option for building a virtual laboratory we choose the term enhanced, not to confuse the concept with augmented reality. In augmented reality, graphics are added to the actual reality [48]. In the enhanced virtual laboratory, it is the virtual environment that is enhanced in relation to a corresponding real-world laboratory. However, some of these enhancements can be conceptually very similar to how augmented reality work. The view of molecular events discussed below, for instance, could very well be added as an augmented reality enhancement in a real-world laboratory.

Students using the cloned, first iteration version of the Gas Laboratory had trouble understanding what the bubbles meant in relation to gas solubility in water. Since the Gas Laboratory was virtual, different enhancements could be added to clarify the experiments. One suggested enhancement was imagery showing events on the molecular scale, in order to provide the students with a cognitive model for the chemical process Figure 54. Eventually it was decided not to show this molecular view, in order to make the enhanced virtual laboratory as realistic as possible compared to a cloned virtual laboratory.

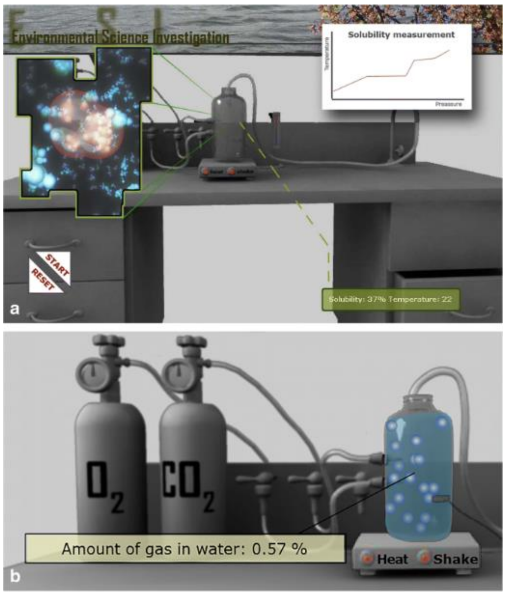


Figure 54 A cognitive model for the chemical process

5) How to find the best learning situation for the virtual laboratory?

One crucial challenge lied in determining how the virtual laboratories were best put to use. Should the laboratory be open for use to anyone with an interest in the content, only guided by the information on the web page? Or, should it be designed for usage in a specific learning situation, i.e., as a complementing demonstration for a teacher? The two laboratories were used in different settings, the Gas Laboratory was evaluated in a classroom situation, and the Color Laboratory evaluated by users at home.

The Gas Laboratory was initially intended to be a self-instructive exercise, which proved to be a major difficulty. In the first user tests the students generally did not reach the intended learning outcome; the main problem was interpretation of the gas bubbles, especially since gas bubbles were seen twice; first, during gassing of the water and after that, during the subsequent change of physical parameters. The first bubbles meant that the water was bubbled with gas in order to dissolve gas in the water, while the subsequent bubbles meant that the level of dissolved gas decreased and that it left the water. This switch in meaning was difficult for the learners to understand without guidance. In the second version of the gas laboratory guiding texts were added, especially an explanatory text to be read after the exercise, as well as a gas meter; a graphical element containing a feigned measurement of amount of solved gas. This increased the achieved learning outcome. In the third version a teacher did an in-class debriefing, and both post-test questions, ethnographic observations and post-interviews suggested that most of the students understood the exercise and achieved the intended learning outcome. This result clearly indicates that the Gas Laboratory benefited from being used with teacher guidance. Teachers are needed to take an expert role in students' use of digital technology [23], [49], [50].

Regarding the Color Laboratory, the simplicity in appearance of the different stations sometimes prevented users from actually perceiving the full complexity of the demonstrated color phenomena, which at least in some cases affected the learning outcome. The interpretation is that the Color Laboratory would be put to best use in a controlled environment where a teacher could provide a context around it, and fill in any information gaps.

A common demand on virtual laboratories is that they should function as efficiently as self-instructive learning materials. Our difficulties in making students achieving the learning goals without teacher guidance suggest that it cannot be taken for granted that a virtual laboratory can function without a teacher-lead debriefing. This is similar to real laboratories where students need either written guides or a teacher/assistant that go through the process. On one hand the interactive and adaptive discussion between the students and their teacher is unique and cannot be recreated in a self-instructive tool such as a virtual laboratory. On the other hand, well-written texts should be able to recreate the required rhetorical argumentation, as a "discussion" between the text and the student. However, there is no conclusive answer to the debate. In the third version of the Gas Laboratory, the quite extensive guiding texts before, during, and after the actual laboratory experiment were very appreciated by the students. The guiding texts were appreciated also in the Color Laboratory, in particular the possibility to choose from different levels of information depending on the user's interest in the station at hand. It would certainly have been possible to perform the exercises in the two laboratories without written text. However, then the exercises would have been harder to interpret correctly, and the overall context might have been lost.

6) Conclusions: Design challenges and considerations

The aim with this comparative study is to gain a deeper understanding of common problems related to design, development and implementation of virtual laboratories. The purpose of this study has been to summarize observations gained through the work on two web-based virtual laboratories, based on the following questions: Which production and implementation issues appear to be common when comparing the two different virtual laboratory projects? Which design considerations can be drawn from these observations? A common concern in both projects was how to choose a suitable level, kind, and purpose, of both interactivity and visual realism in the laboratories. Due to technical problems and lack of resources, both projects produced virtual laboratories that were far simpler than the initially expected result. A conclusion drawn from this is that the development of successful virtual laboratories requires a huge amount of resources and time. However, results indicate that despite the technical production issues, the users actually did achieve most of the intended learning outcomes.

Appendix (10)
Detailed Results of Task 5.2

T5.2: Design an efficient virtual assistant technique for online laboratory experimentations.

The importance of using remote virtual laboratories is suggested in [51]. It enables students to conduct practical experiments in an appropriate manner [52]. The research work in [53] assures us that virtual laboratories enable learners to carry out practical experiments, repeat them several times, watch their interactions, as they greatly simulate the real laboratory, and achieve results similar to the results of real laboratories.

There are several challenges facing virtual laboratories, including how can the students be assisted and how can the necessary support be provided to them based on their level of knowledge and their faced difficulties. In addition, how can the students themselves organize their learning without direct supervision from the teacher? Artificial intelligence (AI) has greatly helped in enhancing the e-learning experience due to its ability to measure and analyze the behavior and data of learners in order to understand the learning process and the environments in which learning takes place.

Regarding the different mouse interaction modeling approaches found in the literature, several features have been identified. Another kind of movement-related feature commonly found in some studies is speed [55], [56], [57], and [58] with some variations in adjusted speed [55] or instantaneous speed in different trajectory points. Other movement-based features include acceleration and instantaneous acceleration. Regarding the trajectory described by the cursor, absolute direction is used in [55] and angle-related features in [55] and [57]. Some studies examine other mouse interactions such as click frequency [54] and [58], and scroll frequency [54]. Other related work generates features from the periods of mouse inactivity [57] and [58].

An attempt to measure personality from mouse and keyboard delivered by [59] to predict the personality of users from the mouse traits and keyboard. The research work in [59][60] and [62]finds the relationship between the mouse movements in online experiments and the personality identification. The research work in [63] presented a system that captures patterns with interacting with online surveys based on mouse behaviors. The research work in [64] finds the correlation between end user behavior and mouse and keyboard patterns. The mouse movements, hover can be associated with self-efficacy and willingness to learn.

The present work aims to design an Intelligent Virtual Tutor (IVT) system that automatically assist the student if he/she faced with problems, difficulties, or misunderstanding of any steps of the online laboratory experiment. The proposed IVT system captures the mouse movement trajectory made by the students during conducting the experiment steps for identifying the difficulties that the student faced during conducting the lab's experiment. The major contribution of this work is the adoption of mouse movement activities with a simple image analysis technique for developing an Intelligent Virtual Tutor system.

1) The proposed IVT system

The main technique used by IVT to detect the difficulties is based on the mouse movement trajectory (x,y), as illustrated in Figure 55, which discriminates the normal trajectory that indicates the good understanding from the abnormal trajectory that indicates that there is misunderstanding or confusion. This technique has been developed by building up the relation between the measured mouse (x,y) signals which are the horizontal positions (x) on the X-axis and the vertical positions (y) on the Y-axis. Then, this relation is converted to an image of pixels which enable us to determine the number of pixels of the trajectory.

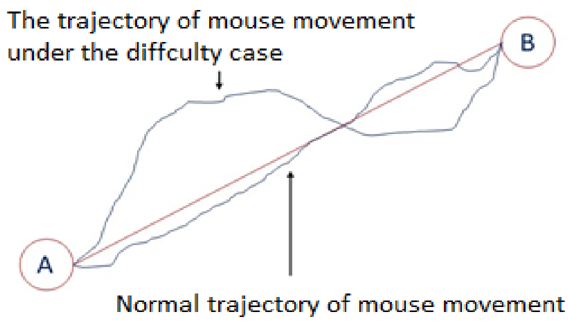


Figure 55 The mouse movement from point A to point B in different cases

The number of pixels for the locus of any image can enable us to detect the normal case from the abnormal case. The proposed technique used in discrimination will be discussed below in details.

At first, the approach for describing the trajectory of a mouse movement is discussed; the length of a trajectory is one of its simplest descriptors. The number of pixels along a trajectory gives a rough approximation of its length [56]. The new technique is based on measuring the x position and measuring the y position of the mouse. Then, the locus boundary of (y) with (x) is created. These measuring signals are taken from mouse movement. The next equation will enable us to make the background of the image M white.

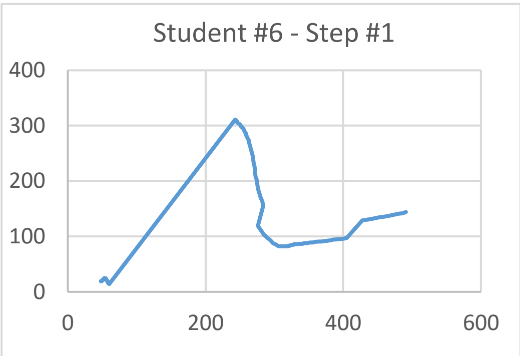
$$M(i, j) = 255 \quad (1)$$

where i and j are the coordinate of the pixel.

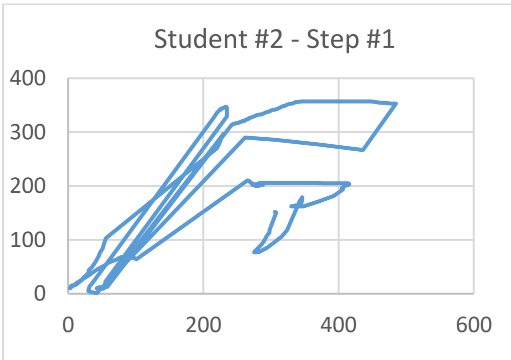
So, the number of pixels for the measured signals can be determined using the next equation:

$$M\,(I\,,\,j) = 0 \tag{2}$$

Figure 56 shows a comparison between the images in two different cases. It is quite evident that in Figure 56 (a), the absence of disturbance in both x and y positions, that makes the (X-Y) relation, has short length during the normal operation (reference trajectory made by the teacher). On the other hand, the effect of the disturbance during difficulty cases makes (X-Y) relation has a different length (which is greater than that in the normal case), as shown in Figure 56 (b). Also, the difference between the two images is obviously clear. The length of a locus boundary, as a simple image descriptor, consequently leads to very fast computations in discrimination between the easy and the difficult cases.



(a)



(b)

Figure 56 The mouse movement of two different students in step #1 in a certain experiment: (a) Normal case, and (b) Difficult case

The number of pixels along a boundary of the locus (X-Y) leads us to get a good value of the setting the difficulty threshold ε1. The setting value ε1 may be determined by testing the normal condition under different values of non-difficulty cases. Then, it can enable us to discriminate between different types of difficulty and non-difficulty cases. Extra setting values can be introduced. These threshold values ε2, ε3, …. are the second, third, …. setting values will help in discriminating between the difficulty cases.

2) <u>The experimental setup</u>

A proposed system was developed so that we can analyze the behavior of users while interacting with Lab experiments. The system first asks the teacher to compose a C++ lab experiment with different steps. The programing experiment steps starts with opening the C++ compiler and write a bice code then answer a set of questions with different types to reflect the various behaviors in response to each GUI component on the screen. The types of lab experiment questions are (Match, MCQ, True or false, fill in text). The experiment is composed of number of steps that at the end make the students achieve the goal and get score for his/her steps. Once the experiment is available to the student, he/she starts interacting with the different components on the screen by using mouse or touch pad.

The system captures all the events fired by the mouse (x,y) traces and time spent on each component on the screen in addition to the count of hover on each component. The data is then collected and stored for further analysis. The data captured by the application is then sent to a consolidated data storage for data analysis. Figure 57 shows the step #1 in a certain online lab experiment.

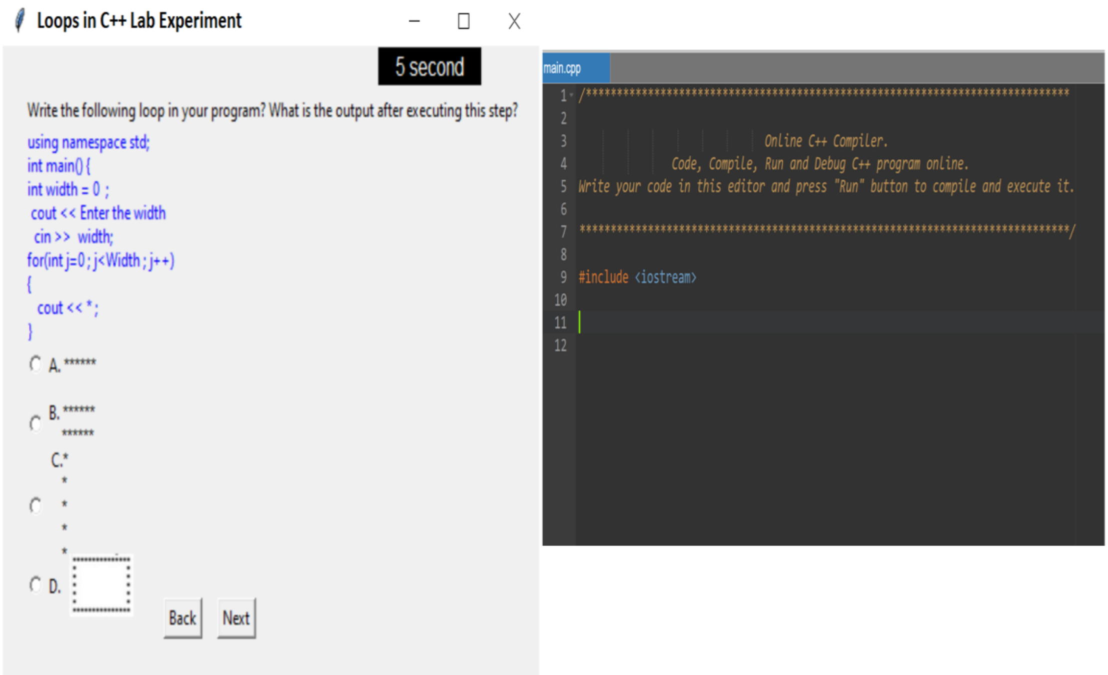


Figure 57 C++ Programing Experiment Step #1

The complete experiment is demonstrated below in details:

Programming Experiment (1)

Open C++ Compiler http://cpp.sh/ Write a C++ program to draw a Triangle

Step# 1

Ask the user to enter the length (3 to 5) and the width (5 to 7)

Ask the user to enter a Special Character like "*, -, # , ~" to draw the shape

Step # 2 Inner loop

Write the following loop in your program? What is the output after executing this step?

```
for(int i=0;i<Width;i++)
   {
      cout<< SpecialChar;
   }
```

•	**********
•	********** **********
•	*************** * * * * * * * * * * ***************
•	* * * * * * * * * *

Step # 3…… Joining outer loop with inner loop to draw rectangle

Add the following outer loop to the previous inner loop

```
for(int i=X;i<Y;Z)
   {
//inner loop
}
```

- TF/ The value for X should be Zero True or false?
- TEXTBOX/ The value for Y should be TextBox
- MCQ/ The value for Z should be (1**. J++** , 2 J--, 3 Length++, 4 J+=2)

- MCQ/ Where should we add the line break
- Inner Loop
- **Outer Loop**
- Main program
- No need for any linebreak

Step #4… converting Rectangle to Triangle

After adding the missing line, Change the inner loop to be

- **for(int i=0;i<=j;i++)**
- for(int i=0;i<=Widht;i++)
- for(int i=0;i<=Length;i++)
- for(int i=0;true;i++)

```
*
*   *
*   *   *
*   *   *   *
```

3) Data design

The data set is consisting of a *.CSV file that contains the mouse features, as in Table 4 Sample of the dataset (a) and (b) the point at X, the point at Y, pressed at X, pressed at Y, released at X, released at Y, scrolled, and scrolled at y) collected from the student's experiment to detect what the student needs and gets the best help method needed.

Table 4 Sample of the dataset (a) and (b)

Level of Programming	Cognitive Style : Gathering Information -> Intuitive Score	Cognitive Style : Gathering Information -> Sensing Score	Cognitive Style : Evaluating Information -> Thinking Score	Cognitive Style : Evaluating Information -> Feeling Score
4	6	6	9	3
4	1	3	4	2
4	4	8	10	2
2	4	8	4	8
5	9	3	11	1
4	4	8	8	4

Sample of the dataset (a)

Next Button Counter	Back Button Counter	Total Second of experiment	Sum of Left Click of first step	Sum of left click in second step	Sum of left click in third step	Sum of left click in fourth step	Sum of Right Click of first step
2	0	128	1	0	3	1	0
2	0	134	0	0	3	2	0
2	0	69	0	0	3	1	0
2	0	462	0	1	5	2	0
2	0	188	0	0	3	2	0

Sample of the dataset (b)

The dataset is divided into two datasets; training dataset and testing dataset. The training dataset is used to train the system, whereas, the testing dataset is used to test the system. The training dataset is 80% of the total dataset, whereas the testing dataset is 20% of the total dataset, as illustrated in the following Figure 58.

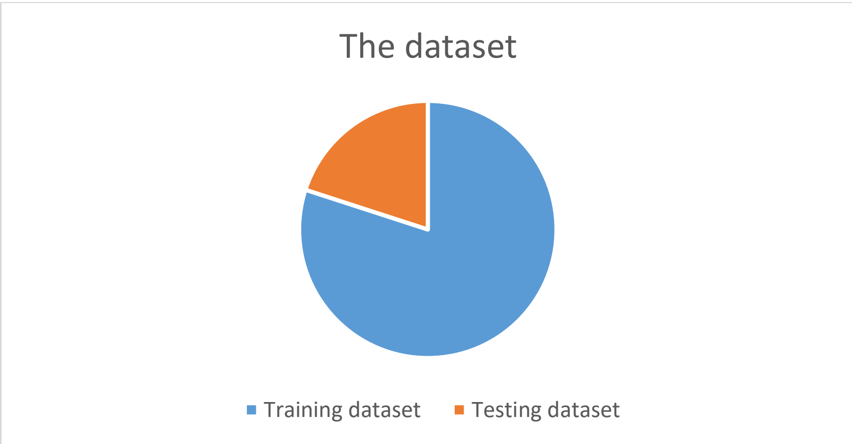


Figure 58 The dataset

4) The functional requirements

The functional requirements are divided into instructor requirements and student requirements.

- **The instructor requirements**

Firstly, the instructor and the real assistant (RA) will conduct the experiment. This step will enable us to collect the data with high score.

Secondly, this collected dataset will be used as a reference or model answer to compare the answer of the student with it.

Thirdly, the instructor should insert the proper way that help the student. The instructor/RA will insert in advance a text, an image, or a video.

- **The student requirements**

Firstly, the student will normally conduct the experiment. The data should be recorded and stored in CSV file.

Secondly, according to the distance between the answer of the student and the model answer that was collected from the instructor and the RA, the level of the student will be classified into four categories.

1. Normal student, the student did not face by any difficulties, and in this case, there is no need for the virtual assistant (VA).
2. The student faced with *low-difficulty*.
3. The student faced *medium-difficulty*.
4. The student faced *high-difficulty*.

Thirdly, the help will be automatically appeared to student, according to his/her level. In the first case, the help will not have appeared. However, in other cases, the help will be appeared differently. In the second case, a chat bot will appear in order to help the student in text form. In the third case, an image will be appeared in order help the student with the *medium-difficulty*. In the last case, a video will be played to help the student.

The pseudocode

```
for everytraining_data_set do

        voting = 0

        If Length_of_position > Length_of_position_thershold
                voting = voting + Length_of_position_weight
        End if

        If Number_of_leave_app > Number_of_leave_app_thershold
                voting = voting + Number_of_leave_app_weight
        End if

        If Total_Second_of_experiment > Total_Second_of_experiment_thershold
                voting = voting + Total_Second_of_experiment_weight
        End if

        If Sum_of_mouse_stand  > Sum_of_mouse_stand_thershold
                voting = voting + Sum_of_mouse_stand_weight
        End if

End for
```

Appendix (11)
Detailed Results of Task 5.3

T5.3: Develop and test the designed virtual assistant technique.

Serval experiments have been conducted to demonstrate the effectiveness of the proposed technique on discriminating between the normal case and the difficulty case(s).

1) Normal Case

The proposed system is tested for different cases. The length of the locus boundary of the relation (X-Y) can be determined by counting the number of pixels of the trajectory. This enables us to select $\varepsilon 1 = 1000$ as a setting value, to discriminate between the normal condition, which is smaller than 1000, and other cases of difficulties, which are greater than 1000.

It should be noticed that, the length of the locus boundary of the normal case does not exceeds the setting value ε1, as shown in Figure 59, indicating that there is no need to assist the student in this case.

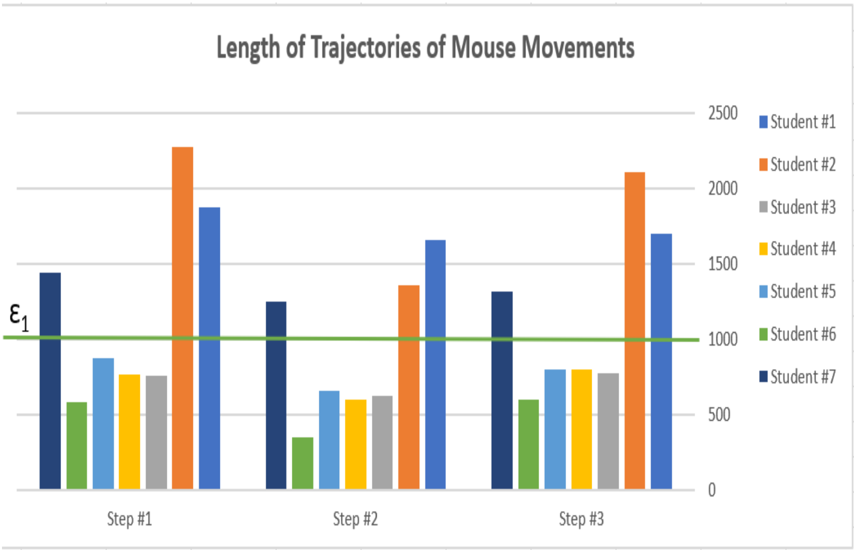
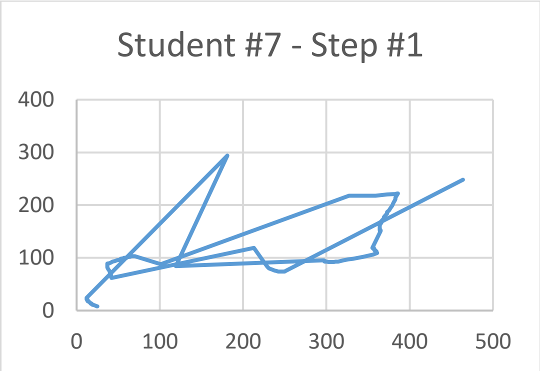


Figure 59 Discrimination between normal case and difficulty case using a threshold ε1

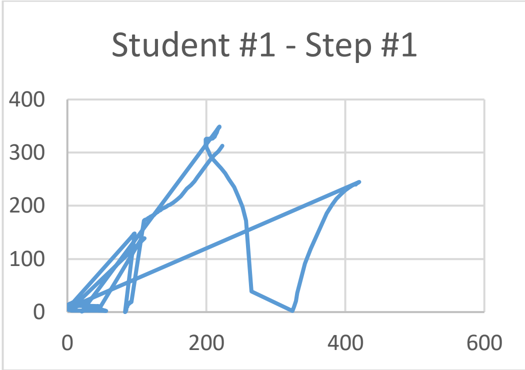
2) Difficulty case

It is clear from Figure 59 that, the detection of difficulty case can be easily achieved as the length of the locus boundary exceeds the setting value ε1, which enables us to detect this case. The locus of (X-Y) for different difficulty cases are shown in Figure 60 (a) and (b).

Figure 60 shows the deviations of the length of trajectory of mouse movement (x,y) for each student in each step in the experiment. The computed number of pixels of the trajectory in Figure 60 (a) is 1441 pixels, whereas in Figure 60 (b), the number of pixels is 1877 pixels. Both of these students have some difficulties in conducting step #1 of the experiment. However, one of them has larger difficulty than the other. Experimentally, as the number of pixels of the trajectory increases as the difficulty increases.



(a)



(b)

Figure 60 The mouse movement of two different students with two different difficulty levels in step #1 in a certain experiment: (a) Low-difficulty case, and (b) High-difficulty case

3) The experimental results

The number of pixels of different trajectories of different mouse movements in different steps of different students are illustrated in Table 5 . The length of the locus boundary of the relation (X-Y) is in the range between 345 and 2274.

Table 5 The number of pixels of different trajectories of different mouse movements of different students

Step/Student	Step #1	Step #2	Step #3
Student #1	1877	1658	1700
Student #2	2274	1356	2109
Student #3	755	620	773
Student #4	765	598	796
Student #5	877	657	795
Student #6	580	345	602
Student #7	1441	1247	1320

Experimentally, it is proven in every step in the conducted experiment that the average length of the locus boundary for the normal case is smaller than for the difficulty case. For instance, in step #1, the average length is 744 pixels for the normal case, whereas for the difficulty case, it is 1864 pixels. This explains why the mouse trajectories are longer when the students have more difficulties or the students are stuck in the experiment.

The difficulties have different levels; from low difficulty to high difficulty. The difficulties' levels can be classified via multi-setting or threshold levels; e.g.; ε2, ε3, ε4, … etc. The low difficulty occurs when the length of locus boundary is greater than the first threshold ε1 and less than the second threshold ε2. The next difficulty level will be from the second threshold ε2 to the third threshold ε3, … etc. So, the new technique can discriminate between the difficulty levels, as illustrated in Figure 61.

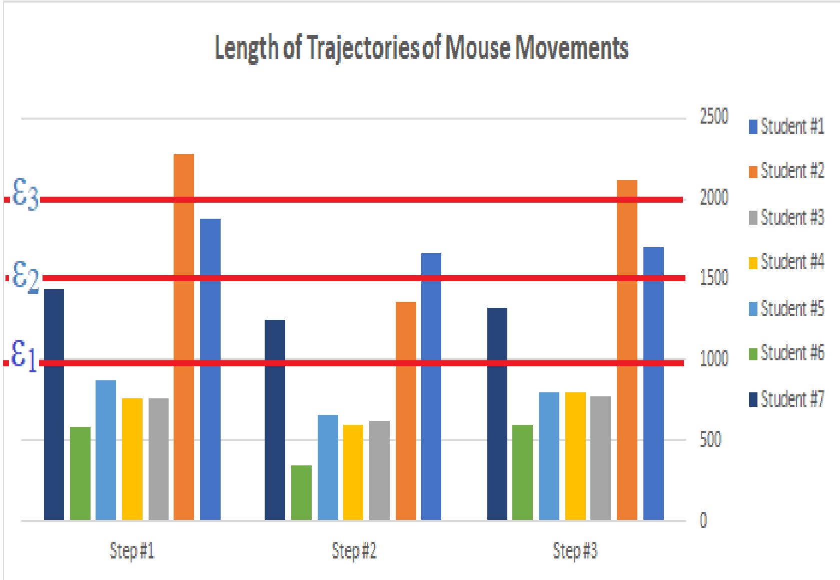
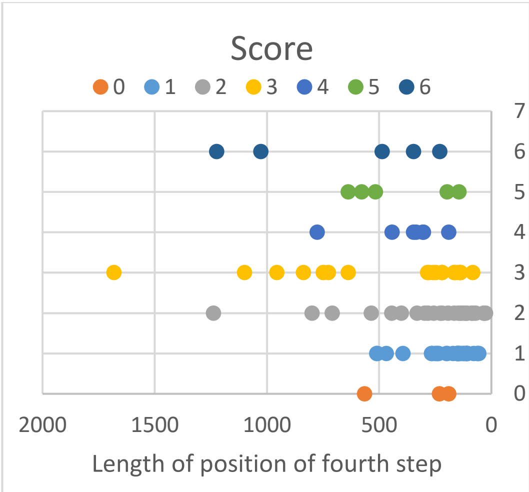
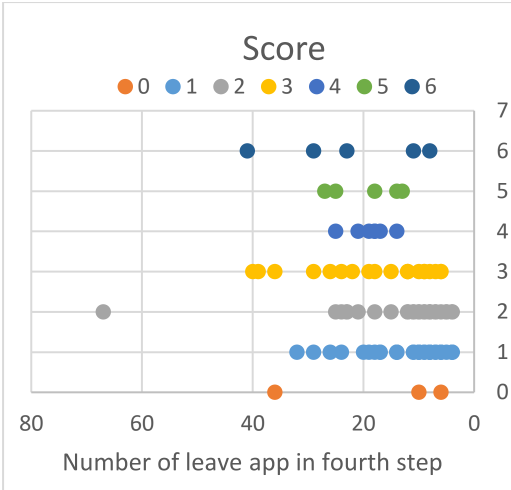


Figure 61 Discrimination between normal case and difficult cases using a threshold ε1, and classification of the difficulty levels via several threshold levels ε2 and ε3

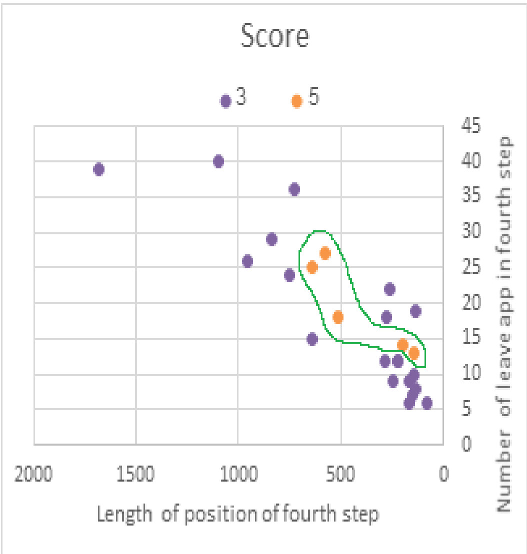
Figure62 shows the feature space for certain extracted features. In Figure 62 (a) and (b) show the feature space of each individual extracted features; length of position and number of leave application; respectively. It is obviously from Figure62 (a) and (b) that, there are several overlapping between classes. In other words, none of these features; length of position nor number of leave application; are suitable to discriminate between classes 0 to 6. If these two features are selected, as in Figure62 (c), one can discriminate between class 3 and class 5. However, these two features can not discriminate between class 0 – class 6, as illustrated in Figure62 (d), unless additional features are added to them.



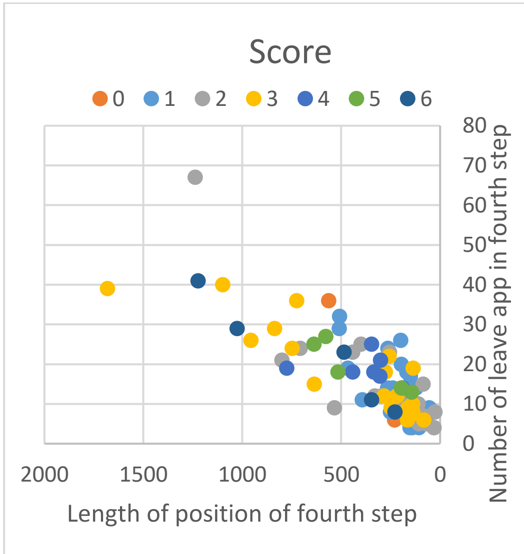
•



(b)



(c)



(d)

Figure62 The feature space for certain extracted features

Figure 63 shows the graphical user interface (GUI) that should appear to the student and Figure 64 shows the chatbot appeared when the student faced with low-difficulty.

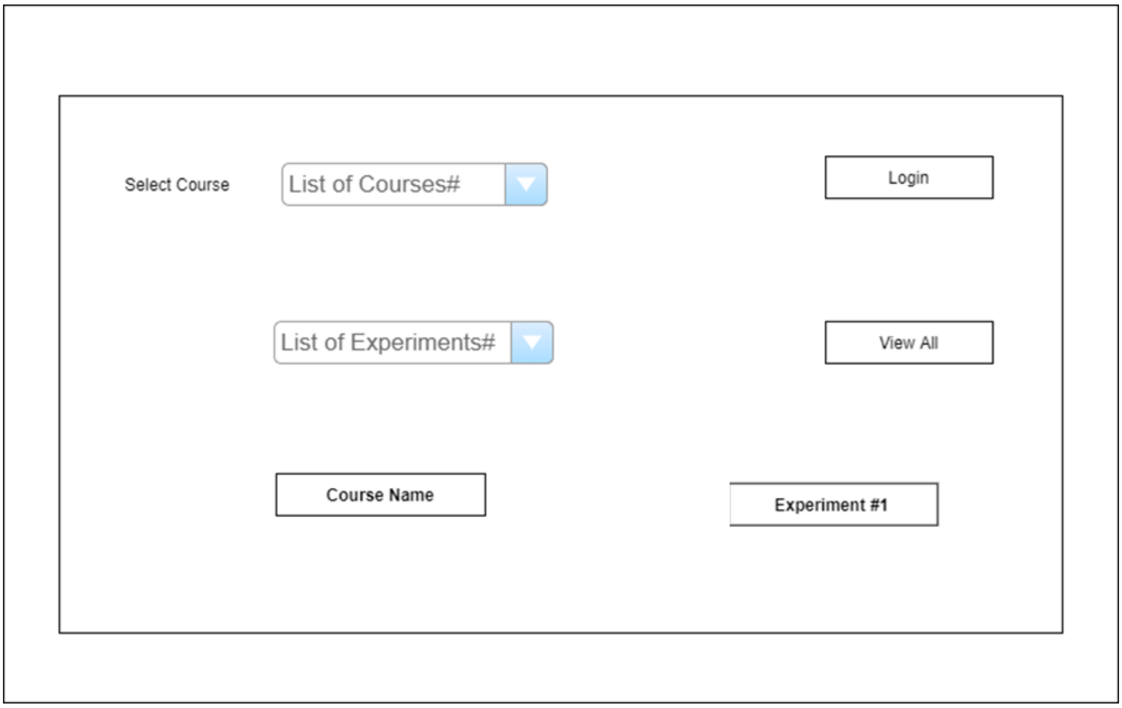


Figure 63 The GUI

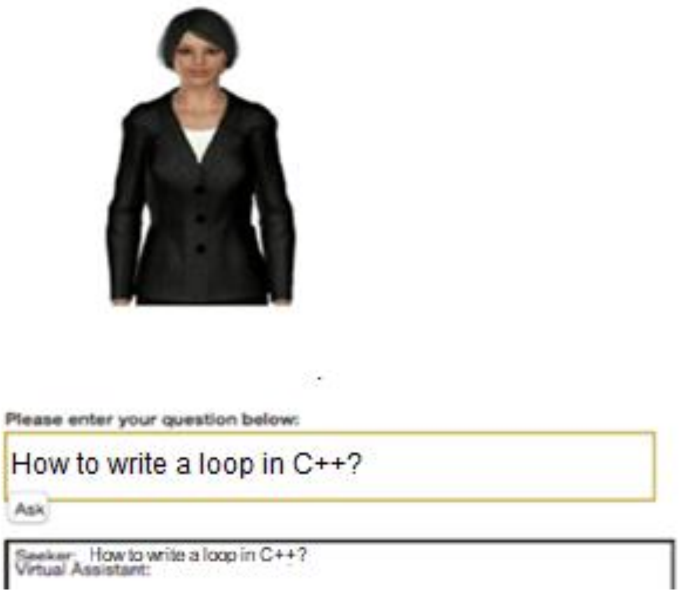


Fig. 14

Figure 64 A chatbot appeared in the second case.

4) Conclusions

An Intelligent Virtual Tutor (IVT) system based on image analysis scheme for classifying the difficulties that the student faced during conducting online lab's experiment is presented. Several features of student’s mouse interaction behavior are extracted. The extracted features are the back button counter, sum of left clicks, next button counter, sum of right clicks, time of the step, sum of mouse leave question, sum of mouse stand on question, and length of trajectories. The mouse movement trajectory is chosen as the best feature according to its correlation with the student's score.

The classification of student’s behavior is achieved by comparing the length of the mouse movement trajectory done by the student during each experiment step with a threshold value derived from the reference trajectory length value done by the teacher. The obtained results clearly show that the scheme can provide accurate discrimination between the normal and difficulty cases as well as identifying the difficultly levels.

Appendix (12)
Detailed Results of Task 6.1

T6.1: Survey and investigate existing techniques for student performance evaluation and assessment in online learning process.

Online evaluation is a set of appropriate methods and tools that are used in educational assessment and employs the capabilities in online learning laboratories of all kinds to serve the evaluation process and the desired objectives to be achieved in the educational learning process according to the foundations and learning objectives [80]. There is no doubt that assessment represents one of the important elements in the educational process, and the concept of educational evaluation in its simple sense is the collection and analysis of data for the purpose of determining the degree of achieving goals in order to make decisions and address shortcomings, and knowledge of achieving goals can be done in several ways, including remote online assessment (E-assessment). Which is carried out according to scientific methods and mechanisms, and has many keywords, including digital assessment, online assessment, and computer-based assessment, regardless of the different names, but it is used to describe the use of computers and the Internet in evaluation process and knowing the extent to which the objectives have been achieved [68].

1) <u>Important characteristics online assessment</u>

The most important characteristics of online assessment are the following:

Students prefer self-assessment quizzes because it enables them to have more control over interfaces and simulations that are similar to the learning, entertainment and activities environment, and it is fast and easy to use [76]. It improves the level of learning and increases the motivation to improve the performance of learners and enables the creation of multiple methods and methods of electronic assessment that are consistent with the explosion of knowledge and the continuous demand for education [72].

Furthermore, the online assessment gains its importance because it saves teachers time and effort, enables them to test students and reduces the workload, enables identification of learning problems, facilitates reporting and communication between learners, and it is also possible to practice multiple methods of electronic assessment that clearly reflect the teacher's performance level [79]. The main characteristics can be summarized in the following diagram.

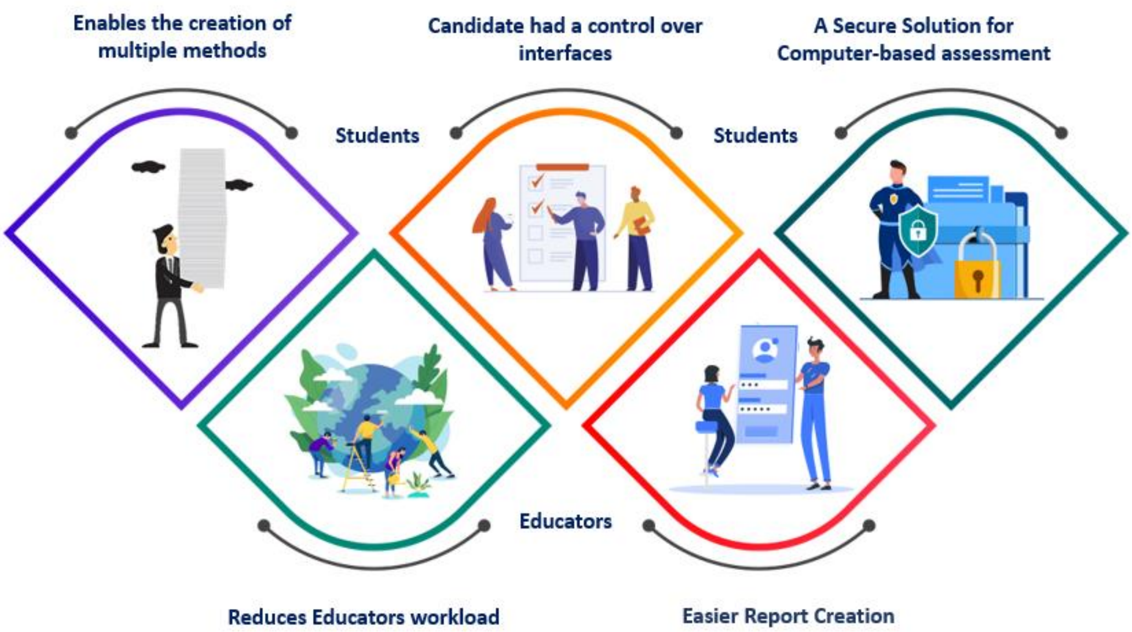


Figure 65 : Important characteristics online assessment

2) Types of online assessment

Online assessment has several types, any of which can be used according to the purpose of the learning objectives, for example, if the purpose is assessment for learning, then discussion boards, online interviews, or worksheets can be used that employ formative assessment to measure what students have acquired of skills and knowledge. During the study, this type of assessment helps to give feedback and thus make an action plan in order to increase student learning [67]. If the purpose is assessment of learning, scientific knowledge during the online laboratories that can be evaluated using electronic quizzes tools, or sometimes audio recording. And video conferencing, especially knowledge that requires memorization, or concepts can be evaluated using presentation programs through e-learning platforms or essay exams, and practical skills can be evaluated using simulation programs or electronic files [71]. Studies and research mention many successful and effective methods and strategies in eLearning assessment evaluation, which can be used with high reliability if some important requirements are applied [73]. These strategies include the following:

1. **Short electronic quizzes**, which measure the level of the student's ability to recall and understand knowledge. Essays, which measure the level of cognitive abilities, especially with regard to critical thinking and creative thinking [70].

2. Homework and assignments, which are a set of specific tasks or activities that the student completes at home and electronically sent to the teacher [83].
3. Discussion forums and help to assess the student's comprehension of the scientific material through discussions with the teacher and among the students themselves, where the student was able to express his opinion on the topics of the lesson in a direct manner [84].
4. **Performance observation assessment tool** is concerned with measuring the learner's ability to perform specific skills or accomplish a specific educational task [66]. Online and backend analytics
5. Interviews help in evaluating the scientific knowledge and concepts acquired by the student through video conferencing in a simultaneous manner [75].
6. **E-Portfolios**, which is an organized compilation done by the student of his work related to the content of the scientific material and presented to the teacher [82]. ***Computer based portfolios***
7. Educational and research projects assessment, whether collective or individual, and help to measure the skills acquired by the student during the period of his studies. Self-assessment: It helps the learner to understand what he has gained during his study period, and to benefit from the feedback. It is considered a diagnostic assessment that should not be based on its results [78].
8. **Simulation**: Students' practical skills can be assessed without the possibility of any risks, as students use all their resources and skills to complete the task in a safe online virtual environment [69].
9. Electronic games (Gamification): It is one of the electronic assessment tools that encourage students, especially young people, to show what they have acquired from the objectives of the scientific subject [74].

One of the most important aspects to help in implementing the above strategies in the process of evaluating students is the spread of software and applications that help to apply them easily, in this case we need to identify the type of assessment goal in our case in LLS we need the formal assessment within formative strategies as depicted in figure 2. The objective of evaluation and how the results are used is what really determines whether the evaluation is formative or concluding. which they have evaluated, it is not a formative assessment [77].

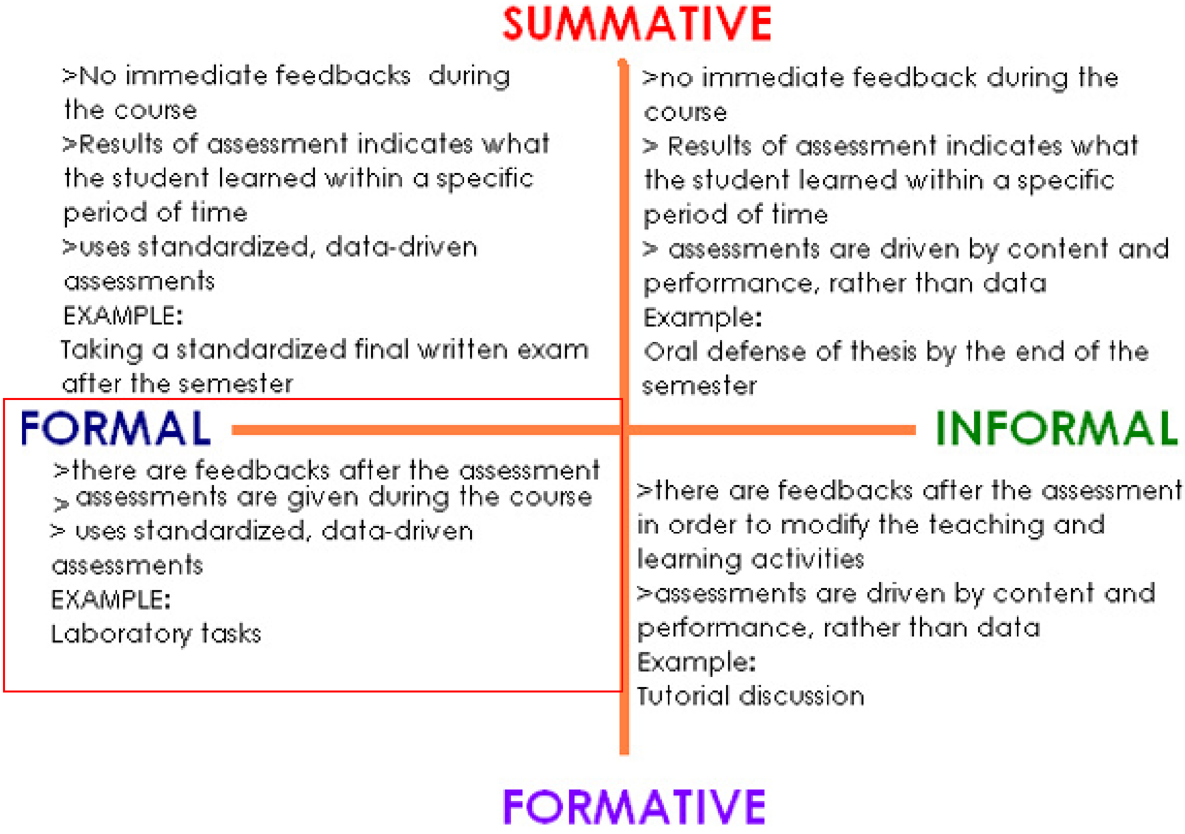


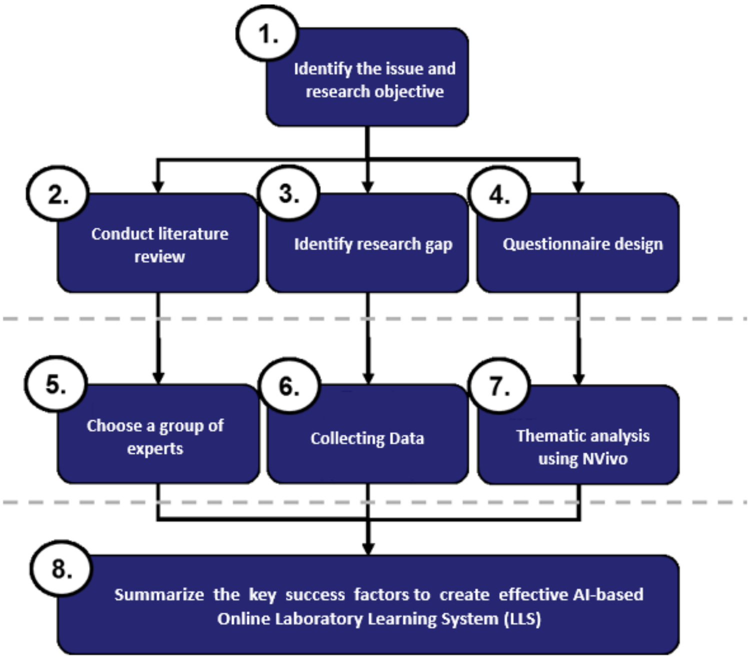
Figure 66 : Implementing assessment strategies

In conclusion, designing authentic assessment tasks is becoming increasingly important as teaching moves away from moribund classroom-based methods to more realistic learning. This forces a change in assessment types, from paper articles to increasingly reliable assessment activities. Virtual environments are a very authentic, yet controlled setting, which necessitates the need for new types of assessment when used in the classroom and especially in science, engineering, and technology education in order to provide the appropriate environment for evaluation in the distance [81].

Appendix (13)
Detailed Results of Task 6.2

T6.2: Design of an effective evaluation and assessment criteria for online experimentation activities.

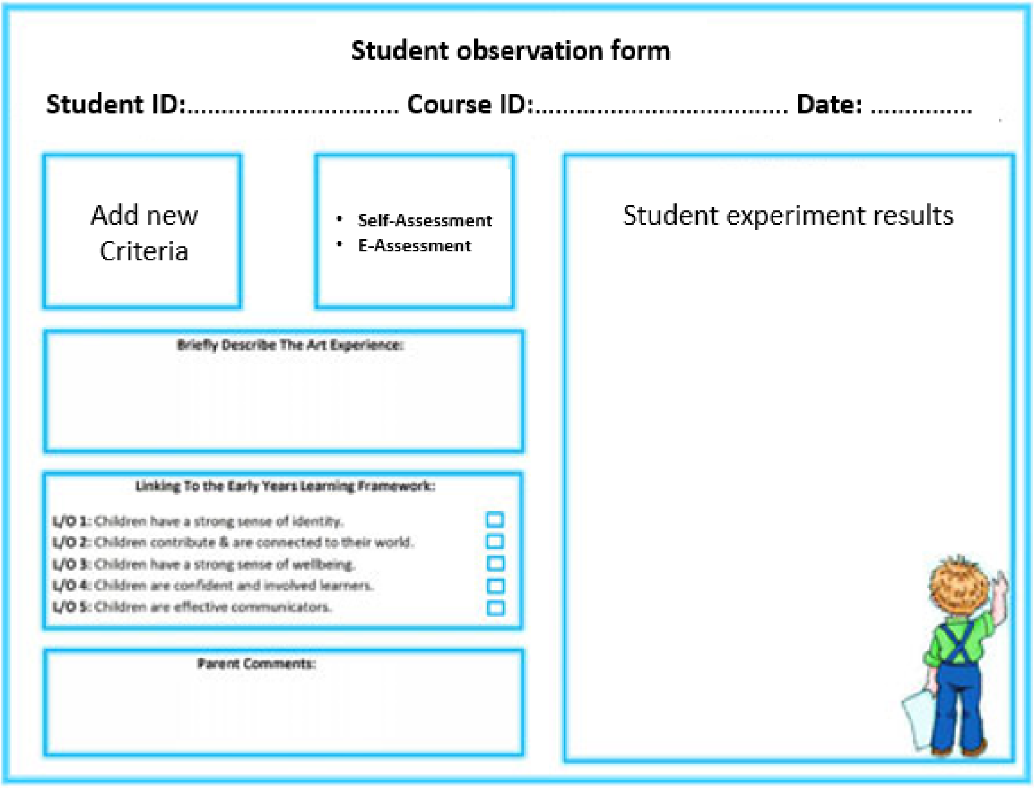
Our method for designing the evaluation and assessment criteria consists of eight main activities as illustrated below. In the first step, we defined the study objective which was for designing an online laboratory learning system assessment to conduct student experiences in the field of science, engineering, and technology. Steps 2, 3 and 4 being conducted partially in parallel and independent from each other, based on a literature review that confirmed the research gap in the design criteria for assessment methods in laboratories. The open questionnaire was used as one of the strategies for gathering data from a panel of experts in this study. This questionnaire relies on experts who are knowledgeable about design and implementations of eLearning applications so they can forecast the outcome of future LLS assessment design scenarios, predict the likelihood of assessment use cases, or reach consensus about evaluation design criteria for online experimentation activities as depicted below. The fifth step dealt with identifying a group of experts to participate in the open-ended questionnaire. The expert has to meet certain criteria, such as designing some eLearning assessment applications and publishing research in the same field. An invitation to participate in this study was sent to (60) eLearning experts and (43) participants were accepted, and (31) of them completed the questionnaire successfully. The participants were representative with respect to gender, just over half the sample (52%) was male, the ages ranged between 35 and 60 years old. The sample was also representative of a number of different cultures, as 48% are representatives of Arab universities, 30% of European universities, and the rest are from North America.



Experts have identified a number of criteria that must be taken into account when designing assessment in LLS as details below:

1. Authentic Assessment in the LLS replicates or simulates the contexts in which students are “tested” in the workplace, in civic life, and in personal life.
2. Use formative assessment during experiments to ensure students understand the content of the Lab.
3. Implement drag-and-drop formative assessments that demonstrate a learner's capacity to connect information and use knowledge to solve a real-world problem.
4. The assessments allow for a holistic approach rather than a piecemeal one.
5. Students can adapt the tasks to their own requirements and interests because they are sufficiently flexible i.e., time and self-reflection.
6. Use the same simulation program in evaluation operations when necessary.

The best practices of designing evaluation for the online laboratory experiments is observation form checklist [85]. The process of designing the observation form comes to clarify all the research notes recorded in this form, as the information remains static and incomprehensible until a design process is carried out for it. By conducting the student and his experiments inside the virtual lab, the student’s performance level is compiled through a number of indicators, including the time of the experiment, the number of times the student stumbled, the number of times he received help from peers or the system, the number of attempts by the mouse and the extent of his use of the keyboard, Elapsed time while running the VM as illustrated in Figure 67. We did a study using the machine learning to automatic Identification of Student's Cognitive Style from Online Laboratory Experimentation using Machine Learning Techniques [86].


Student observation form

Student ID:............................... Course ID:.................................... Date: ....

Add new Criteria

- Self-Assessment
- E-Assessment

Student experiment results

Briefly Describe The Art Experience:

Linking To the Early Years Learning Framework:

L/O 1: Children have a strong sense of identity.
L/O 2: Children contribute & are connected to their world.
L/O 3: Children have a strong sense of wellbeing.
L/O 4: Children are confident and involved learners.
L/O 5: Children are effective communicators.

Parent Comments:

Figure 67 : Student observation form sample

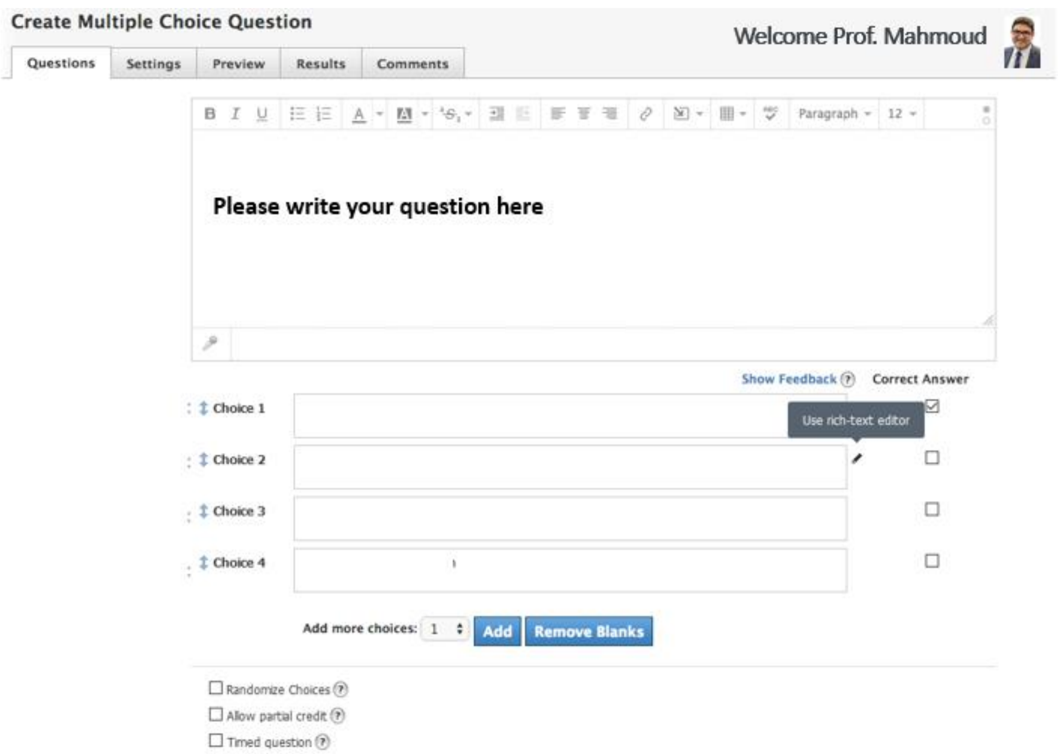
Appendix (14)
Detailed Results of Task 6.3

T6.3: Develop and test the designed evaluation and assessment criteria.

1) Online assessment quizzes

Short electronic quizzes, as the name implies, is the use of computer and internet technology to conduct time and location independent evaluation procedures. In its broadest sense. León et al. [87] defines e-assessment as all technology-enabled assessment activities. Because technology is so important in all sectors of study, assessment benefits from it as well, particularly in LLS situations. Following advantages of e-assessment caused it to become very popular in recent years:

- Reduce workload of management and administration.
- Time and location independent.
- Reusable, easy to adapt.
- Immediate feedback for learners.
- Active involvement of learners via interactive forms.
- Variety in design of assessments such as e-portfolios and interactive games, which is not possible by other means.
- Easy, fast, and effective submission, grading and management.



2) Grading Services

Grading Services It is a system based on all aspects of learning: cognitive, skill, and emotional for the learner. Therefore, it means a method for collecting everything related to the skills related to the performance or practical aspect, such as doing an online experiment, upload pictures and geometric shapes - using some VM devices - writing an expression topic and others.... This aspect is measured using tests, quizzes, Performance observation assessment tool and E-Portfolios.

1. Grading book

Grading book is an online record of a student's points, assignments, progress, and grades for their quizzes. An electronic grade book connects to a student learning analytics, which stores a lab district's student records such as grades, attendance records, transcripts, student schedules, and other information.

2. Performance observation assessment tool

In the past decade, several studies have sought to focus on the use of Artificial Intelligence (AI) in educational context. Indeed, the capabilities of AI technology have increased considerably, with an opportunity to provide learners with automating analytics and virtual assistance based on their cognitive style [88]. And are presented in 4 basic forms as depicted this Figure 68.

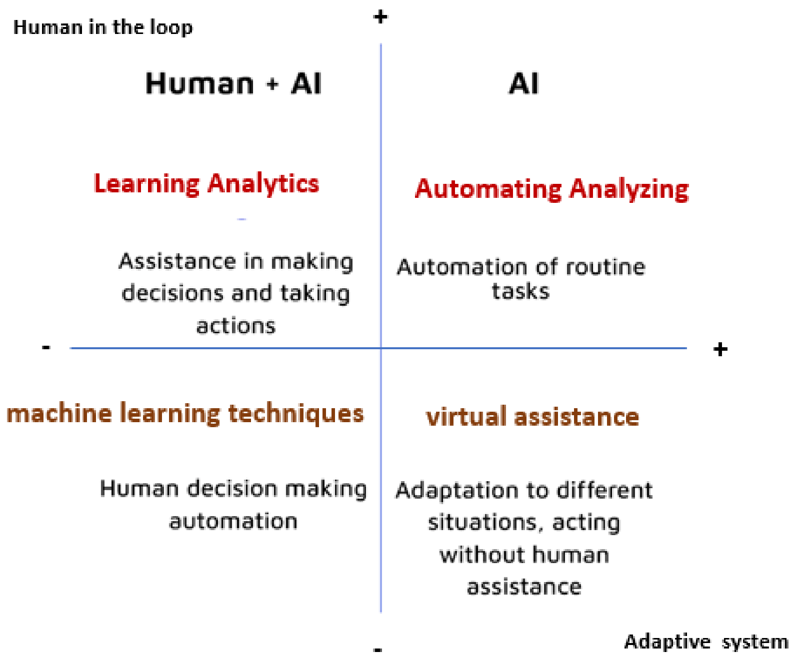


Figure 68: The four basic forms of applied AI in education

The specific indicators that should be considered in implementing AI in LLS including:

- **Personalization:** LLS should adapting experiments feedback to meet the needs of each individual student.
- **Tutoring:** Providing online help and guidance based on the learning difficulties faced by students i.e., visual assistance can provide one-on-one instruction without the presence of a course instructor to answer questions.
- **Chatbot:** LLS should support automation and conversational intelligence that can help course participants get answers to their most frequently asked questions.
- **Learning analytics:** Provide course dashboard that including measurement, collection, analysis student performance.

3. E-Portfolios

The student's academic ePortfolio is a digital collection of their course-related work, such as essays, posters, photographs, videos, and artwork. Academic ePortfolios can also capture other aspects of a student's life, such as volunteer experiences, employment history, extracurricular activities, and more. In other words, ePortfolios are digital portfolios that document and display student learning. A strong ePortfolio, on the other hand, should be more than a collection of products as depicted in this Figure 69.

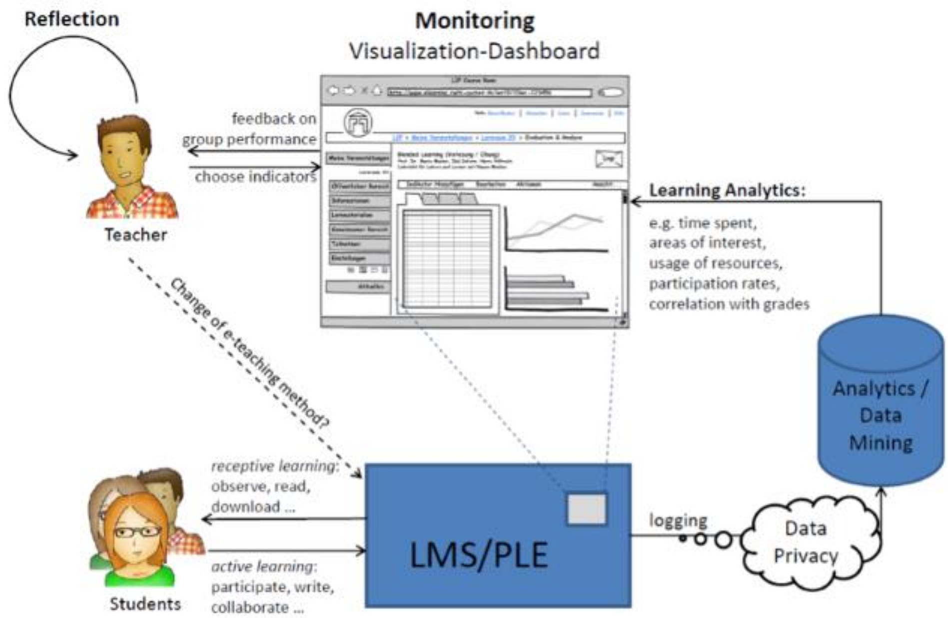


Figure 69 : student profile design [89]

Appendix (15)
Detailed Results of Task 7.2

T7.2: Prepare and configure the hardware/instruments for remote access and control through Internet.

1) Laboratory physical resources

The proposed remote laboratory architecture is composed of a server, which can provide a pool of virtual machines that can be configured to be accessed remotely through internet. The laboratory is also composed of several physical machines (computers). These physical machines are generally used by students for in laboratory software tools-based experiments. Some hardware instruments can also be connected to the physical machines (e.g. Elvis boards, USRPs, etc.), in order to provide instruments-based experiments. These physical machines are connected to the laboratory network, by which they can be configured to be accessed remotely through internet. The laboratory also is composed of some instruments that have the ability to be connected to the laboratory network (e.g. oscilloscope, waveform generator, spectrum analyzer, etc.), hence, it can be configured to be accessed by any of the physical and virtual machines on the laboratory network.

2) Defining the available hardware/instruments

2.1 Digital oscilloscope (RIGOL DS1202Z-E)

Features

Figure 70 shows the digital oscilloscope laboratory resource RIGOL model DS1202Z-E.

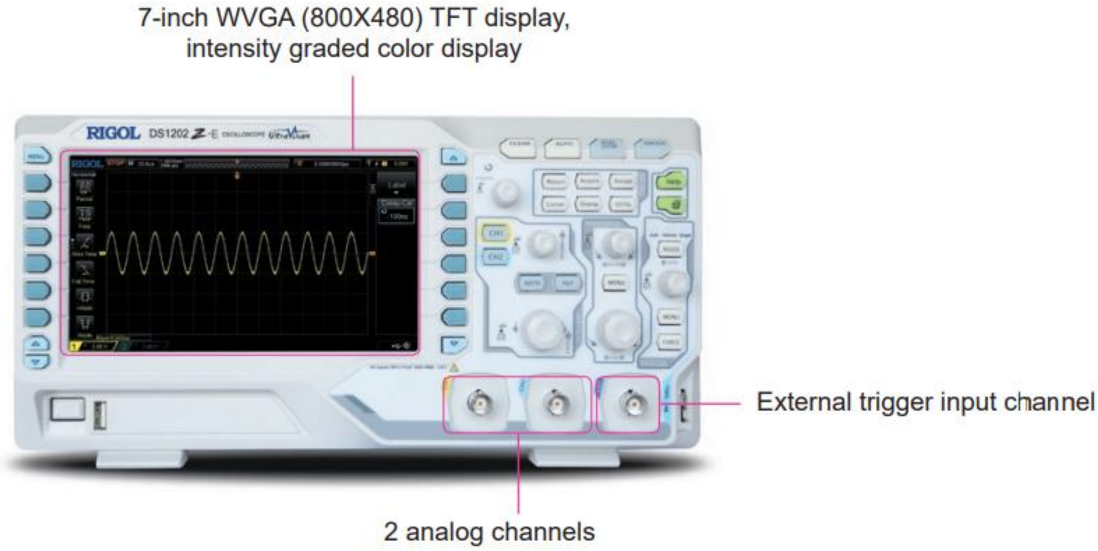


Figure 70 Digital Oscilloscope (RIGOL DS1202Z-E).

- Analog channel bandwidth: 200 MHz
- 2 analog channels
- Real-time sample rate up to 1 GSa/s
- Memory depth up to 24 Mpts(Std.)
- Up to 30,000 wfms/s waveform capture rate
- Up to 60,000 frames hardware real-time waveform recording and playback functions
- Innovative "UltraVision" technology
- Various trigger and bus decoding functions
- Low noise floor, vertical scale range: 500 uV/div to 10 V/div Various interfaces: USB Host&Device, LAN (LXI), AUX Novel and delicate industrial design, easy to use
- 7-inch WVGA (800x480) TFT LCD, intensity graded color display

2.2 Function/Arbitrary Waveform Generator (RIGOL DG2052)

Features

Figure71 shows the Function/Arbitrary Waveform Generator laboratory resource RIGOL model DG2052.

Figure71 Function/Arbitrary Waveform Generator (RIGOL DG2052).

- Unique SiFi II (Signal Fidelity II) technology: generate the arbitrary waveforms point by point; recover the signal without distortion; sample rate accurate and adjustable; jitter of all the output waveforms (including Sine, Pulse, etc.) as low as 200 ps
- 16 Mpts memory depth per channel for arbitrary waveforms
- Standard dual-channel with the same performance, equivalent to two independent signal sources
- High frequency stability: ±1 ppm; low phase noise: -105 dBc/Hz Built-in high-order harmonic generator (at most 8-order harmonics) Built-in 7 digits/s, 240 MHz bandwidth full featured frequency counter Up to 160 built-in arbitrary waveforms, covering the common signals
- in engineering application, medical electronics, auto electronics, math
- processing, and other various fields
- Sample rate up to 250 MSa/s, vertical resolution 16 bits
- Arbitrary waveform sequence editing function available; arbitrary waveforms also can be generated through the PC software
- Various analog and digital modulation functions: AM, FM, PM, ASK, FSK, PSK, and PWM.
- Standard waveform combine function, capable of outputting specified
- waveforms combined with the basic waveforms
- Standard channel tracking function, when enabled, all the parameters of
- both channels are updated based on users' configurations
- Standard interface: USB Host&Device and LAN (LXI Core 2011 Device); USB-GPIB function supported
- 4.3" TFT color touch screen

2.3 Spectrum Analyzer (RIGOL RSA3045)

Features

Figure**71** Figure72 shows the Spectrum Analyzer laboratory resource RIGOL model RSA3045.

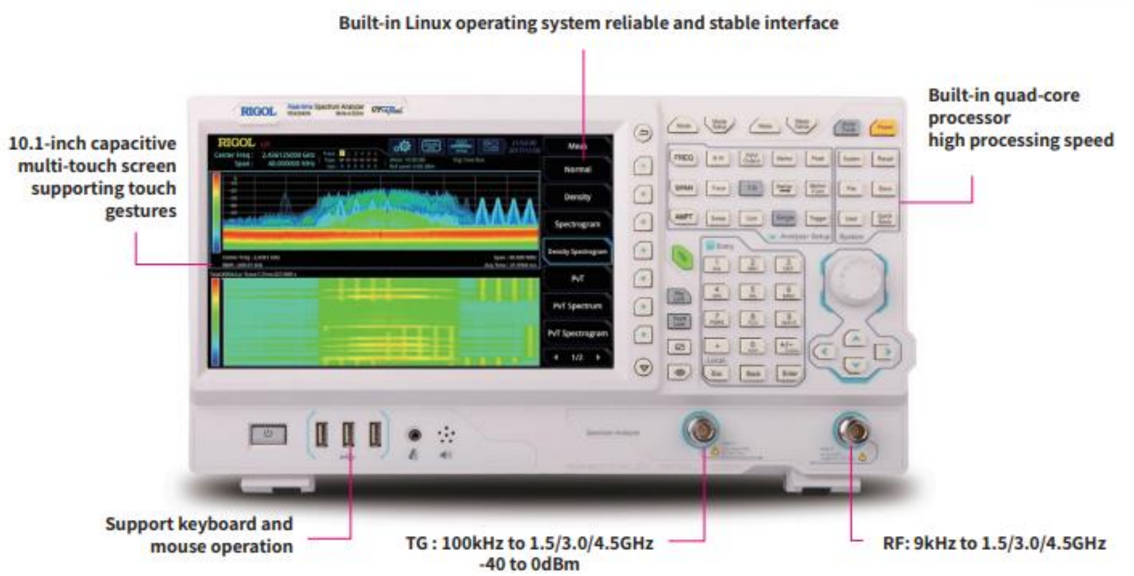


Figure72 Spectrum Analyzer (RIGOL RSA3045).

- Ultra-Real technology
- Frequency: up to 4.5 GHz
- Displayed average noise level (DANL): <-161 dBm (typical) Phase noise: <-102 dBc/Hz (typical)
- Level measurement uncertainty: <1.0 dB
- 4.5 GHz tracking generator
- Min. RBW 1 Hz
- Up to 40 MHz real-time analysis bandwidth
- Multiple measurement modes
- Various advanced measurement functions EMI measurement application (option) Vector network analyzer application Multiple trigger modes and trigger masks
- Density, spectrogram, and other display modes
- PC software options
- 10.1" capacitive multi-touch screen; supporting touch gestures
- USB, LAN, HDMI and other communication and display interfaces

2.4 RF Signal Generator (RIGOL DSG3060)

Features

Figure73 shows the RF Signal Generator laboratory resource RIGOL model DSG3060.

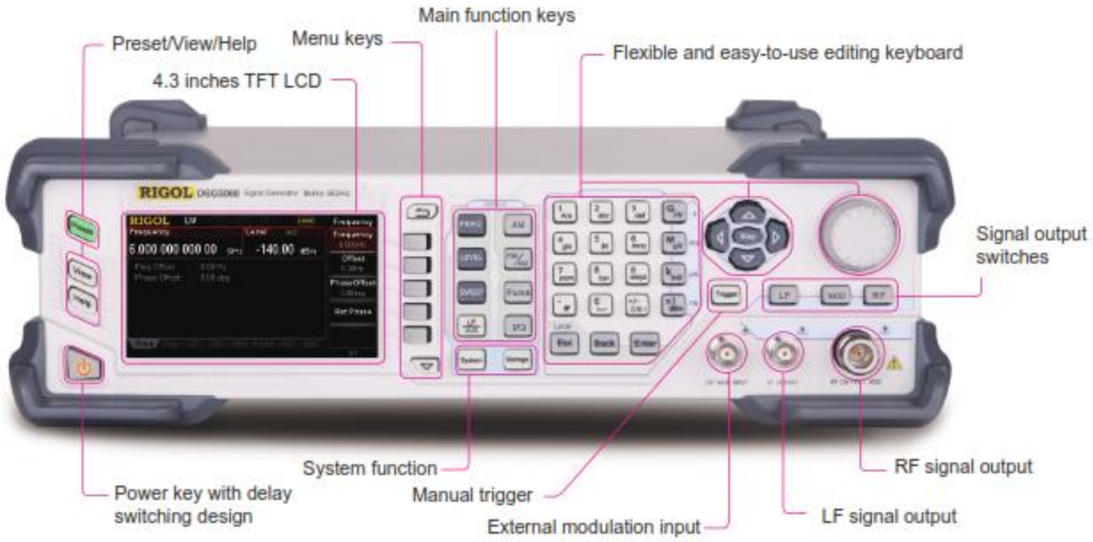


Figure73 RF Signal Generator (RIGOL DSG3060).

- Highest frequency: 3GHz/6GHz
- Amplitude accuracy: <0.5dB (typical)
- Output amplitude range: -130 dBm to +13 dBm
- High signal purity, phase noise: <-110dBc/Hz@20kHz (typical) Standard 0.5ppm internal clock; 5ppb high stable clock for option Standard AM/FM/ΦM analog modulation
- Standard pulse modulation; on/off ratio up to 80dB;
- pulse train generator for option
- I/Q modulation and I/Q baseband output
- All modulations support internal and external modulation modes
- Standard 2U height design to save rack space;
- rack mount kit is available
- Standard USB/LAN/GPIB remote control interfaces;
- support SCPI command set
- Wear-free electronic attenuator design
- Well-designed automatic flatness calibration function (Cables, attenuators, amplifiers and so on) for test system with power meter control

2.5 NI Elvis III

Features

Figure74 shows the advanced circuit board laboratory resource NI model Elvis III.

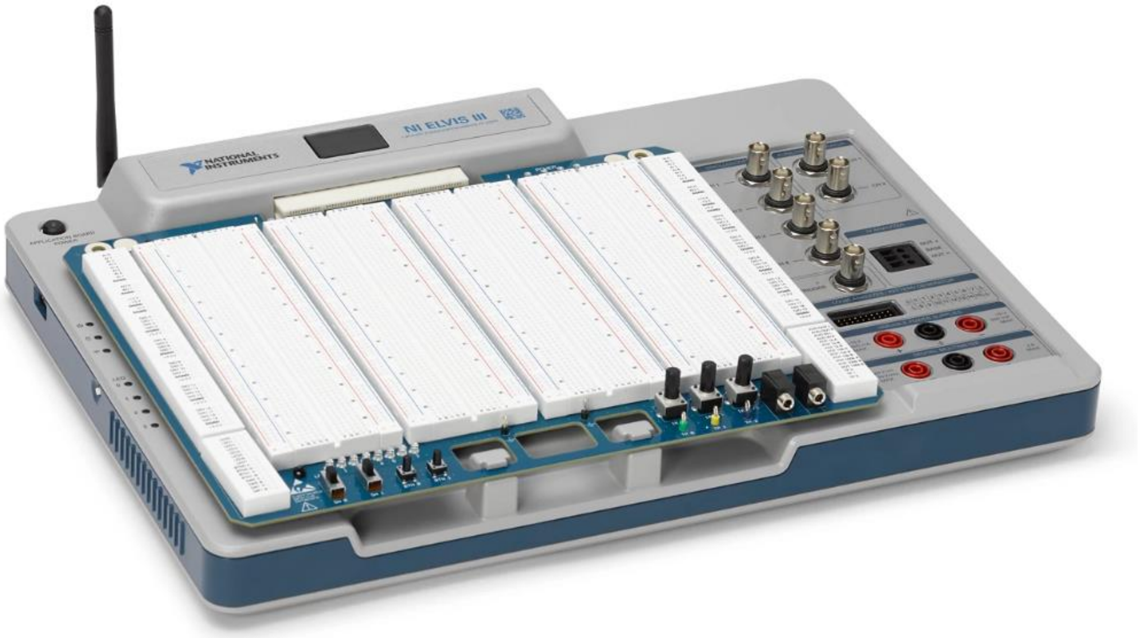


Figure74 NI Elvis III board.

- Software includes interactive web and desktop soft front panels, instrumentation support for Windows and Mac, API support for LabVIEW and text-based languages, shipping examples, and detailed help files
- Seven hardware instruments plus control I/O containing 16 AI, 4 AO, and 40 DIO
- 4-channel, 100 MS/s (400 MS/s single channel), 50 MHz oscilloscope with 14-bit resolution
- 16-channel, 100 MS/s logic analyzer/pattern generator
- 16-channel, 1 MS/s analog input with 16-bit resolution
- 40 DIO lines individually programmable as input, output, PWM, or digital protocols

2.6 Remote control configuration for each hardware/instruments

- **RIGOL instruments**

In order to configure RIGOL instruments to be remotely controlled, the instruments should be connected via USB interface, or via LAN interface to the local network. This will allow the RIGOL instruments to be remotely accessed by a PC or a virtual machine. The remote controlling can be realized by using the standard Commands for Programmable Instruments (SCPI) commands. These commands can be used through the following two methods:

1. User defined programming: Where the RIGOL instruments can be remotely controlled using the SCPI commands through National Instrument – Virtual Instrument Software Architecture (NI-VISA) library.
2. PC software: Where the RIGOL instruments can be remotely controlled using the SCPI commands through the Ultra Sigma software when installed on a PC or a virtual machine.

Using the Ultra Sigma software, we will describe how to configure the RIGOL instruments for remote control vis USB or LAN interfaces.

Remote Control via USB

1. Connect the instrument to the PC via USB cable.
2. After connecting the instrument to the PC, power on the instrument, and follow the instructions for installing the USB driver.
3. Assuming that the Ultra Sigma is already installed, start the Ultra Sigma up, and the software will search automatically for the connected instruments to your PC.
4. Also, by clicking on the (USB-TMC) icon, the software will search the connected devices for a RIGOL instrument connected via USB as shown in Figure 75 .

Figure 75 Ultra Sigma RIGOL software.

5. The resources found will appear under the RIGOL Online Resources directory, along with the model number and USB interface information. For example, RSA3045 (USB0::0x1AB1::0xA4A9::L355010000000::INSTR) as shown in Figure 76.

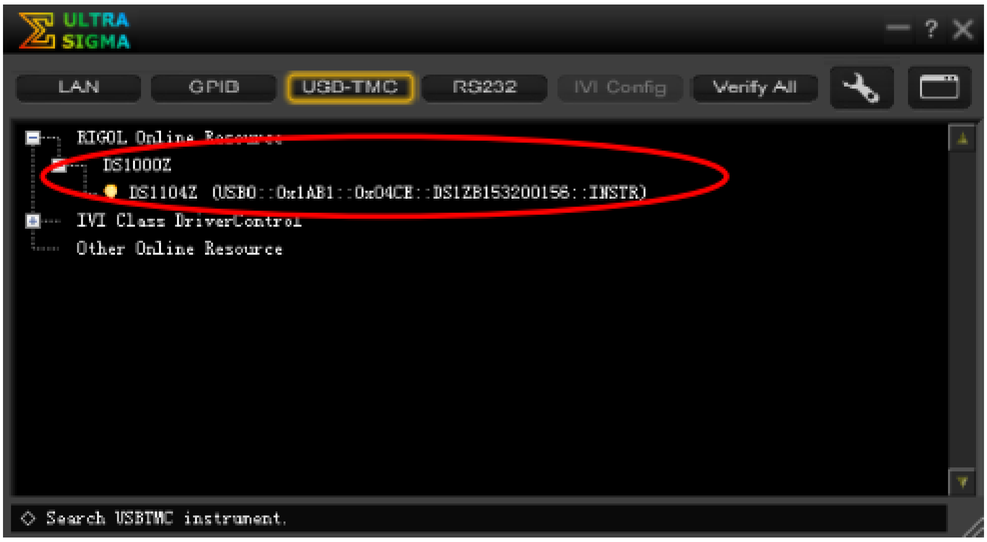


Figure 76 USB connected RIGOL Online Resources directory.

6. By right clicking on the instrument name and choosing the SCPI panel control option from the drop-down menu, this will open the remote-control panel, where you can send commands and read data using the SCPI commands.

Remote Control via LAN interface

1. Connect the instrument using the network cable to the local area network (LAN).
2. Tap the setting information icon at the top of the user interface, then tap the network setting icon, so that the LAN parameters settings can be shown Figure 77.
3. Configure the network parameters. Start by setting the mode of obtaining the IP address, whether it is DHCP, or Auto IP, or Manual IP.
4. Also, the IP address, subnet mask, gateway, and DNS may be configured.
5. Start the Ultra Sigma software up, and click on the LAN tab.
6. At the opened pop-up window, press the search button. Ultra Sigma will search for the connected instruments through the LAN. Then, the connected instruments will be displayed on the right side of the window. Select the desired instrument and press ok as shown in Figure 78.

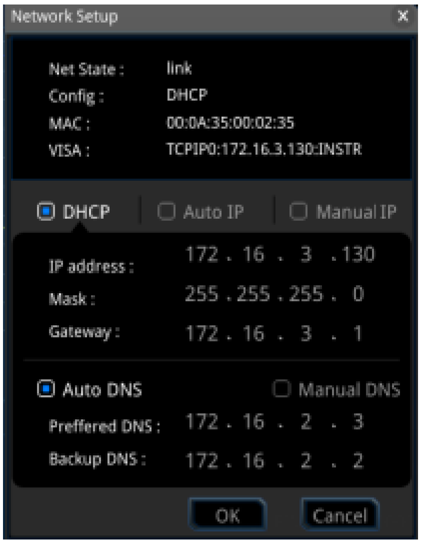


Figure 77 LAN parameters settings.

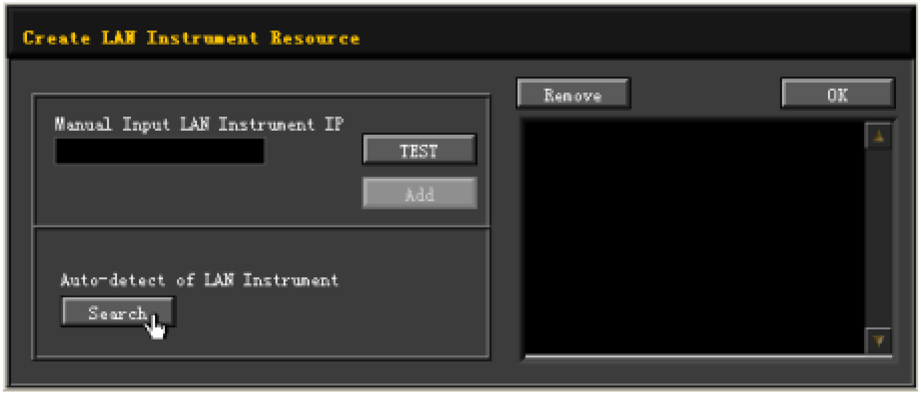


Figure 78 Ultra Sigma connected instruments through the LAN.

7. The resources found will appear under the RIGOL Online Resources directory, along with the model number and LAN interface information. For example, RSA3045 (TCPIP::172.16.3.194::INSTR) as shown in Figure 79.

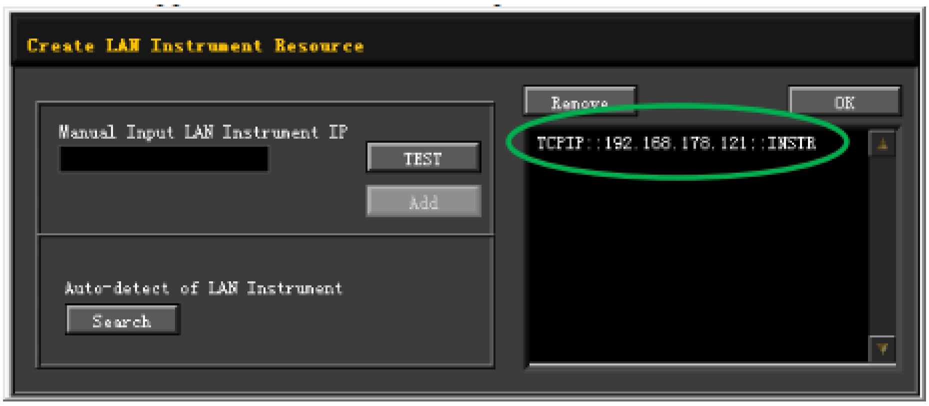


Figure 79 LAN connected RIGOL Online Resources directory.

8. By right clicking on the instrument name and choosing the SCPI panel control option from the drop-down menu, this will open the remote-control panel, where you can send commands and read data using the SCPI commands.

Instruments interfaces

The laboratory RIGOL instruments can be controlled remotely using the available PC software interfaces for each instrument. After installing the appropriate interface software, you can right click on the instrument from the Ultra Sigma window under the RIGOL Online Resources directory and choose the appropriate interface software option from the drop-down menu. This will automatically open the desired software interface and connect to the related instrument. The remote-control interfaces for the installed instruments in the laboratory are described below.

1. Ultra Scope Software

Ultra Scope software is a software designed to control the RIGOL digital oscilloscopes remotely. The Ultra Scope main screen is shown in Figure80 .

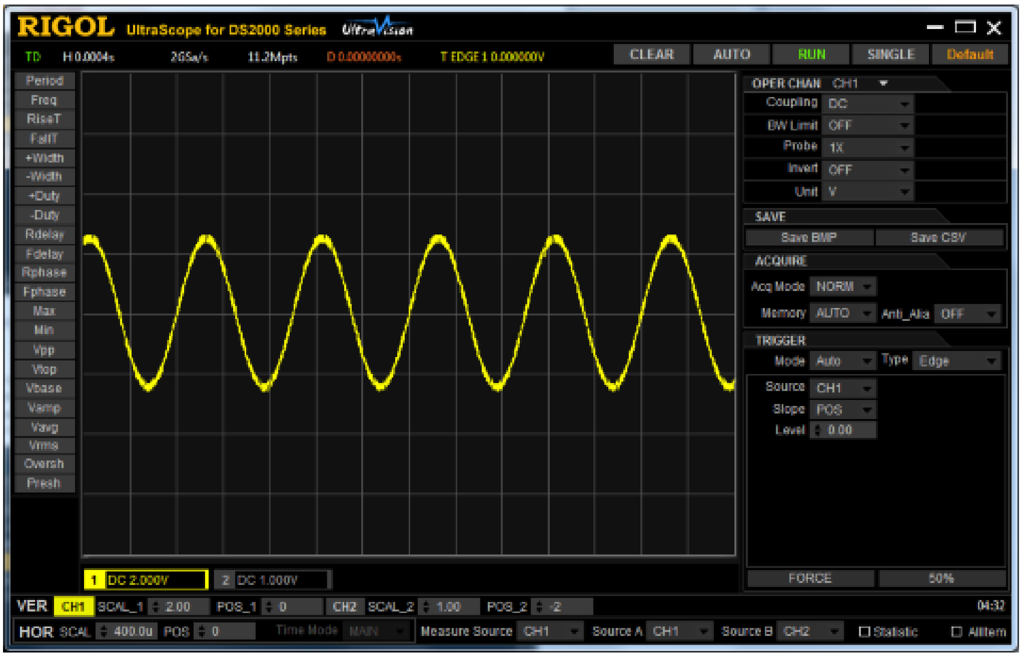


Figure80 The Ultra Scope main screen.

In order to control the vertical scales and positions for the different channels, select the channel tabs indicated in Figure81 .

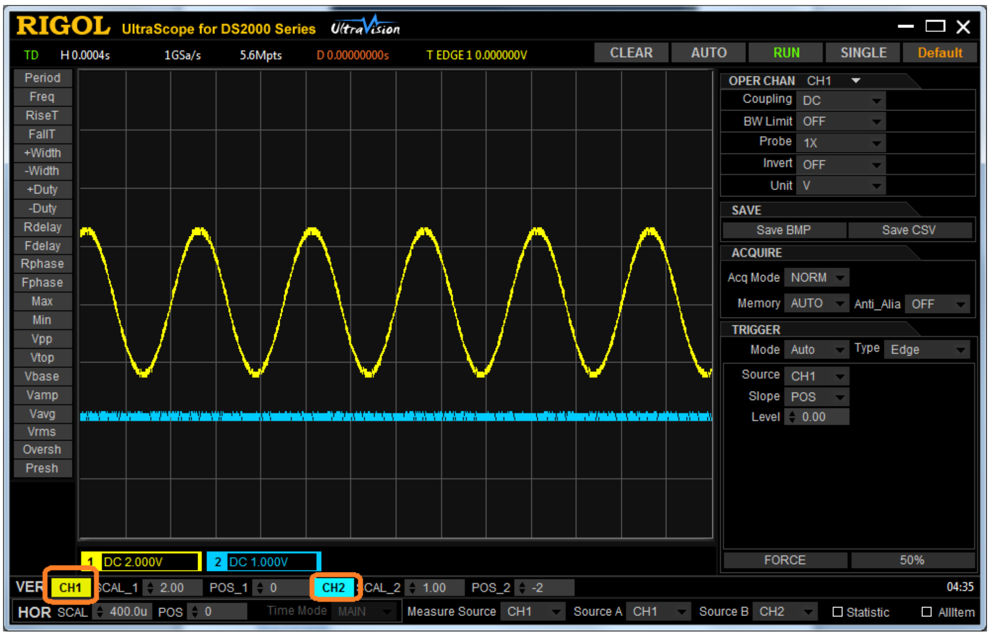


Figure81 Vertical scales and positions in Ultra Scope.

In order to control the horizontal scale and position, use the SCAL and POS indicated in Figure82 .

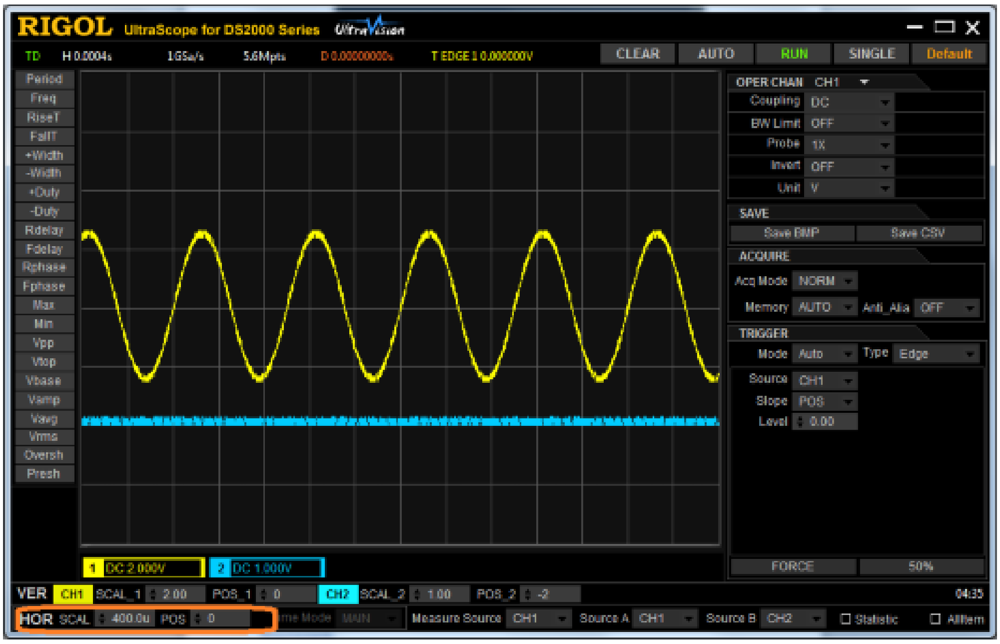


Figure82 Horizontal scale and position in Ultra Scope.

The Trigger can be controlled from the Trigger area indicated in Figure 83 .

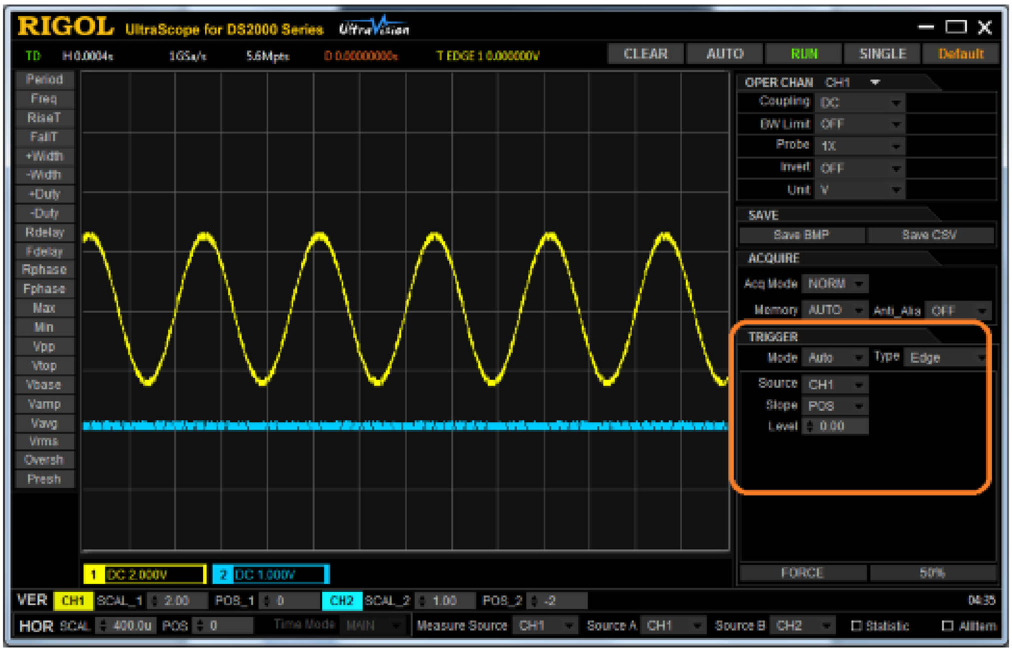


Figure83 Trigger parameters in Ultra Scope.

The different measurement types can be found on the left-hand side panel shown in Figure84 .

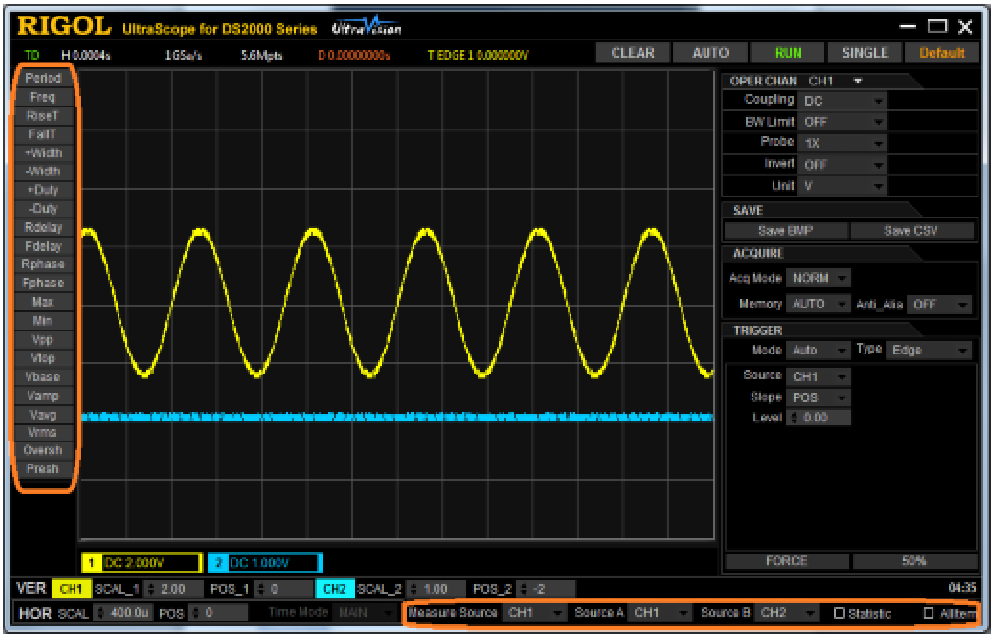


Figure84 The different measurement types in Ultra Scope.

Different data captures can be taken as CSV or BMP files from the panel indicated in Figure85 .

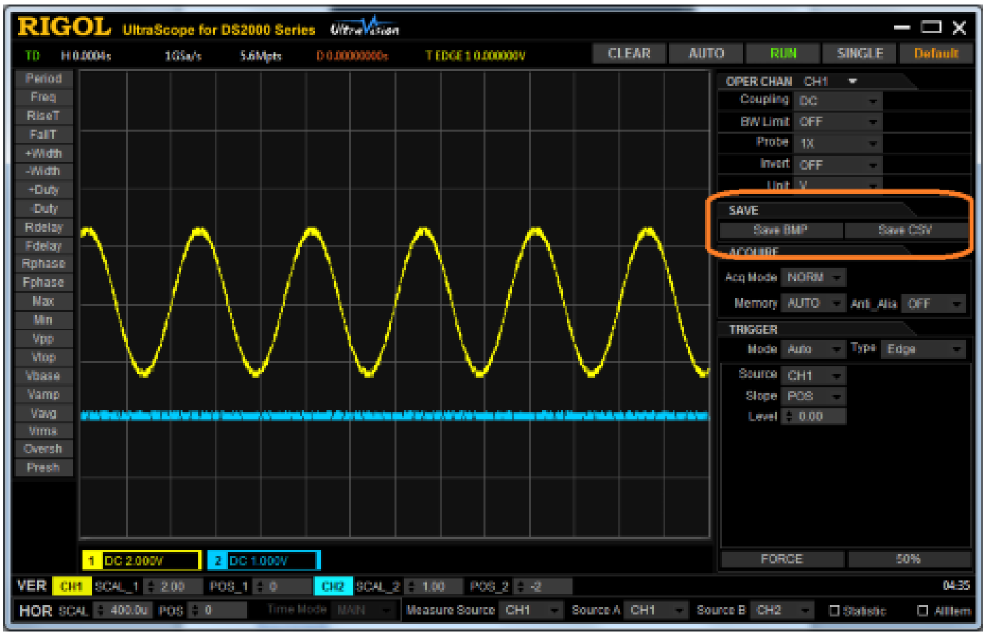


Figure85 Saving data in Ultra Sigma.

2. Ultra Spectrum Software

Ultra Spectrum software is a software designed to control the RIGOL spectrum analyzers remotely. The Ultra Spectrum main screen is shown in Figure86 .

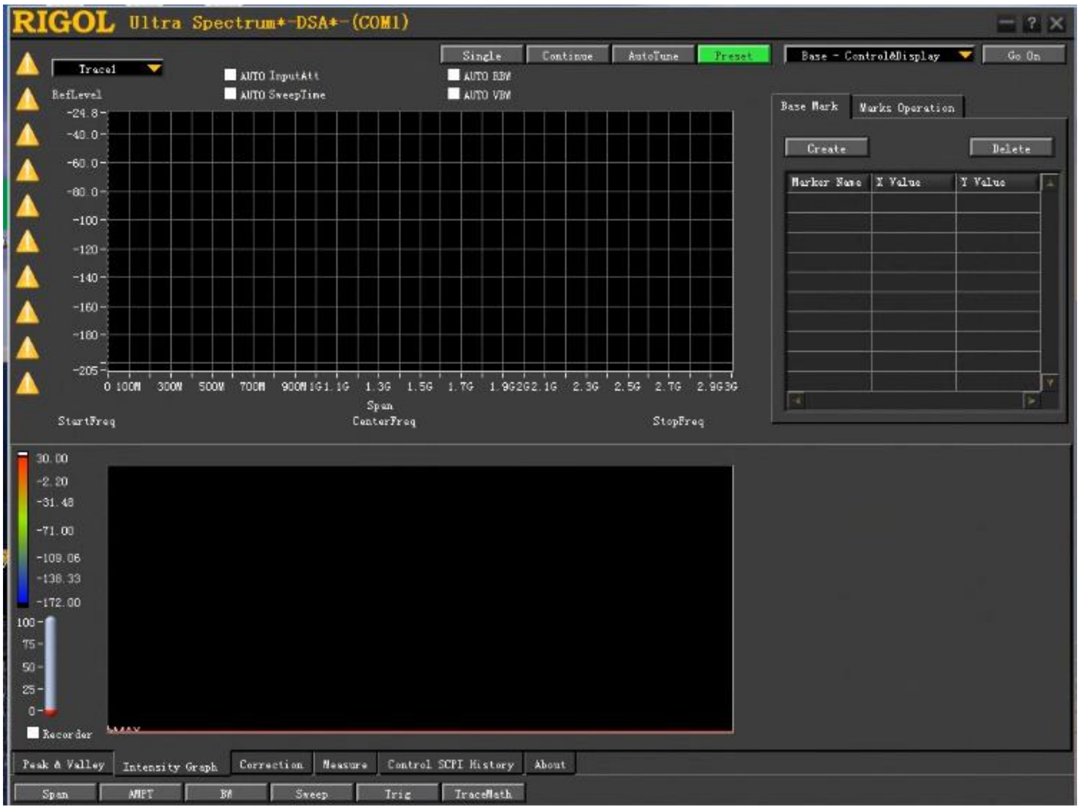


Figure86 The Ultra Spectrum main screen.

Different markers can be created and their values can be displayed in a marker table. Up to 20 different markers can be created. The marker creation window is shown in Figure87 .

Figure87 Markers settings in Ultra Spectrum.

Also, for tracing options, there are seven basic and twelve user defined trace operations shown in Figure88 .

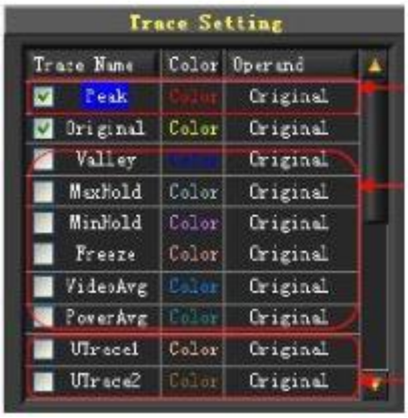


Figure88 Tracing settings in Ultra Spectrum.

3. Ultra Station Software

Ultra Station software is a software designed to control the RIGOL Function/Arbitrary Waveform Generators remotely. It provides an intuitive and powerful waveform editing tools, such as Standard Waveform Library, Math Editing tools, Waveform Formula tools and Waveform Drawing tools, which make the arbitrary waveforms editing easier.

The software starts with the waveform creation wizard is shown in Figure89 .

Figure89 Waveform creation wizard in Ultra Station.

One can easily create standard function from the standard waveform tab as shown in Figure90 .

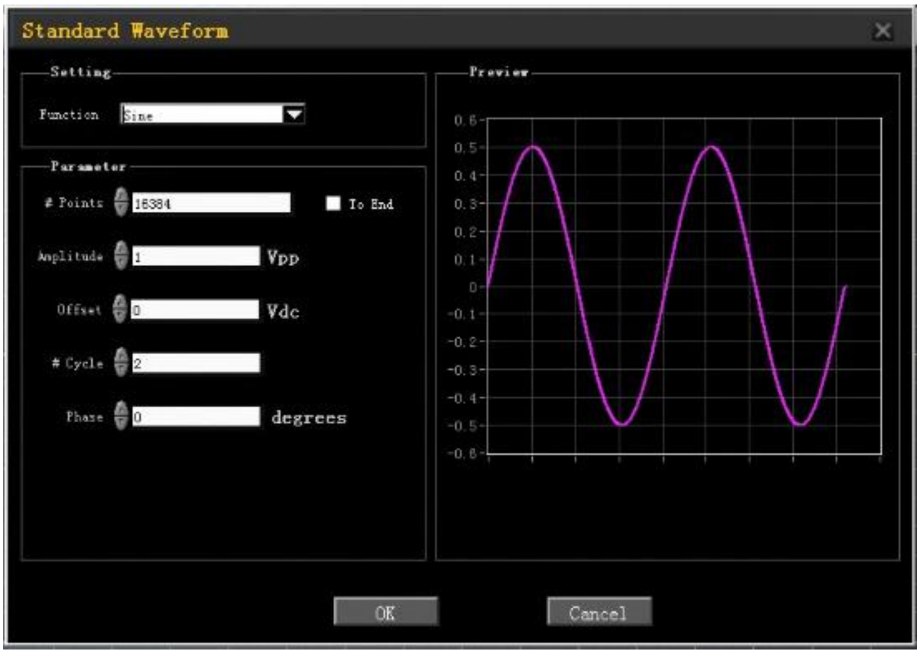


Figure90 The standard waveform tab in Ultra Station.

The created waveform can be shown in the main screen as shown in Figure91 .

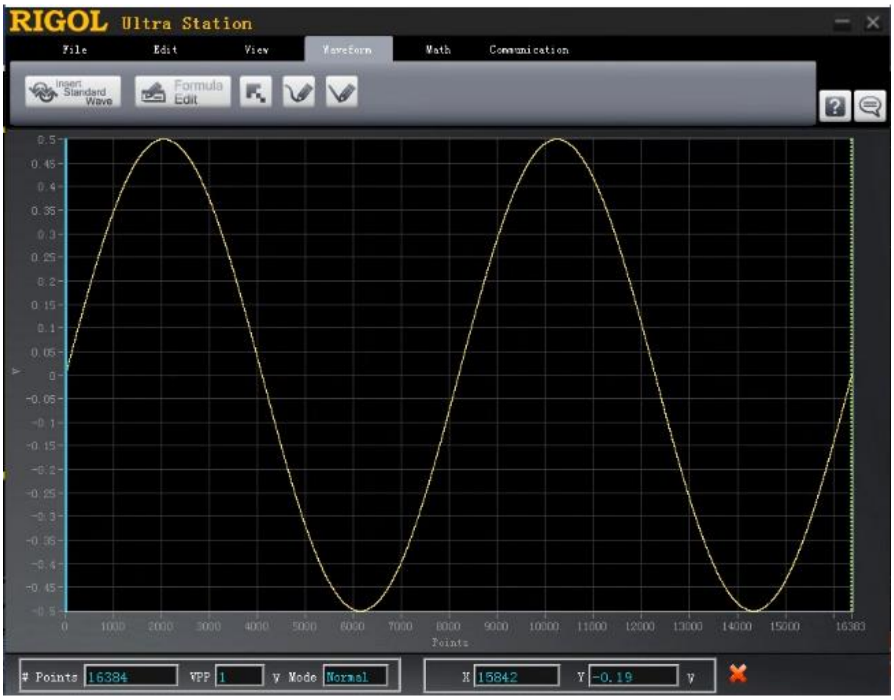


Figure91 The Ultra Station main screen.

The Ultra Station can show the power spectrum and phase spectrum in the editing mode as shown in Figure92 .

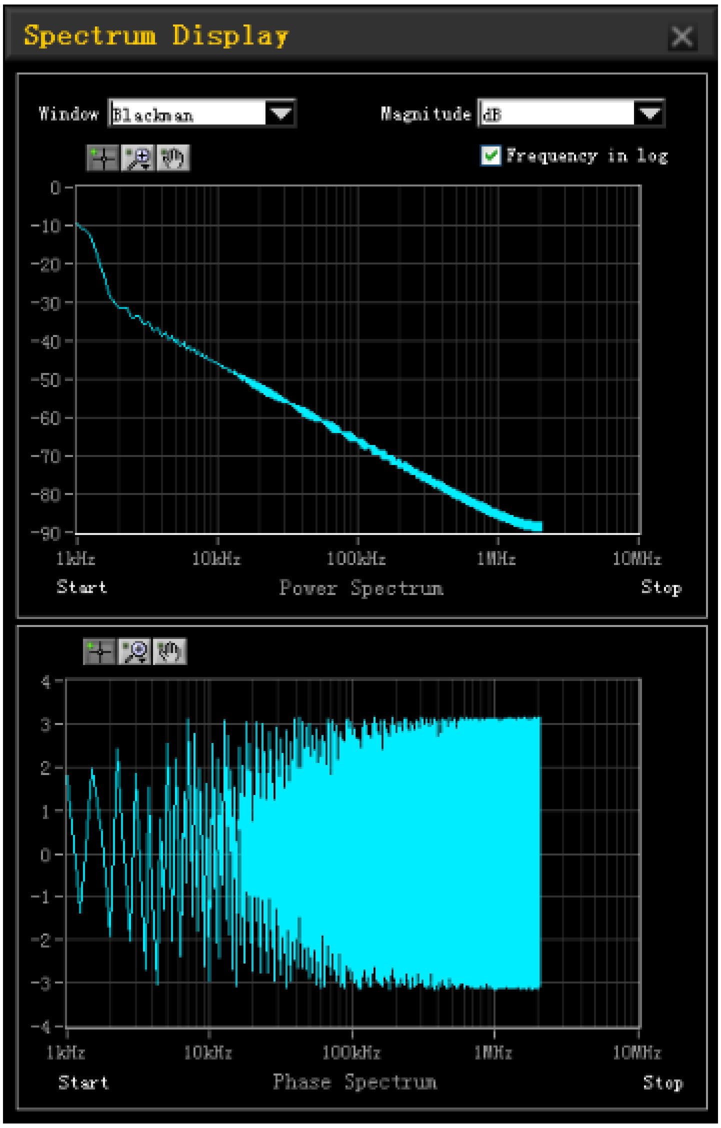


Figure92 The power spectrum and phase spectrum in Ultra Station.

The Math Editing tools can be used in editing the waveform by the Ultra Station as shown in Figure93 .

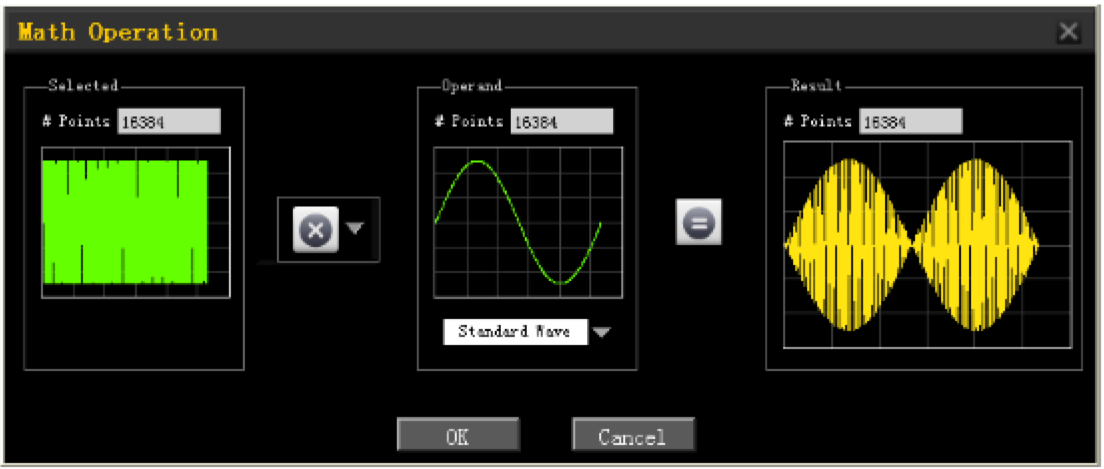


Figure93 Math Editing tools in Ultra Station.

Standard Commands for Programmable Instruments (SCPI) programming

Another way to control the laboratory instruments remotely is using the SCPI commands through the Ultra Sigma software. After identifying the RIGOL instrument under the RIGOL Online Resources directory, right click on the instrument name and choosing the SCPI panel control option from the drop-down menu. The remote-control panel will be opened as shown in Figure 94. At the SCPI Command tab, you can enter the different SCPI commands in order to exchange data and control the RIGOL instrument. The communication log is found on the down side of the remote-control panel.

The SCPI commands comply with the IEEE488.2 common commands, which are used to query the instrument's basic information, and to execute common operations. A programming guide is available for each instrument to help users with the SCPI commands for that specific instrument. The programming guide contains a programming overview, the command system, examples and applications, and some programming demos.

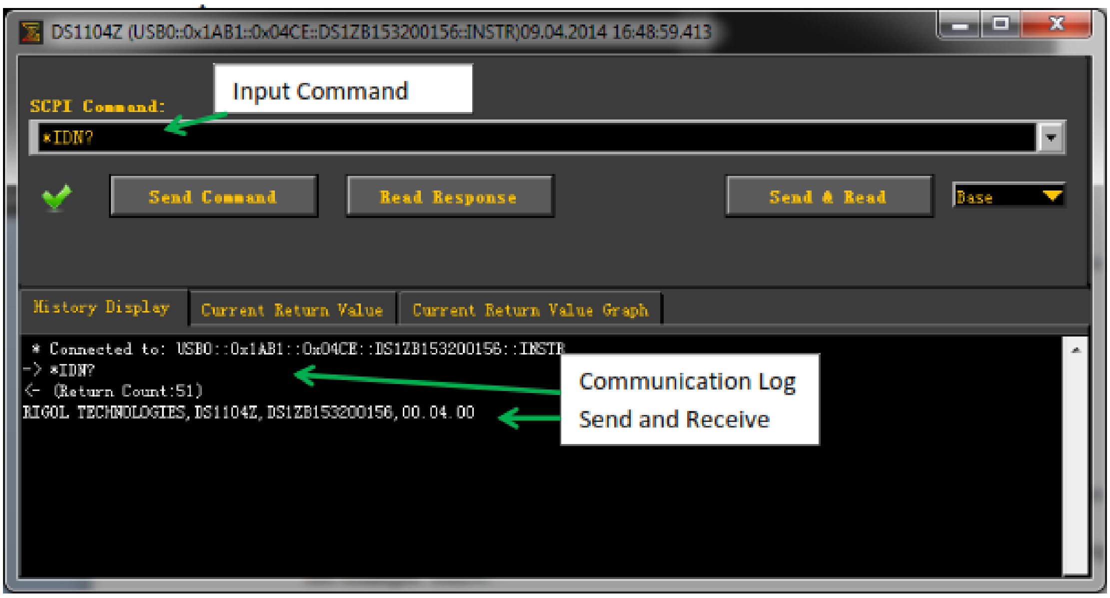


Figure 94 SCPI remote-control panel.

3) Laboratory instruments specifications

3.1 Digital oscilloscope (RIGOL DS1202Z-E)

Sample

Sample Mode	Real-time sample
Real-time Sample Rate	1 GSa/s (single-channel), 500 MSa/s (dual-channel)
Peak Detect	4 ns
Averaging	After all the channels finish N samples at the same time, N can be 2, 4, 8, 16, 32, 64, 128, 256, 512 or 1024
High Resolution	12 bits (max.)
Interpolation	Sin(x)/x
Memory Depth	24 Mpts (single-channel), 12 Mpts (dual- channel)

Input

Number of Channels	2 analog channels
Input Coupling	DC, AC or GND
Input Impedance	(1 MΩ±1%) || (15 pF±3 pF)
	0.01X to 1000X, in 1-2-5 step

Probe Attenuation Coefficient	
Maximum Input Voltage (1 MΩ)	CAT I 300 Vrms, CAT II 100 Vrms, transient overvoltage 1000 Vpk

Horizontal

Timebase Scale	2 ns/div to 50 s/div
Maximum Record Length	24 Mpts
Timebase Accuracy	≤±25 ppm
Clock Drift	≤±5 ppm/year
Maximum Delay Range	Negative delay: ≥1/2 screen width
	Positive delay: 1 s to 500 s
Timebase Mode	YT, XY, Roll
Number of X-Ys	1
Waveform Capture Rate	30,000 wfms/s (dots display)
Zero Offset	±0.5 div*minimum timebase scale

Vertical

Bandwidth (-3 dB)	DS1202Z-E: DC to 200 MHz
	DS1102Z-E: DC to 100 MHz
Single-shot Bandwidth	DS1202Z-E: DC to 200 MHz
	DS1102Z-E: DC to 100 MHz
Vertical Resolution	8 bits
Vertical Scale (Probe ratio is 1X)	500 uV/div to 10 V/div
Offset Range	500 uV/div to 499 mV/div: ±2 V
(Probe ratio is 1X)	500 mV/div to 10 V/div: ±100 V
Bandwidth Limit	20 MHz
Low Frequency Response (AC Coupling, -3 dB)	≤5 Hz (on BNC)

Calculated Rise	DS1202Z-E: 1.75 ns
Time	DS1102Z-E: 3.5 ns
DC Gain Accuracy	<10 mV: ±4% full scale
	≥10 mV: ±3% full scale
DC Offset Accuracy	±0.1 div ± 2 mV ± 1% offset value

Measure

Cursor	Manual mode	Voltage deviation between cursors (△V)
		Time deviation between cursors (△T)
		Reciprocal of △T (Hz) (1/△T)
	Track mode	Voltage and time values of the waveform point
	Auto mode	Allow to display cursors during auto measurement
Auto Measurement	Period, Frequency, Rise Time, Fall Time, Positive Pulse Width, Negative Pulse Width, Positive Duty Cycle, Negative Duty Cycle, tVmax, tVmin, Positive Rate, Negative Rate, Delay 1à2 , Delay 1à2, Phase 1→2, Phase 1→2 _, Maximum, Minimum, Peak-Peak Value, Top Value, Bottom Value, Amplitude, Upper Value, Middle Value, Lower Value, Average, Vrms, Overshoot, Pre-shoot, Area, Period Area, Period Vrms, Variance.	
Number of Measurements	Display 5 measurements at the same time.	
Measurement Range	Screen or cursor	
Measurement Statistic	Average, Max, Min, Standard Deviation, Number of Measurements	

Math Operation

Waveform Operation	A+B, A-B, A×B, A/B, FFT, A&&B, A||B, A^B, !A, Intg, Diff, Sqrt, Lg, Ln, Exp, Abs, Filter
FFT Window	Rectangle, Hanning, Blackman, Hamming, Flat Top, Triangle
FFT Mode	Trace, Memory
FFT Display	Half, Full
FFT Vertical	dB/dBm, Vrms
Filter	Low Pass Filter, High Pass Filter, Band
	Pass Filter, Band Stop Filter

Number of Buses for	2
Decoding Type	Parallel, RS232/UART, I2C, SPI

Display

Screen Type	7.0-inch TFT LCD display
Display Resolution	800 horizontal × RGB × 480 vertical pixel
Display Color	16 million color (24-bit true color)
Persistence Time	Min, 100 ms, 200 ms, 500 ms, 1 s, 5 s, 10 s, Infinite
Display Type	Dots, Vector

3.2 Function/Arbitrary Waveform Generator (RIGOL DG2052)

Model	DG2052
Channel	2
Max. Frequency	50 MHz
Sample Rate	250 MSa/s

Waveform	
Basic Waveforms	Sine, Square, Ramp, Pulse, Noise, DC, Dual-tone
Advanced Waveforms	PRBS, RS232, Sequence
Built-in Arbitrary Waveforms	160 types of waveforms, including Sinc, Exponential Rise, Exponential Fall, ECG, Gauss, HaverSine, Lorentz, etc.

Frequency Characteristics	
Sine	1 μHz to 50 MHz
Square	1 μHz to 15 MHz
Ramp	1 μHz to 1.5 MHz
Pulse	1 μHz to 15 MHz
Harmonic	1 μHz to 20 MHz
PRBS	2 kbps to 40 Mbps
Dual-tone	1 μHz to 20 MHz
RS232	baud rate range: 9600, 14400, 19200, 38400, 57600, 115200, 128000, 230400
Sequence	2 k to 60 MSa/s

Noise (-3 dB)	100 MHz bandwidth
Arbitrary Waveform	1 µHz to 15 MHz
Resolution	1 µHz
Accuracy	± (1 ppm of the setting value + 10 pHz), 18°C to 28°C

Sine Wave Spectrum Purity	
Harmonic Distortion	Typical
	DC to 10 MHz (included): <-55 dBc
	10 MHz to 20 MHz (included): <-50 dBc
	20 MHz to 40 MHz (included): <-40 dBc
	>40 MHz: <-35 dBc
Total Harmonic Distortion	<0.075% (10 Hz to 20 kHz)
Spurious (non-harmonic)	Typical
	≤10 MHz: <-60 dBc
	>10 MHz: <-60 dBc + 6 dB/octave
Phase Noise	Typical (0 dBm, 10 kHz offset) 10 MHz: <-105 dBc/Hz

Burst Characteristics	
Carrier Waveform	Sine, Square, Ramp, Pulse, Noise, Arb, PRBS, RS232, Sequence (except DC, dual-tone, and Harmonic)
Carrier Frequency	2 mHz to 50 MHz
Burst Count	1 to 1,000,000 or Infinite
Internal Period	1 µs to 500 s
Gated Source	External Trigger
Source	Internal, External, Manual
Trigger Delay	0 ns to 100 s

Sweep Characteristics	
Carrier Waveform	Sine, Square, Ramp, Arb
Type	Linear, Log, and Step
Orientation	Up/Down
Start/Stop Frequency	Same as the upper/lower limit of the corresponding carrier frequency
Sweep Time	1 ms to 500 s

Hold/Return Time	0 ms to 500 s
Source	Internal, External, Manual

Frequency Counter	
Measurement Function	Frequency, Period, Positive/Negative Pulse Width, Duty Cycle
Frequency Resolution	7 digits/s (Gate Time = 1 s)
Input Signal Range	Disruptive Discharge Voltage
Input Adjustment	Coupling Mode
	High Frequency Rejection
Input Trigger	Trigger Level Range
	Trigger Sensitivity Range
GateTime	1 ms
	10 ms
	100 ms
	1 s
	10 s
	>10 s

Frequency and Amplitude	
Ranges	1 µHz to 25 MHz
Pulse Width	Min. Pulse Width
	Pulse Width Resolution
Duty	Measurement Range (display)
DC Coupling	DC Offset Range
	1 µHz to 100 MHz
	100 MHz to 240 MHz
AC Coupling	1 µHz to 100 MHz
	100 MHz to 240 MHz

Two-channel Characteristics - Phase Offset	
Range	0° to 360°
Waveform Phase Resolution	0.03°

Synchronous Output	
Level	TTL-compatible
Impedance	50 Ω, nominal value

Programming Time	
Configuration Changes	USB
Function Change	10 ms
Amplitude Change	5 ms
Frequency Change	5 ms

3.3 Spectrum Analyzer (RIGOL RSA3045)

Measurement Mode

Measurement Mode
General-Purpose Spectrum Analyzer (GPSA) Real-Time Spectrum Analyzer (RTSA)
EMI Measurement Application (EMI)

Measurement Mode and Product Model Adaptation Table	
	RSA3045
GPSA	√
RTSA	√
EMI	O
VNA	×
Tracking Generator	×

Note: x indicates not supported; √ indicates standard configuration; O indicates optional configuration.

All Measurement Modes

Frequency			
Frequency Range	9 kHz to 4.5 GHz		
Internal Reference Frequency			
Reference Frequency	10 MHz		
Accuracy	± [(time since last calibration × aging rate) + temperature stability + calibration accuracy]		

Initial Calibration	Standard	<1 ppm
Accuracy	Option OCXO-C08	<0.1 ppm
Temperature Stability	0°C to 50°C, with the reference 25°C	
	Standard	<0.5 ppm
	Option OCXO-C08	<0.005 ppm
Aging Rate	Standard	<1 ppm/year
	Option OCXO-C08	<0.03 ppm/year

GPSA Mode

Frequency

Frequency Readout Accuracy	
Marker Frequency Resolution	span/ (number of sweep points - 1)
Marker Frequency Uncertainty	± (marker frequency readout × reference frequency accuracy + 1% × span + 10% × resolution bandwidth + marker frequency resolution)

Frequency Counter		
Resolution	1 Hz	
Uncertainty	± (marker frequency readout × reference frequency accuracy + counter resolution)	
Frequency Span		
Range	Standard	0 Hz, 100 Hz to maximum frequency
	Option RSA3000	0 Hz, 100 Hz to maximum frequency
Resolution	2 Hz	
Uncertainty	±span/ (number of sweep points - 1) SSB Phase Noise	
SSB Phase Noise		
Carrier Offset	1 kHz	<-90 dBc/Hz (typical)
	10 kHz	<-100 dBc/Hz, <-102 dBc/Hz (typical)
	100 kHz	<-100 dBc/Hz, <-102 dBc/Hz (typical)
	1 MHz	<-110 dBc/Hz, <-112 dBc/Hz (typical)

Residual FM		
Residual FM		20°C to 30°C, RBW = VBW = 1 kHz
		<10 Hz (nominal)
Bandwidth		
		Set "Sweep Time Rule" to "Accy"
Resolution Bandwidth	Standard	1 Hz to 3 MHz, in 1-3-10 sequence
(-3 dB)	Option RSA3000-BW1	1 Hz to 10 MHz, in 1-3-10 sequence
RBW Accuracy		3 kHz to 10 MHz, <5% (nominal)
		10 Hz to 1 kHz, <15% (nominal)
Resolution Filter Shape Factor (60 dB: 3 dB)		<5 (nominal)
Video Bandwidth (-3 dB)		1 Hz to 10 MHz, in 1-3-10 sequence
Resolution Bandwidth (-6 dB) (Option RSA3000-EMC)		200 Hz, 9 kHz, 120 kHz, 1 MHz

Amplitude

Measurement Range	
Range	fc ≥ 10 MHz
	DANL to +30 dBm
Maximum Safe Input Level	
DC Voltage	50 V
CW RF Power	+30 dBm, attenuation ≥ 40 dB, preamp off.
	-10 dBm, attenuation = 20 dB, preamp on.
Maximum Damage Level	
CW RF Power	+33 dBm (2 W)

Displayed Average Noise Level (DANL)		
		attenuation = 0 dB, sample detector, trace averages ≥ 50, tracking generator off, normalized to 1 Hz, 20°C to 30°C, input impedance = 50 Ω.
Preamp off	9 kHz to 100 kHz	<-120 dBm (typical)
	100 kHz to 20 MHz	<-135 dBm, <-140 dBm (typical)
	20 MHz to 2.7 GHz	<-138 dBm, <-141 dBm (typical)
	2.7 GHz to 3.0 GHz	<-136 dBm, <-141 dBm (typical)

	3.0 GHz to 4.5 GHz	<-136 dBm, <-140 dBm (typical)
Preamp on	100 kHz to 20 MHz	<-152 dBm, <-160 dBm (typical)
	20 MHz to 2.7 GHz	<-158 dBm, <-161 dBm (typical)
	2.7 GHz to 3.0 GHz	<-156 dBm, <-161 dBm (typical)
	3.0 GHz to 4.5 GHz	<-154 dBm, <-159 dBm (typical)

Level Display		
Logarithmic Scale		1 dB to 200 dB
Linear Scale		0 to reference level
Number of Display Points		801
Number of Traces		6
Trace Detector		normal, pos-peak, neg-peak, sample, RMS average, voltage average, and quasi-peak (Option RSA3000-EMC)
Trace Function		clear write, max hold, min hold, average, view, blank
Scale Unit		dBm, dBmV, dBμV, nV, μV, mV, V, nW, μW, mW, W
Frequency Response		
		attenuation = 10 dB, relative to 50 MHz, 20°C to 30°C
Preamp off	100 kHz to 3.0 GHz	<0.7 dB, <0.5 dB (typical)
	3.0 GHz to 4.5 GHz	<0.9 dB, <0.5 dB (typical)
		attenuation = 0 dB, relative to 50 MHz, 20°C to 30°C
Preamp on	100 kHz to 3.0 GHz	<1.0 dB, <0.5 dB (typical)
	3.0 GHz to 4.5 GHz	<1.2 dB, <0.5 dB (typical)

Input Attenuation Switching Uncertainty	
Setting Range	0 dB to 50 dB, in 1 dB step
Switching Uncertainty	fc = 50 MHz, relative to 10 dB, preamp off, 20°C to 30°C
	<0.3 dB

RF Input VSWR		
		attenuation ≥ 10 dB, preamp off
VSWR	300 kHz to 3.0 GHz	<1.6 (nominal)
	3.0 GHz to 4.5 GHz	<1.8 (nominal)

Distortion	
Second Harmonic Intercept (SHI)	fc ≥ 50 MHz, input signal level = -20 dBm, attenuation = 0 dB, preamp off.
	+45 dBm
	fc ≥ 50 MHz, two -20 dBm tones at input mixer spaced by 200 kHz, attenuation = 0 dB, preamp off.
Third-order Intercept (TOI)	+10 dBm, +15 dBm (typical)
1 dB Gain Compression (P1dB)	fc ≥ 50 MHz, attenuation = 0 dB, preamp off
	0 dBm (norminal)

Spurious Response	
Residual Response	input terminated with a 50 Ω load, attenuation = 0 dB, 20°C to 30°C
	<-90 dBm, <-100 dBm (typical)
Intermediate Frequency	<-60 dBc
	referenced to local oscillators, referenced to A/D conversion, referenced to subharmonic of first LO, referenced to harmonic of first LO
System-related Sideband	<-60 dBc
Input-related Spurious	mixer level = -30 dBm
	<-60 dBc

Sweep

Sweep		
Sweep Time	span ≥ 10 Hz	1 ms to 4,000 s
	zero span	1 μs to 6,000 s

Sweep Time	span ≥ 10 Hz, RBW ≥ 1 kHz	5% (nominal)
Uncertainty	zero span (sweep time > 1 ms)	5% (nominal)
Sweep Mode		continue, single

Trigger

Trigger		
Trigger Source		free run, external 1, external 2, video
Trigger Delay	span ≥ 10 Hz	0 to 500 ms
	zero span	0 to 500 ms

Tracking Generator

Tracking Generator Output	
Frequency Range	100 kHz to 4.5 GHz
Output Level Range	-40 dBm to 0 dBm
Output Level Resolution	1 dB
Output Flatness	relative to 50 MHz
	±3 dB (nominal)

RTSA Mode

	Span	Min. bandwidth	Max. bandwidth
Resolution Bandwidth	40 MHz	100 kHz	3.21 MHz
	25 MHz	62.8 kHz	2.01 MHz
	10 MHz	25.1 kHz	804 kHz
	1 MHz	2.51 kHz	80.4 kHz
	100 kHz	251 Hz	8.04 kHz
Max. Sample Rate	51.2 Msa/s		
FFT Rate	146,484/s (norminal)		
Number of Markers	8		

Amplitude Resolution	0.01 dB		
Frequency Point	801		
Acquisition Time	Max. sample rate		
	>156.5 µs		

Min. Signal Duration for 100% POI at Different RBWs						
	Duration Time (µs)					
Span	RBW1	RBW2	RBW3	RBW4	RBW5	RBW6
40 GHz	26.9	16.9	11.9	9.32	8.07	7.45
25 MHz	38.9	22.9	14.9	10.9	8.82	7.82
10 MHz	86.8	46.8	26.8	16.8	11.8	9.3
1 MHz	807	407	207	107	56.3	31.3

3.4 RF Signal Generator (Rigol DSG3060)

Frequency

Frequency		
Frequency range	DSG3060	9kHz to 6GHz
Frequency resolution	0.01Hz	
Setting time	<10ms (typ.)	
Phase offset	Adjustable in 0.01° steps (nom.)	

Frequency Band		
Band	Frequency	N
1	f ≤ 23.4375MHz	1
2	23.4375MHz < f ≤46.875MHz	0.03125
3	46.875MHz < f ≤ 93.75MHz	0.0625
4	93.75MHz < f ≤ 187.5MHz	0.125
5	187.5MHz < f ≤ 375MHz	0.25
6	375MHz < f ≤ 750MHz	0.5
7	750MHz < f ≤ 1500MHz	1
8	1500MHz < f ≤ 3000MHz	2
9	3000MHz < f ≤ 6000MHz	4

Internal Reference Frequency	
Reference frequency	10MHz

Temperature stability	In temperature range 0°C to 50°C, reference to 25°C	< 0.5ppm
	With OCXO-A08 option	< 5ppb
Aging rate		< 1ppm/year
	With OCXO-A08 option	< 30ppb/year
Output for internal reference frequency	Frequency	10MHz
	Level	+8dBm (typ.)
	Output impedance	50Ω (nom.)
Input for external reference frequency	Frequency	10MHz
	Level	0dBm to +10dBm
	Maximum deviation	±5ppm
	Input impedance	50Ω (nom.)

Frequency Sweep		
Operating mode	Step sweep (equally or logarithmically spaced frequency steps) List sweep (the list of arbitrary frequency steps)	
Sweep mode	Single, continuous	
Sweep range	Full frequency range	
Sweep shape	Triangle, ramp	
Step change	Linear or logarithmic	
Number of points	Step sweep	2 to 65535
	List sweep	1 to 6001
Dwell time range	20ms to 100s	

Spectral Purity		
Harmonic	CW mode, 1MHz ≤ f ≤ 6GHz, level ≤ +13dBm	<-30dBc
	CW mode	
Sub harmonic	f ≤ 3GHz	<-65dBc, <-80dBc (typ.)
	3GHz < f ≤ 6GHz	<-52dBc, <-70dBc (typ.)
	CW mode, level > -10dBm, carrier offset > 10kHz	
Non-harmonic	f ≤ 1.5GHz	<-64dBc, <-70dBc (typ.)
	1.5GHz < f ≤ 3GHz	<-58dBc, <-64dBc (typ.)
	3GHz < f ≤ 6GHz	<-52dBc, <-58dBc (typ.)
	CW mode, at 20kHz carrier offset, 1Hz measurement bandwidth	
SSB phase noise	f = 100MHz	<-120dBc/Hz
	f = 1GHz	<-108dBc/Hz, <-110dBc/Hz (typ.)

	f = 3GHz	<-102dBc/Hz, <-104dBc/Hz (typ.)
	f = 6GHz	<-96dBc/Hz, <-98dBc/Hz (typ.)
	CW mode, RMS value at f = 1GHz	
Residual FM	0.3kHz to 3kHz	<5Hz rms, <1Hz rms (typ.)
	0.03kHz to 20kHz	<30Hz rms, <8Hz rms (typ.)

Level

Setting Range			
		Specification level range	Setting range
Maximum output level	9kHz ≤ f <100kHz	+7dBm	+10dBm
	100kHz ≤ f <1MHz	+13dBm	+15dBm
	1MHz ≤f ≤3GHz	+13dBm	+25dBm
	3GHz <f ≤6GHz	+13dBm	+20dBm
Minimum output level	9kHz ≤ f <100kHz	-110dBm	-120dBm
	100kHz ≤ f ≤ 6GHz	-130dBm	-140dBm
Setting resolution	0.01dB		

Absolute Level Uncertainty				
Level uncertainty		+13 to -60dBm	-60 to -110dBm	-110 to -130dBm
	9kHz ≤ f <100kHz	≤ 0.5dB (typ.)	≤ 0.7dB (typ.)	
		≤ 0.7dB,	≤0.9dB,	
	100kHz ≤ f ≤3GHz	≤0.5 (typ.)	≤0.5 (typ.)	≤0.7dB (typ.)
		≤ 0.9dB,	≤1.1dB,	
	3GHz < f ≤6GHz	≤0.5 (typ.)	≤0.5 (typ.)	≤0.9dB (typ.)
VSWR	1MHz ≤ f ≤6GHz			

Level Setting		
Setting time	ALC state on, frequency fixed, temperature range: 20°C to 30°C	≤ 5ms (typ.)

Uninterrupted level setting range	ATT fixed mode, ALC state on, level range -110dBm to +13dBm	>20dB (typ.)

Max. Reverse Power		
Max. reverse Power	Max. DC voltage	50V
	1MHz < f ≤ 6GHz	10W

Level Sweep		
Operating mode	Step sweep (equally spaced level steps) List sweep (the list of arbitrary level steps)	
Sweep mode	Single, continuous	
Sweep range	Full level range	
Sweep shape	Triangle, ramp	
Step change	Linear	
Number of points	Step sweep	2 to 65535
	List sweep	1 to 6001
Dwell time range	20ms to 100s	
Triggering	Auto, trigger key, external, bus (GPIB, USB, LAN)	

Internal Modulation Generator (LF)

Internal Modulation Generator (LF)		
Waveform	Sine, square, triangle, ramp, sine sweep	
Frequency range	Sine, sine sweep	0.1Hz to 1MHz
	Square	0.1Hz to 20kHz
	Triangle, ramp	0.1Hz to 100kHz
Resolution	0.01Hz	
Frequency error	Same as RF reference source	
Output voltage	Setting range	1mV to 3V
	Resolution	1mV
Output impedance	50Ω (nom.)	
Sine sweep	Sweep mode	Single, continuous
	Sweep range	Frequency range of LF output
	Sweep time	1ms to 1000s
	Sweep shape	Triangle, ramp

	Triggering	Auto, trigger key, external, bus (GPIB, USB, LAN)

Simultaneous Modulation					
	AM	FM	ØM	Pulse mod.	I/Q mod. (option)
AM	-	o	o	△	×
FM	o	-	×	o	o
ØM	o	×	-	o	o
Pulse mod.	△	o	o	-	o
I/Q mod. (option)	×	o	o	o	-

NOTE: o: compatible; ×: incompatible; △: compatible with AM performance reduced

Amplitude Modulation		
Modulation source	Internal, external, internal + external	
Modulation depth	0% to 100%	
Resolution	0.10%	
Modulation accuracy	fmod = 1kHz	<4% of setting+1%
AM distortion	fmod = 1kHz, m ≤ 30%, level = 0dBm	<3% (typ.)
Modulation frequency response	m ≤ 80%, 10Hz to 50kHz	<3dB (nom.)
Sensitivity when using external input	fmod = 1kHz	1Vpp for indicated depth (nom.)

Input and Output

Front Panel Connector		
RF output	Impedance	50Ω (nom.)
	Connector	N female
External modulation signal input	Impedance	100kΩ (nom.)
	Connector	BNC female
Internal modulation generator. (LF) output	Impedance	50Ω (nom.)
	Connector	BNC female

Rear Panel Connector		
External trigger in	Impedance	1kΩ (nom.)
	Connector	BNC female
	Trigger voltage	5V TTL level
Signal valid output	Connector	BNC female
	Output voltage	0V/3.3V (nom.)
Sweep out	Connector	BNC female
	Output voltage	0 to 10V (nom.)
Pulse input or output	Impedance	50Ω (nom.)
	Input/output voltage	0V/3.3V (nom.)
10MHz in (external frequency reference input)	Impedance	50Ω (nom.)
	Connector	BNC female
10MHz out (external frequency reference output)	Impedance	50Ω (nom.)
	Connector	BNC female
I/Q baseband input/output (option IQ-DSG3000)	Impedance	50Ω (nom.)
	Connector	BNC female

Rear Panel Communication Interface		
USB host	Connector	A plug
	Protocol	Version2.0
USB device	Connector	B plug
	Protocol	Version2.0
LAN	LXI Core 2011 Device	10/100Base, RJ-45
IEC/IEEE bus (GPIB)		IEEE488.2

3.5 NI Elvis III

NI ELVIS III	
Description	Latest NI ELVIS with integrated instrumentation and control I/O
Oscilloscope	4 ch, 400 MS/s,[1] 14 bits
Function Generator	2 ch, 100 MS/s, 15 MHz, 14 bits
Logic Analyzer/Pattern Generator	16 ch, 100 MS/s
IV Analyzer	±10 V, ±30 mA, 15 MHz
Digital Multimeter	4½ digits
Variable Power Supply	±15 V,[2] 500 mA
Processor FPGA	Xilinx Zynq-7020
AI/AO	16 ch, 16 bits/4 ch, 16 bits
DIO	40 ch

SFP Support	Windows, Mac, Web
Programming Language Support	LabVIEW, Python, C, Simulink
Enclosure	metal, NI compass silver

Appendix (16)
Detailed Results of Task 7.3

T7.3: Test the remote access functionality and performance of the experimentation resources.

Designing and implementation of a single hardware/instruments interfacing module using MATLAB.

In order to unify the electronic circuits instruments remote controlled interfaces, and to support experiments that requires multiple instruments we developed a MATLAB application that can be used to control the electronic circuits instruments remotely. The developed application can control the signal waveform generators and the digital oscilloscope remotely. Instead of using the SCPI programming commands to control the different instruments, and to make it easier for the instructors and students to control the instruments remotely, we designed and developed a unified interactive MATLAB application for controlling the RIGOL instruments remotely, by exploiting the VISA library and the SCPI programming commands for each instrument.

Generally, the MATLAB applications typically have a graphical user interface (GUI), where each action in the GUI is mapped to the designed code for it. After developing the application, MATLAB offers a packaging tool in order to package the developed application into a single file, which can be shared and distributed to others. The application packaging tool automatically find and include all the files needed for the developed application. When a user installs the packaged developed application, it will appear in the applications tab in the MATLAB Toolstrip. MATLAB also enables to create a web deployed application, such that users within an organization can run the developed application on their browser, it requires MATLAB Compiler to be installed.

The function/arbitrary waveform generator MATLAB application is shown in Figure95 . The application GUI shows a demo for the basic functionalities used in function/arbitrary waveform generator. For each tab, a call back function is assigned, in order to run a specific code that uses VISA to communicate with the function/arbitrary waveform generator using the SCPI commands. The application is customizable, such that advanced configuration settings may be extended.

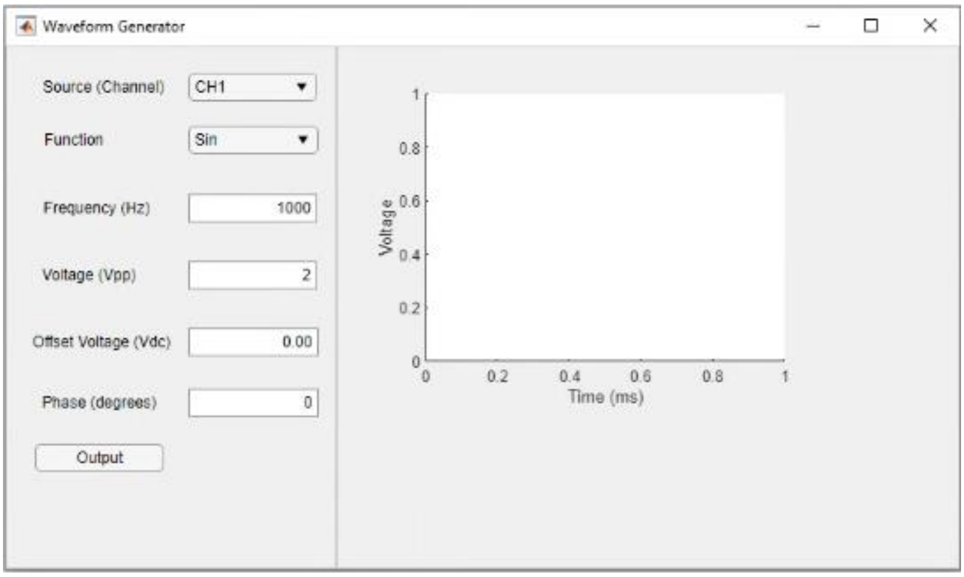


Figure95 MATLAB application for Wavorm Generator interface.

The digital oscilloscope MATLAB application developed is shown in Figure96 . The developed application shows a demo for the basic functionalities of the digital oscilloscope. The shown tabs in the developed MATLAB application are associated with call back functions, where each call back function runs a specific code that exploits VISA to communicate with the RIGOL digital oscilloscope instrument via SCPI commands. The developed application is customizable, where the application may be upgraded to add advanced functionalities.

Figure96 MATLAB application for Oscilloscope interface.

Appendix (17)
Detailed Results of Tasks 8.1, 8.2, and 8.3

T8.1: Preparation of the laboratory learning contents and learning scenarios for Electronics and Telecommunication experiments.

T8.2: Preparation of the laboratory learning tools for Electronics and Telecommunication experiments.

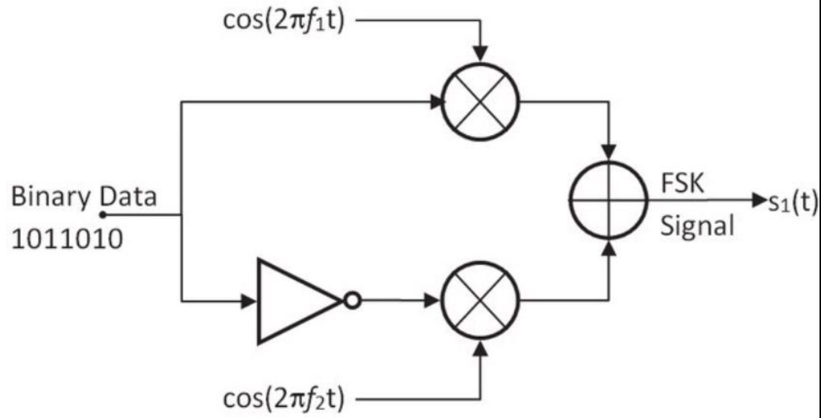
T8.3: Preparation of the laboratory evaluation and assessment contents for Electronics and Telecommunication experiments.

1) Creation for a LLO for Experiment #1

Add Title " **Binary Frequency shift keying (BFSK) Modulation using MatLab** "

Action	Content	Settings
Add Section	**Objective**	
Add Text Box	understand and implement Binary Frequency shift keying modulation (BFSK) technique using **Matlab**	
Add Section	**Introduction**	
Add Text Box	Frequency shift keying (FSK) is a modulation Data transmitting technique in which carrier frequency is shifted between two distinct fixed frequencies to represent logic 1 and logic 0. The low carrier frequency represents a digital 0 and higher carrier frequency is a 1.	
Add Equation	$S_1(t)=\sqrt{\frac{2Eb}{Tb}}\cos(2\pi f1t+\varphi)\ ,\quad 0<t<Tb$ for logic 1 $S_2(t)=\sqrt{\frac{2Eb}{Tb}}\cos(2\pi f2t+\varphi)\ ,\quad 0<t<Tb$ for logic 0	
Add Section	**Experiment Given**	
Add Text Box	φ: initial phase at t=0 E_b: transmitted energy/bit **<u>Add symbol</u>** T_b: time interval $f_i=(nc+i)/T_b$ where i=1, 2	

<table>
<tr><td>Add Image</td><td>



</td><td></td></tr>
<tr><td>Add Image Caption</td><td>BFSK Modulation Block diagram</td><td></td></tr>
<tr><td colspan="2">Add Page</td><td>Change Page Theme</td></tr>
<tr><td>Add VRL</td><td>Select Matlab from VRL tool list</td><td></td></tr>
<tr><td>Add Text Box</td><td>Click Start to open Matlab</td><td>Add Time</td></tr>
<tr><td>Add Section</td><td>Generation of FSK modulation Matlab Procedures</td><td></td></tr>
<tr><td>Add Text Box</td><td>

4- Open new m.file and name it FSK_modulation

5- Generate two-carrier signals using below code, Tb=1, fc1,fc2 any integer value (2,3,4,…)

```
Tb=1;  fc1=3;fc2=6;
t=0:(Tb/100):Tb;
c1=sqrt(2/Tb)*sin(2*pi*fc1*t);
c2=sqrt(2/Tb)*sin(2*pi*fc2*t);
```

6- Generate the message signal with random 8 binary bits, N=8. Then, generate the inverted message signal

```
N=8;
m=rand(1,N);
t1=0;
t2=Tb;
For i=1:N
    t=t1:(Tb/100):t2;
 if m(i)>0.5
    m(i)=1;
    m_s=ones(1,length(t));
     invm_s=zeros(1,length(t));
 else
 m(i)=0;
```

</td><td>Add VA</td></tr>
</table>

```
  m_s=zeros(1,length(t));
  invm_s=ones(1,length(t));
end
message(i,:)=m_s;
```

7- Create the first FSK1 signal multiply the fc1 with generated message, to create the second FSK2 signal multiply the fC2 with inverted message signal using the below code

```
fsk_sig1(i,:)=c1.*m_s;
fsk_sig2(i,:)=c2.*invm_s;
```

8- Perform addition for FSK modulation signal

```
fsk=fsk_sig1+fsk_sig2;
```

9- Plot the FSK modulated signal and message signal using below code

```
Image (1)
axis([0 N -2 2]);
plot(t,message(i,:),'r');
title('messagesignal');
xlabel('t---->');
ylabel('m(t)');
grid on;
hold on;
Image (5)
plot(t,fsk(i,:));
title('FSK signal');
xlabel('t---->');
ylabel('s(t)');
grid on;
hold on;
t1=t1+(Tb+.01);
t2=t2+(Tb+.01);
end
hold off
```

10- Plot the input binary data and carrier signals

```
Image (2)
stem(m);
title('binary data');
xlabel('n---->');
```

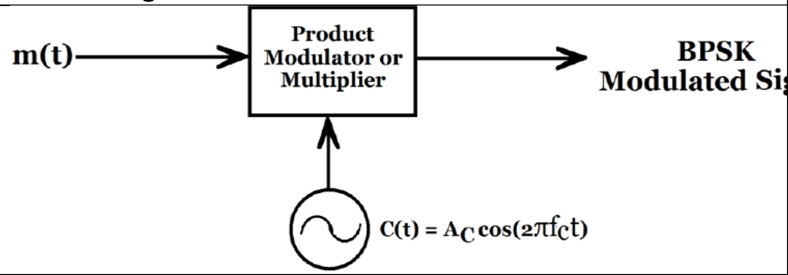
	ylabel('b(n)');
	grid on;
	Image (3)
	plot(t,c1);
	title('carrier signal-1');
	xlabel('t---->');
	ylabel('c1(t)');
	grid on;
	Image (4)
	plot(t,c2);
	title('carrier signal-2');
	xlabel('t---->');
	ylabel('c2(t)');
	grid on;	

Add Page		Change Page Theme
Add Section	**Results**	
Add Text Box	Run Matlab File , Snapshot your results using “Take A snapshot” from VRL	
Add “Take a Snapshot from VRL”	Allow Student to “Take snapshot from VRL” from running VRL	Add Grade
Add Text Box	Upload your m.file using “Submit File from VRL”	
Add Submit file from VRL	Allow Student to submit m.file from running VRL	Add Grade
Add Page		Change Page Theme
Add Section	**Questions**	
Add Open Question	A. Define the Main function of BFSK Modulation	Add Grade
Add Open	B. Write the expression for bit error rate for coherent binary FSK	Add Grade

Question		

2) Creation for a LLO for Experiment #2

Add Title " **Binary Amplitude Shift Key Modulation Techniques (BPSK) using Matlab** "

Action	Content	Settings
Add Section	**Objective**	
Add Text Box	The main objective of the experiment is to understand the principles of Binary Phase Shift Keying (BPSK) digital modulation and demodulation scheme, its performance through simulation of BPSK modulation.	
Add Section	**Introduction**	
Add Text Box	The general analytic expression for PSK can be represented using the below equation	
Add Equation	$$S_i(t) = \sqrt{\frac{2E}{T_b}}\ \cos(2\pi f_c + \theta_i)$$	
Add Text Box	Where, $\mathbf{0<t<Tb}$, $\boldsymbol{i}$=,............$\boldsymbol{M}$. Note that $\boldsymbol{fc}$ is the carrier frequency, $\boldsymbol{Tb}$ is the symbol duration. $\boldsymbol{E}$ is the symbol energy and has M discrete value,	
Add Equation	$$\theta_i = \frac{2\pi i}{M}$$	
Add Text Box	In case of Binary Phase Shift Key modulation, binary '1' is represented by actual carrier and binary '0' is represented by the $\mathbf{180^o}$ phase shifted carrier signal. The block diagram of BPSK transmitter can be represented as shown in the Image below	
Add Image		
Add Image Caption	BPSK Modulation Block diagram	

<table>
<tr><th colspan="3">Add Page</th></tr>
<tr><td>Add VRL</td><td>Select Matlab from VRL tool list</td><td></td></tr>
<tr><td>Add Text Box</td><td>Click Start to open Matlab</td><td>Add Time
<u>Add Progress bar</u></td></tr>
<tr><td>Add Section</td><td>Generation of BPSK modulation Matlab Procedures</td><td></td></tr>
<tr><td>Add Text Box</td><td>5- Create new m file with name BPSK_MOD<pre>
format long;
% Clear all variables and close all
Images
clear all;
close all;
% The number of bits to send - Frame
Length
N = 8;
% Generate a random bit stream
bit_stream = round(rand(1,N));
% Enter the two Phase shifts - in
Radians
% Phase for 0 bit
P1 = 0;
% Phase for 1 bit
P2 = pi;
% Frequency of Modulating Signal
f = 3;
% Sampling rate - This will define
the resoultion
fs = 100;
% Time for one bit
t = 0: 1/fs : 1;
% This time variable is just for plot
time = [];
PSK_signal = [];
Digital_signal = [];
for ii = 1: 1: length(bit_stream)

    % The FSK Signal
    PSK_signal = [PSK_signal
(bit_stream(ii)==0)*sin(2*pi*f*t +
P1)+...

(bit_stream(ii)==1)*sin(2*pi*f*t +
P2)];

    % The Original Digital Signal
</pre></td><td>Add VA</td></tr>
</table>

<table>
<tr><td></td><td><pre>   Digital_signal = [Digital_signal
(bit_stream(ii)==0)*...
        zeros(1,length(t)) +
(bit_stream(ii)==1)*ones(1,length(t))
];

    time = [time t];
    t = t + 1;

end
% Plot the PSK Signal
subplot(2,1,1);
plot(time,PSK_signal,'LineWidth',2);
xlabel('Time (bit period)');
ylabel('Amplitude');
title('PSK Signal with two Phase
Shifts');
axis([0 time(end) -1.5 1.5]);
grid on;
% Plot the Original Digital Signal
subplot(2,1,2);
plot(time,Digital_signal,'r','LineWid
th',2);
xlabel('Time (bit period)');
ylabel('Amplitude');
title('Original Digital Signal');
axis([0 time(end) -0.5 1.5]);
grid on;</pre></td><td></td></tr>
<tr><td colspan="3">Add Page</td></tr>
<tr><td>Add Section</td><td>Results</td><td></td></tr>
<tr><td>Add Text Box</td><td>Run Matlab File , Snapshot your results using “Take A snapshot” from VRL</td><td></td></tr>
<tr><td>Add “Take Snapshot from VRL”</td><td>Allow student to take snapshot from Running VRL</td><td>Add Grade</td></tr>
<tr><td>Add Text Box</td><td>Upload m.file using “Submit file from VRL”</td><td>Add Grade</td></tr>
<tr><td>Add “ Submit file from VRL”</td><td>Allow student to submit a file from running VRL</td><td></td></tr>
<tr><td colspan="3">Add page</td></tr>
<tr><td>Add Section</td><td>Questions</td><td></td></tr>
<tr><td>Add Multiple Choice Question</td><td>The distance between the constellation point of 16QAM is …… the value of 16PSK
a) 1.6</td><td>Add Grade
Add Help</td></tr>
</table>

	b) 110 c) 1.20 d) 3	

3) <u>Creation for a LLO for Experiment #3</u>

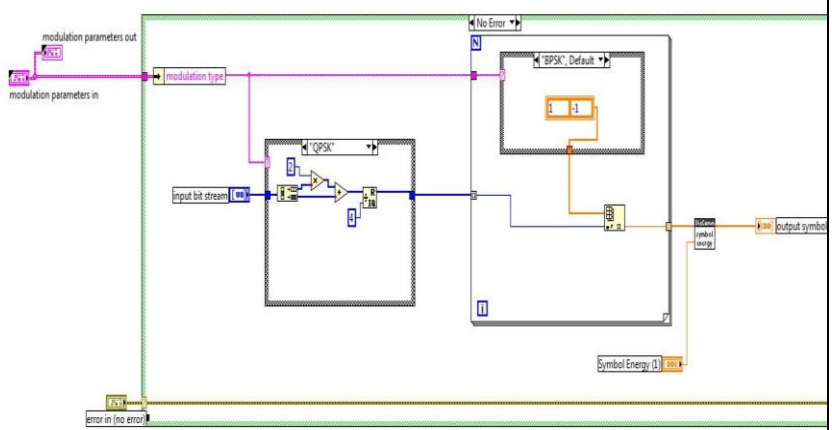
Add Title “ **Phase shift keying (BPSK) Modulation using LabView** “

Action	Content	Settings
Add Section	**Objective**	
Add Text Box Box	In this Lab, a LabVIEW virtual instrument is developed as a baseband digital transmitter that can use either Binary Phase Shift Keying (BPSK) or Quadrature Phase Shift Keying (QPSK) modulation to transmit a modulated carrier cos(2πfc t)at frequency fc (e.g., 2.47 GHz) using USRP N210 as the transmitting hardware	
Add Section	**Functions and VI (Virtual Instrument) used using LabView in VLR window**	
Add Text Box Box	• Case Structure (Function) • Decimate 1D Array (Function) • Multiply (Function), Add (Function) • Quotient & Remainder (Function) • Numeric Constant (Function) • For Loop (Function) • Index Array (Function) • Symbol energy (VI) • Subtract (Function) • Complex To Polar (Function) • Max &Min (Function) • Array Constant (Function) • DBL Numeric Constant (Function) • and Interleave 1D Arrays	
	Add Page	
Add Section	**Setup Phase Procedures**	Add Progress Bar
Add VRL	Select LabView from VRL tool list	
Add Text Box	Click Start to open LabView	Add Time

Add Text Box	Open " student_modulation.vit" found in the below path "this will open a basic graphic user interface (GUI) "	
Add Insert File into VRL	Select File > upload > Local Disk/ Public URL >	
Add Section	**Modulation Phase** 4. Open Block diagram (Window> show block diagram 5. Enable Function Palette (View > Function Palette) 6. Insert Case structure box (Functions Palette > Programming> structures> select and drag case structure) Move "Modulation type" , " input bit stream", " output symbols" and symbol energy inside Case structure	
Add Text Box	• Place a Case Structure box (Functions Palette > Programming > Structures > select and drag Case Structure) inside the previous Case Structure box. This Case Structure is used as the foundation of modulation selection and converts the input bit stream into decimal numbers by using the algorithm defined under each modulation case. • Click on the arrow on Case Structure box and select "false". Double click on the Text Box and change it to "QPSK". This case is used to insert the algorithm for QPSK modulation. • Repeat the same step to change "true" to "BPSK". This case is used to insert the algorithm for BPSK modulation. • When BPSK is selected, right click on the name and select "Make This the Default Case". After this step, case label reads - "BPSK", Default -. This step makes BPSK our default modulation scheme	
Add Page		
Add Section	**BPSK mapping to levels**	
Add Text Box	Select BPSK • Place a Quotient & Remainder function and connect the input bit stream to its x input. • Create a Numeric Constant and connect it to the y input of Quotient & Remainder. Set the constant value to 2	
Add Section	**QPSK mapping to levels**	

Add Text Box	Select QPSK: • Place a Decimate 1D Array inside the Case Structure box (Functions Palette > Programming > Array > Decimate 1D Array). This function divides the elements of the input bit stream into two output arrays (even array elements (0, 2, 4,…) in one output and odd array elements (1, 3, 5,…) in another output). • Connect the input bit stream to array input of Decimate 1D Array. • Place a Multiply function inside the Case Structure box (Functions Palette > Programming > Numeric > Multiply). • Create a Numeric Constant (Functions Palette > Programming > Numeric > Numeric Constant) and connect it to the x input of the multiplier. Set the constant value to 2. • Connect the y input of multiplier to the "elements 0, n, 2n,…" output of Decimate 1D Array. • Place an Add function (Functions Palette > Programming > Numeric > Add). • Connect the x input of Adder to x*y output of multiplier. • Connect the y input of Adder to the "elements 1, n+1, 2n+1,…" output of Decimate 1D Array. • Place a Quotient & Remainder function and connect its x input to the output of Multiply (Functions Palette > Programming > Numeric > Quotient & Remainder). • Connect the x input of Quotient & Remainder to x+y output of Adder. • Create a Numeric Constant and connect it to the y input of Quotient & Remainder. Set the constant value to 4. • The process accomplished with above steps is explained in section I. Overview, under "The mapping procedure for QPSK".	
Add page		
Add Section	**Sequences and modulation setup**	
Add Text Box	• Create a For Loop inside the bigger Case Structure but outside the modulation Case Structure (Functions Palette > Structure > For Loop). • Place a Case Structure inside this For Loop. This allows virtual instrument to map all elements of the input bit stream into an analog signal level.	

	• Connect “modulation type” output to “case selector” node on Case Structure box as we did for the previous Case Structure box. This step ensures that both Case Structures operate on the same modulation setting once the type is selected by the operator on simulation/hardware control front panel. • Click on the arrow on Case Structure box and select “false”. Double click on the Text Box and change it to “QPSK”. • Repeat the same step to change “true” to “BPSK” and make this the default case as you did earlier for the first Case Structure.	
Add Section	**Mapping to BPSK constellation**	
Add Text Box	Select BPSK • Place an Index Array inside the For Loop but outside the Case Structure box (Functions Palette > Programming > Array > Index Array). • Right click of the “array” input of this Index Array and create a constant (Right click menu > Create > Constant), then move this constant inside the Case Structure box. • Right click on this constant and deselect “index display” (Right click menu > Visible items > Index display). • Make this constant display two bits by simply (carefully) extending from its sides. Replace the 0|0 with 1|-1 and connect it to the “array” input of Index Array. • Change the first Case Structure box to “BPSK, Default” and connect the “R” output of Quotient & Remainder to the “index” input of the Index Array in the For Loop. • Select the two bits (1|-1) you placed under BPSK, copy them go to QPSK case of the second Case Structure, and paste the copied constant there.	
Add Page		
Add Section	**Mapping to QPSK constellation**	
Add Text Box	Select QPSK : • Right click on the constant and change its representation to CDB (Right click menu > Representation > CDB). This displays the constant value as complex double. • Make it four bits by stretching from sides and change the values as follows (with the same order from left to right): 1+1i | 1-1i |-1+1i | -1-1i	

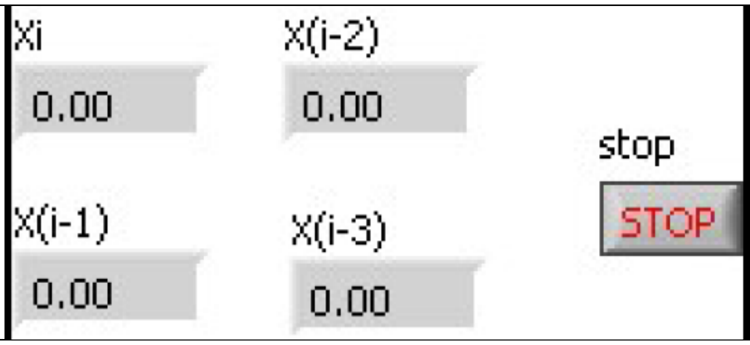
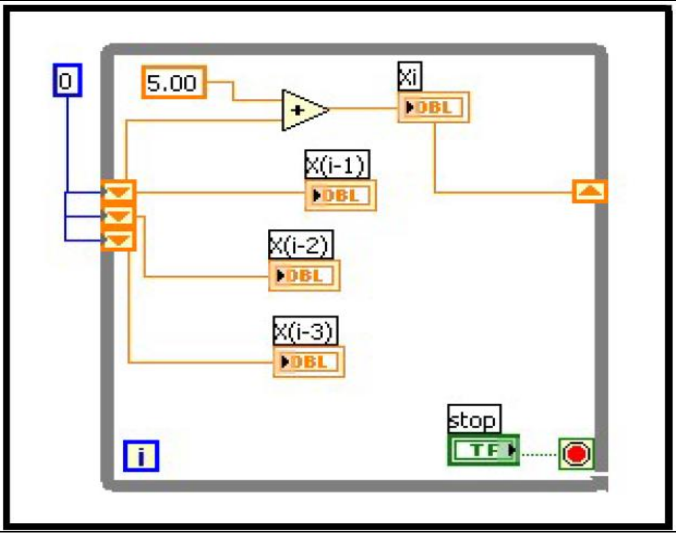
	• Connect this constant to “array” input of the Index Array. • Change both Case Structures to “QPSK” and connect the “R” output of Quotient & Remainder to the “index” input of the Index Array in the For Loop. • Place the “symbol_energy.vi” outside the For Loop (Function Palette > Select a VI) • Connect “element” output of the Index Array to “input symbols” input of symbol_energy.vi. • Connect the output of Symbol Energy (1) element to “symbol energy (1)” input of the “symbol_energy.vi”	
Add Section	**Necessary Connections**	
Add Text Box	• Connect the error in (no error) element to “case selector” of the big Case Structure box (“True” changes into “No error” and box color becomes light green). Connect this case selector to the error out element. • Change the case to “Error” and connect the error in (no error) element to the error out element through the Case Structure box.	
Add Image		
Add Image Caption	OUTPUT Block Diagram	
Add Text Box	Your Final Block Diagram should be as above image	
Add Text Box	Snapshot your final block diagram using “take snaphot fromVRL”	

Add "Take snapshot from VRL"	Allow student to take snapshot from running VRL	Add grade
Add Text Box	Save Your LabView File .vi using "Take File from VRL"	
Add "Submit file from VRL"	Allow student to submit file from running VRL	Add Grade

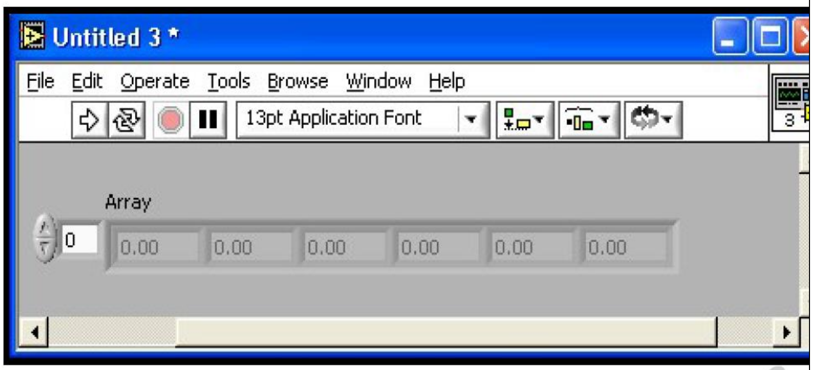
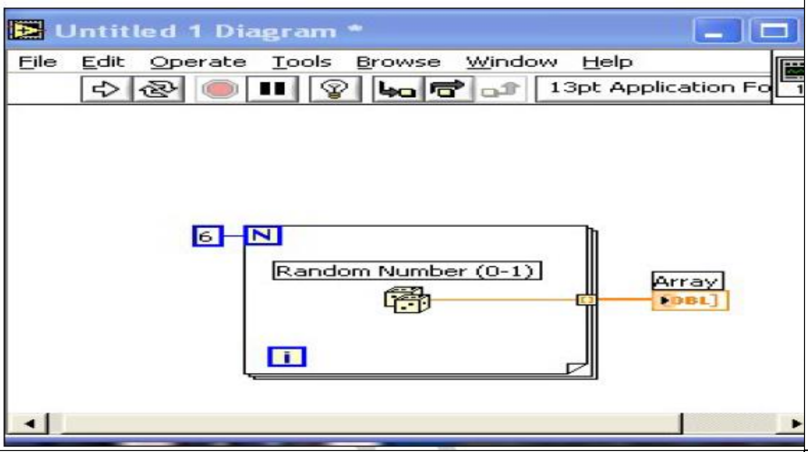
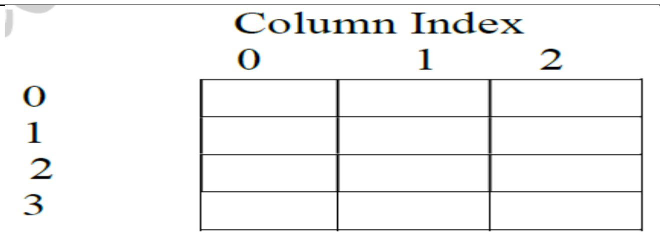
4) Creation for a LLO for Experiment #4

Add Title "**Shift Registers and Arrays Using LabView**"

Action	Content	Settings
Add Section	**Data Shift Register**	
Add Text Box Box	You can use shift register to remember values from previous iterations. This technique is useful for averaging data points To make a shift register to carry more than one value to the next iteration, right click the left terminal and select add element from the shortcut menu. To initialize a shift register, wire any value from outside the loop to the left terminal. If you don't initialize the register, the loop uses the value written to the register when the loop last Executed or the default value for the data type if the loop has never executed. For example, if the shift register data type is Boolean, the initial value is false. Similarly, if the shift register data type is numeric, the initial value is 0	
Add Section	**Shift Register VI**	
Add VRL	Select LabView from VRL tool list	
Add Text Box	Click Start to open LabView	**Add Time**

		[Add Progress Bar]()
Add Text Box	Build the Below Front Panel	
Add Image		
Add Image Caption	Shift register front panel values	
Add Text Box	Open the below Block diagram found in below path ….	
Add “Insert File into XFM”	Select File> Upload > local disk/ Publick URL	
Add Image		
Add Image Caption	Shift Register Block Diagram	
Add Text Box	• The Xi indicator displays the current value), which shifts to the left terminal at the beginning of the next iteration. The X (i-1) indicator displays the value one	

	iteration ago, the X (i-2) indicator displays the value two iterations ago, and so on. • The 0 wired to the left terminal initializes the elements of the shift register to 0. • Click the highlight Execution button to enable execution step by step. • In each iteration of the while loop, the VI transfers the previous values through the left terminals of the shift register. • Each iteration of the loop adds 5 to the current data, Xi .this value shifts to the left terminal, X (i-1), at the beginning of the next iteration. • The values at the left terminal tunnel downward through the terminals. This VI retains the last three values. • The output of the first iteration is: Xi=5,X(i-1) =0 ,X(i-2) =0 ,X(i-3) =0.The second iteration is: Xi=10,X(i-1) =5 ,X(i-2) =0 ,X(i-3) =0 , etc.	
Add Page		
Add Section	**Arrays**	
Add Text Box	Arrays group data elements of the same type. An array consists of elements and dimensions. Elements are the data that make up the array; a dimension is the length, height or depth of an array. An array can have one or more dimensions. An array uses an index so you can readily access any particular element. The index is zero based, which means it is in the range 0 to n-1.where n is the number of elements in the array.	
Add Text Box	Open New file	
Add Section	**Creating 1D Array of random number**	
Add Text Box	Front panel: Select an array on the controls >> **arrays and cluster** palette, place it on the front panel and drag a control or indicator into array shell	

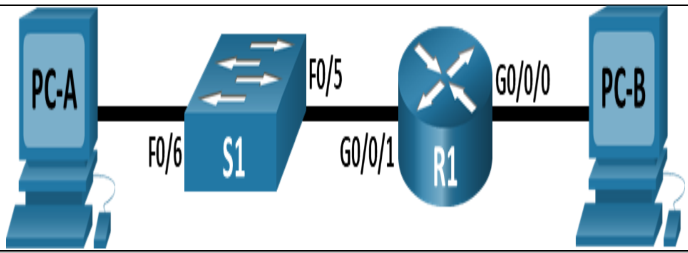
Add Image		
Add Image Caption	Array Front Panel	
Add Text Box	Build the below Array Block Diagram	
Add Image		
Add Image Caption	Array Block Diagram	
	Add Page	
Add Text Box	2D array stores elements in a grid, it requires a column index and a row index to locate an element, both of which are zero based.	
Add Image		
Add Section	**Creating 2D arrays of random numbers**	

Add Text Box	You can use two for loops, one inside the other to create a 2D array. The outer loop creates the row elements and the inner loop creates the column elements.	
Add Text Box	Snapshot your final block diagram using “take snaphot fromVRL”	
Add “Take snapshot fromVRL”	Allow student to take snapshot from running VRL	Add grade
Add Text Box	Save Your LabView File .vi using “Take File from VRL”	
Add “Submit file from VRL”	Allow student to submit file from running VRL	Add Grade
	Add Page	
Add Section	**Array Function Question**	
Add Text Box	Build a VI that first accumulates an array of temperature values using the digital thermometer VI. Incorporate these items: • Set the array size with a control on the front panel. • Initialize an array using the initialize array function of the same size where all values are equal to 10. • Add the two arrays, calculate the size of the final array and extract the middle value from the final array. • Display the temperature array, initialized array, final array and mid value.	
Add Text Box	Submit Array function File usinf “Submit file from VRL”	
Add “Submit file from VRL”	**Allow student to Submit Array function Vi file from VRL**	Add Grade

5) Creation for a LLO for Experiment #5

“Lab - IPv6 Addresses on Network Devices Packet Tracer “

Action	Content	Settings

<table>
<tr><td>Add Title</td><td>IPv6 Addresses on Network Devices Packet Tracer</td><td></td></tr>
<tr><td>Add Section</td><td>Objective</td><td></td></tr>
<tr><td>Add Text Box</td><td>IPv6 Addresses on Network Devices Packet Tracer
Part 1: Set Up Topology and Basic Router and Switch Settings
Part 2: Configure IPv6 Addresses Manually
Part 3: Verify End-to-End Connectivity</td><td></td></tr>
<tr><td>Add Section</td><td>Introduction</td><td></td></tr>
<tr><td>Add Text Box</td><td>In this lab, you will Configure hosts and device interfaces with IPv6 addresses. You will issue show commands to view IPv6 unicast addresses. You will also verify end-to-end connectivity using ping and traceroute commands.</td><td></td></tr>
<tr><td>Add Table</td><td>
<table>
<tr><th>Device</th><th>Interface</th><th>IPv6 Address</th><th>Prefix Length</th><th>Default Gateway</th></tr>
<tr><td>R1</td><td>G0/0/0</td><td>2001:db8:acad:a::1</td><td>64</td><td>N/A</td></tr>
<tr><td></td><td>G0/0/1</td><td>2001:db8:acad:1::1</td><td>64</td><td>N/A</td></tr>
<tr><td>S1</td><td>VLAN 1</td><td>2001:db8:acad:1::b</td><td>64</td><td>N/A</td></tr>
<tr><td>PC-A</td><td>NIC</td><td>2001:db8:acad:1::3</td><td>64</td><td>fe80::1</td></tr>
<tr><td>PC-B</td><td>NIC</td><td>2001:db8:acad:a::3</td><td>64</td><td>fe80::1</td></tr>
</table>
</td><td></td></tr>
<tr><td>Add Section</td><td>Required Resources</td><td></td></tr>
<tr><td>Add Text Box</td><td>Open IPV6 network devices network topology found in below path, this will open a network topology as Image below</td><td></td></tr>
<tr><td>Add “Insert file into XFM”</td><td>Select file> upload>local disk/ publick URL</td><td></td></tr>
<tr><td>Add Image</td><td>
</td><td></td></tr>
<tr><td colspan="3">Add Page</td></tr>
<tr><td>Add VRL</td><td>Select Packet Tracer from VRL tool list</td><td></td></tr>
<tr><td>Add Text Box</td><td>Click Start to open Packet Tracer</td><td>Add Time</td></tr>
</table>

Add Section	**Configure IPv6 Addresses on Network Devices**	

Add Text Box	**CABLE THE NETWORK AND CONFIGURE BASIC ROUTER AND SWITCH SETTINGS** After cabling the network, initializing and reloading the router and switch, complete the following: **Step 1: CONFIGURE THE ROUTER.** Assign the hostname and Configure basic device settings. **Step 2: CONFIGURE THE SWITCH.** Assign the hostname and Configure basic device settings. **CONFIGURE IPV6 ADDRESSES MANUALLY** **Step 3: ASSIGN THE IPV6 ADDRESSES TO ETHERNET INTERFACES ON R1.** a. Assign the IPv6 global unicast addresses, listed in the Addressing Table, to both Ethernet interfaces on R1. **R1(config)# interface g0/0/0** **R1(config-if)# ipv6 address 2001:db8:acad:a::1/64** **R1(config-if)# no shutdown** **R1(config-if)# interface g0/0/1** **R1(config-if)# ipv6 address 2001:db8:acad:1::1/64** **R1(config-if)# no shutdown** **R1(config-if)# end** b. Verify that the correct IPv6 unicast address is assigned to each interface. **R1# show ipv6 interface brief** **Em0/0 [administratively down/down]** **unassigned** **GigabitEthernet0/0/0 [up/up]** **FE80::D68C:B5FF:FECE:A0C0** **2001:DB8:ACAD:A::1** **GigabitEthernet0/0/1 [up/up]** **FE80::D68C:B5FF:FECE:A0C1** **2001:DB8:ACAD:1::1** **<output omitted>** **Note**: The link-local address (fe80::) displayed is based on EUI-64 addressing, which automatically uses the interface Media Access Control (MAC) address to create a 128-bit IPv6 link-local address.	

Add Page

c. To get the link-local address to match the global unicast address on the interface, manually enter the link-local addresses on each of the Ethernet interfaces on R1.

```
R1# config t
Enter configuration commands, one per line.
End with CNTL/Z.
R1(config)# interface g0/0/0
R1(config-if)# ipv6 address fe80::1 link-local
R1(config-if)# interface g0/0/1
R1(config-if)# ipv6 address fe80::1 link-local
R1(config-if)# end
```

Note: Each router interface belongs to a separate network. Packets with a link-local address never leave the local network; therefore, you can use the same link-local address on both interfaces.

d. Use a command of your choice to verify that the link-local address has been changed to **fe80::1.**

```
R1# show ipv6 interface g0/0/0
GigabitEthernet0/0/0 is up, line protocol is up
  IPv6 is enabled, link-local address is FE80::1
  No Virtual link-local address(es):
  Global unicast address(es):
    2001:DB8:ACAD:A::1, subnet is
2001:DB8:ACAD:A::/64
  Joined group address(es):
    FF02::1
    FF02::1:FF00:1
  MTU is 1500 bytes
<output omitted>
```

e. On a PC-B command prompt, enter the **ipconfig** command to examine IPv6 address information assigned to the PC interface.

f. Enable IPv6 routing on R1 using the **IPv6 unicast-routing** command.

```
R1 # Configure terminal
R1(config)# ipv6 unicast-routing
R1(config)# exit
```

g. Use a command to verify the new multicast group are assigned to interface G0/0/0. Notice that the all-router multicast group (ff02::2) now appears for interface G0/0/0.

Note: This will allow the PCs to obtain their IP address and default gateway information automatically using Stateless Address Autoconfiguration (SLAAC).

```
R1# show ipv6 interface g0/0/0
GigabitEthernet0/0/0 is up, line protocol is up
 IPv6 is enabled, link-local address is FE80::1
 No Virtual link-local address(es):
 Global unicast address(es):
  2001:DB8:ACAD:A::1, subnet is
2001:DB8:ACAD:A::/64 [EUI]
 Joined group address(es):
  FF02::1
  FF02::2
  FF02::1:FF00:1
 MTU is 1500 bytes
<partial output omitted>
Hosts use stateless autoconfig for addresses.
```

h. Now that R1 is part of the all-router multicast group FF02::2, re-issue the **ipconfig** command on PC-B and examine the IPv6 address information.

Add page

Step 4: Assign IPv6 addresses to the management interface (SVI) on S1.

a. Assign the IPv6 address for S1. Also assign a link-local address for this interface.

```
S1(config)# interface vlan 1
S1(config-if)# ipv6 address
2001:db8:acad:1::b/64
S1(config-if)# ipv6 address fe80::b link-local
S1(config-if)# end
```

b. Use a command of your choice to verify that the IPv6 addresses are properly assigned to the management interface.

```
S1# show ipv6 interface vlan1
Vlan1 is up, line protocol is up
 IPv6 is enabled, link-local address is FE80::B
 No Virtual link-local address(es):
 Global unicast address(es):
```

	2001:DB8:ACAD:1::B, subnet is 2001:DB8:ACAD:1::/64 Joined group address(es): FF02::1 FF02::1:FF00:B MTU is 1500 bytes ICMP error messages limited to one every 100 milliseconds ICMP redirects are enabled ICMP unreachables are sent Output features: Check hwidb ND DAD is enabled, number of DAD attempts: 1 ND reachable time is 30000 milliseconds (using 30000) ND NS retransmit interval is 1000 milliseconds **Step 5: Assign static IPv6 addresses to the PCs.** a. Open the Ethernet Properties window on for each PC and assign IPv6 addressing. b. Verify both PCs have the correct IPv6 address information. Each PC should have two Global IPv6 addresses: one static and one SLACC	
Add Page		
	Verify End-to-End Connectivity From PC-A, ping **fe80::1**. This is the link-local address assigned to G0/0/1 on R1. Ping the S1 management interface from PC-A. Use the **tracert** command on PC-A to verify that you have end-to-end connectivity to PC-B. From PC-B, ping PC-A. From PC-B, ping the link-local address for G0/0/0 on R1. **Note**: If end-to-end connectivity is not established, troubleshoot your IPv6 address assignments to verify that you entered the addresses correctly on all devices.	
Add Page		
Add Section	**Results**	
Add Text Box	Run Packet Tracer, Snapshot your results **percentage and assessment items** using “Take A snapshot from VRL”	
Add “Take Snapshot from VRL”	Allow student to take snapshot from running VRL	Add Grade

Add Text Box	Save Packet tracer file and submit it using “Submit file into VRL”	
Add “Submit file into VRL”	Allow Student to submit file from VRL	Add grade
Add page		
Add Section	**Reflection Questions**	
Add True or false Question	1. Can the same link-local address, fe80::1, be assigned to both Ethernet interfaces on R1? True or false	Add Grade
Add open Question	2. What is the Subnet ID of the IPv6 unicast address 2001:db8:acad::aaaa:1234/64?	Add Grade

6) Creation for a LLO for Experiment #6

“Lab - Configure IPv4 and IPv6 Static and Default Routes by Packet Tracer “

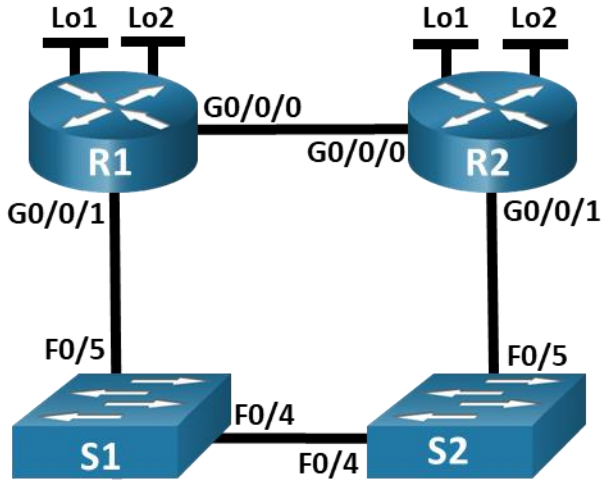
Action	Content	Settings
Add Title	Configure IPv4 and IPv6 Static and Default Routes by Packet Tracer	
Add Section	**Objective**	
Add Text Box	Lab - Configure IPv4 and IPv6 Static and Default Routes **Packet Tracer** **Part 1: Build the Network and Configure Basic Device Settings** **Part 2: Configure and verify IP and IPv6 addressing on R1 and R2** **Part 3: Configure and verify static and default routing for IPv4 on R1 and R2** **Part 4: Configure and verify static and default routing for IPv6 on R1 and R2**	
Add Section	**Introduction**	
Add Text Box	Static and Default routing are the simplest forms of network routing and Configured manually. They are fixed, meaning that they do not change dynamically to meet changing network conditions. They are either valid and made available to the routing table or invalid and not made available to the routing table. Static routes have an administrative distance of one by default. However, static and default routes can be Configured with an administrator-defined administrative distance. This capability allows the administrator to put the static or default route in reserve, and only make it available to the routing	

table when routes with lower administrative distances (usually generated by dynamic routing protocols) are no longer valid.

Add Table

Device	Interface	IP Address / Prefix	Device	Interface	IPv6 Address	Prefix Length	Default Gateway
R1	G0/0/0	172.16.1.1 /24	R1	G0/0/0	2001:db8:acad:a::1	64	N/A
		2001:db8:acad:2::1 /64		G0/0/1	2001:db8:acad:1::1	64	N/A
		fe80::1	S1	VLAN 1	2001:db8:acad:1::b	64	N/A
R1	G0/0/1	192.168.1.1 /24	PC-A	NIC	2001:db8:acad:1::3	64	fe80::1
		2001:db8:acad:1::1 /64	PC-B	NIC	2001:db8:acad:a::3	64	fe80::1
		fe80::1					
	Loopback1	10.1.0.1 /24					
		2001:db8:acad:10::1 /64					
		fe80::1					
	Loopback2	209.165.200.225 /27					
		2001:db8:acad:209::1 /64					
		fe80::1					
R2	G0/0/0	172.16.1.2 /24					
R2	G0/0/0	2001:db8:acad:2::2 /64					
R2	G0/0/0	fe80::2					
R2	G0/0/1	192.168.1.2 /24					
R2	G0/0/1	2001:db8:acad:1::2 /64					
R2	G0/0/1	fe80::2					
R2	Loopback1	10.2.0.1 /24					
R2	Loopback1	2001:db8:acad:11::2 /64					
R2	Loopback1	fe80::2					

R2	Loopback2	209.165.200.193 /27					
R2	Loopback2	2001:db8:acad:210::1 /64					
R2	Loopback2	fe80::2					

Add Section	**Required Resources**	
Add Text Box	2 Routers (Cisco 4221 with Cisco IOS XE Release 16.9.4 universal image or comparable) 2 Switches (Cisco 2960 with Cisco IOS Release 15.2(2) lanbasek9 image or comparable) 1 PC (Windows with a terminal emulation program, such as Tera Term) Console cables to Configure the Cisco IOS devices via the console ports Ethernet cables as shown in the topology	
Add Image		
Add Image Caption	Required Network Topology	
Add Page		
Add VRL	Select **Packet Tracer** from VRL tool list	Add Time
Add Text Box	Click Start to open **Packet Tracer**	
Add Section	**Configure IPv4 and IPv6 Static and Default Routes by Packet Tracer**	
Add Text Box	**BUILD THE NETWORK AND CONFIGURE BASIC DEVICE SETTINGS** In Part 1, you will set up the network topology and Configure basic settings on the PC hosts and switches.	

Step 1: Cable the network as shown in the topology.

Attach the devices as shown in the topology diagram, and cable as necessary.

Step 2: Configure basic settings for each router.

a. Assign a device name to the router.

```
router(config)# hostname R1

router(config)# hostname R2
```

b. Disable DNS lookup to prevent the router from attempting to translate incorrectly entered commands as though they were host names.

```
R1(config)# no ip domain lookup

R2(config)# no ip domain lookup
```

c. Assign **class** as the privileged EXEC encrypted password.

```
R1(config)# enable secret class

R2(config)# enable secret class
```

d. Assign **cisco** as the console password and enable login.

```
R1(config)# line console 0
R1(config-line)# password cisco
R1(config-line)# login

R2(config)# line console 0
R2(config-line)# password cisco
R2(config-line)# login
```

e. Assign **cisco** as the VTY password and enable login.

```
R1(config)# line vty 0 4
R1(config-line)# password cisco
R1(config-line)# login

R2(config)# line vty 0 4
R2(config-line)# password cisco
R2(config-line)# login
```

f. Encrypt the plainText Box passwords.

```
R1(config)# service password-encryption
R2(config)# service password-encryption
```

g. Create a banner that warns anyone accessing the device that unauthorized access is prohibited.

```
R1(config)# banner motd $ Authorized Users Only! $
```

```
R2(config)# banner motd $ Authorized Users Only! $
```

h. Save the running configuration to the startup configuration file.

```
R1(config)# exit
R1# copy running-config startup-config

R2(config)# exit
R2# copy running-config startup-config
```

Step 3: Configure basic settings for each switch.

a. Assign a device name to the switch.

```
switch(config)# hostname S1

switch(config)# hostname S2
```

b. Disable DNS lookup to prevent the router from attempting to translate incorrectly entered commands as though they were host names.

```
S1(config)# no ip domain-lookup

S2(config)# no ip domain-lookup
```

c. Assign **class** as the privileged EXEC encrypted password.

```
S1(config)# enable secret class

S2(config)# enable secret class
```

d. Assign **cisco** as the console password and enable login.

```
S1(config)# line console 0
S1(config-line)# password cisco
S1(config-line)# login

S2(config)# line console 0
S2(config-line)# password cisco
S2(config-line)# login
```

e. Assign **cisco** as the VTY password and enable login.

```
S1(config)# line vty 0 15
S1(config-line)# password cisco
S1(config-line)# login

S2(config)# line vty 0 15
S2(config-line)# password cisco
S2(config-line)# login
```

f. Encrypt the plainText Box passwords.

```
S1(config)# service password-encryption

S2(config)# service password-encryption
```

g. Create a banner that warns anyone accessing the device that unauthorized access is prohibited.

```
S1(config)# banner motd $ Authorized Users Only! $

S2(config)# banner motd $ Authorized Users Only! $
```

h. Shutdown all interfaces that will not be used.

```
S1(config)# interface range f0/1-3, f0/6-24, g0/1-2
S1(config-if-range)# shutdown

S2(config)# interface range f0/1-3, f0/6-24, g0/1-2
S2(config-if-range)# shutdown
```

i. Save the running configuration to the startup configuration file.

```
S1(config-if-range)# exit
S1# copy running-config startup-config

S2(config-if-range)# exit
S2# copy running-config startup-config
```

Configure and verify IPv4 and IPv6 addressing on R1 and R2

In Part 2, you will Configure and verify the IPv4 and IPv6 addresses on R1 and R2. Use the table above for the information necessary to complete this part.

Step 4: Configure IP addresses for both routers.

a. Enable IPv6 Unicast Routing on both routers.

```
R1(config)# ipv6 unicast-routing

R2(config)# ipv6 unicast-routing
```

b. Configure the IP address for all the interfaces according to the Addressing Table.

```
R1(config)# interface g0/0/0
R1(config-if)# ip address 172.16.1.1 255.255.255.0
R1(config-if)# ipv6 address fe80::1 link-local
R1(config-if)# ipv6 address 2001:db8:acad:2::1/64
R1(config-if)# no shutdown
R1(config-if)# interface g0/0/1
R1(config-if)# ip address 192.168.1.1 255.255.255.0
R1(config-if)# ipv6 address fe80::1 link-local
R1(config-if)# ipv6 address 2001:db8:acad:1::1/64
```

```
R1(config-if)# no shutdown
R1(config-if)# interface lo1
R1(config-if)# ip address 10.1.0.1 255.255.255.0
R1(config-if)# ipv6 address fe80::1 link-local
R1(config-if)# ipv6 address 2001:db8:acad:10::1/64
R1(config-if)# no shutdown
R1(config-if)# interface lo2
R1(config-if)# ip address 209.165.200.225
255.255.255.224
R1(config-if)# ipv6 address fe80::1 link-local
R1(config-if)# ipv6 address 2001:db8:acad:209::1/64
R1(config-if)# no shutdown

R2(config)# interface g0/0/0
R2(config-if)# ip address 172.16.1.2 255.255.255.0
R2(config-if)# ipv6 address fe80::2 link-local
R2(config-if)# ipv6 address 2001:db8:acad:2::2/64
R2(config-if)# no shutdown
R2(config-if)# interface g0/0/1
R2(config-if)# ip address 192.168.1.2 255.255.255.0
R2(config-if)# ipv6 address fe80::2 link-local
R2(config-if)# ipv6 address 2001:db8:acad:1::2/64
R2(config-if)# no shutdown
R2(config-if)# interface lo1
R2(config-if)# ip address 10.2.0.1 255.255.255.0
R2(config-if)# ipv6 address fe80::2 link-local
R2(config-if)# ipv6 address 2001:db8:acad:11::2/64
R2(config-if)# no shutdown
R2(config-if)# interface lo2
R2(config-if)# ip address 209.165.200.193
255.255.255.224
R2(config-if)# ipv6 address fe80::2 link-local
R2(config-if)# ipv6 address 2001:db8:acad:210::1/64
R2(config-if)# no shutdown
```

Add Page

Step 5: Verify Addressing

a. Issue the command to verify IPv4 assignments to the interfaces.

```
R1# show ip interface brief
Interface              IP-Address      OK? Method Status
Protocol
GigabitEthernet0/0/0   172.16.1.1      YES unset  up
up
```

```
GigabitEthernet0/0/1   192.168.1.1     YES manual up
up
Serial0/1/0            unassigned      YES unset  up
up
Serial0/1/1            unassigned      YES manual up
up
Loopback1              10.1.0.1        YES manual up
up
Loopback2              209.165.200.225 YES manual up
up
f
R2# show ip interface brie
Interface              IP-Address      OK? Method Status
Protocol
GigabitEthernet0/0/0   172.16.1.2      YES manual up
up
GigabitEthernet0/0/1   192.168.1.2     YES manual up
up
GigabitEthernet0       unassigned      YES unset  down
down
Loopback1              10.2.0.1        YES manual up
up
Loopback2              209.165.200.193 YES manual up
up
```

b. Issue the command to verify IPv6 assignments to the interfaces.

```
R1# show ipv6 interface brief
GigabitEthernet0/0/0   [up/up]
    FE80::1
    2001:DB8:ACAD:2::1
GigabitEthernet0/0/1   [up/up]
    FE80::1
    2001:DB8:ACAD:1::1
Loopback1              [up/up]
    FE80::1
    2001:DB8:ACAD:10::1
Loopback2              [up/up]
    FE80::1
    2001:DB8:ACAD:209::1

R2# show ipv6 interface brief
GigabitEthernet0/0/0   [up/up]
    FE80::2
    2001:DB8:ACAD:2::2
GigabitEthernet0/0/1   [up/up]
    FE80::2
    2001:DB8:ACAD:1::2
Loopback1              [up/up]
    FE80::2
    2001:DB8:ACAD:11::2
```

```
Loopback2                 [up/up]
    FE80::2
    2001:DB8:ACAD:210::1
```

Step 6: Save your configuration

Save the running configuration to the startup configuration file on both routers.

```
R1# copy running-config startup-config

R2# copy running-config startup-config
```

Configure and verify static and default routing for IPv4 on R1 and R2

In Part 3, you will Configure static and default routing on R1 and R2 to enable full connectivity between the routers using IPv4. Once again, the static routing being used here is not meant to represent best practice, but to assess your ability to complete the required configurations.

Step 7: On R1, configure a static route to R2's Loopback1 network, using R2's G0/0/1 address as the next hop.

a. Use the **ping** command to ensure that R2's G0/0/1 interface is reachable.

b. Configure a static route for R2's Loopback1 network via R2's G0/0/1 address.

```
R1(config)# ip route 10.2.0.0 255.255.255.0
192.168.1.2
```

Step 8: On R1, configure a static default route via R2's G0/0/0 address.

a. Use the **ping** command to ensure that R2's G0/0/0 interface is reachable.

b. Configure a static default route via R2's G0/0/0 address.

```
R1(config)# ip route 0.0.0.0 0.0.0.0 172.16.1.2
```

Step 9: On R1, configure a floating static default route via R2's G0/0/1 address.

Configure a floating static default route with an AD of 80 via R2's G0/0/1 address.

```
R1(config)# ip route 0.0.0.0 0.0.0.0 192.168.1.2 80
```

Step 10: On R2, configure a static default route via R1's G0/0/0 address

a. Use the **ping** command to ensure that R1's G0/0/0 interface is reachable.

b. Configure a static default route via R1's G0/0/0 address.

```
R2(config)# ip route 0.0.0.0 0.0.0.0 172.16.1.1
```

Add Page

Step 11: Verify that the routes are operational.

a. Use the **show ip route** command to ensure that R1's routing table shows the static and default routes.

```
R1# show ip route
Codes: L - local, C - connected, S - static, R - RIP, M -
mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF
inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA
external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1,
L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U -
per-user static route
       o - ODR, P - periodic downloaded static route, H -
NHRP, l - LISP
       a - application route
       + - replicated route, % - next hop override, p -
overrides from PfR

Gateway of last resort is 172.16.1.2 to network 0.0.0.0

S*    0.0.0.0/0 [1/0] via 172.16.1.2
      10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
C        10.1.0.0/24 is directly connected, Loopback1
L        10.1.0.1/32 is directly connected, Loopback1
S        10.2.0.0/24 [1/0] via 192.168.1.2
      172.16.0.0/16 is variably subnetted, 2 subnets, 2
masks
C        172.16.1.0/24 is directly connected,
GigabitEthernet0/0/0
L        172.16.1.1/32 is directly connected,
GigabitEthernet0/0/0
      192.168.1.0/24 is variably subnetted, 2 subnets, 2
masks
C        192.168.1.0/24 is directly connected,
GigabitEthernet0/0/1
```

```
L        192.168.1.1/32 is directly connected,
GigabitEthernet0/0/1
      209.165.200.0/24 is variably subnetted, 2 subnets, 2
masks
C        209.165.200.224/27 is directly connected,
Loopback2
L        209.165.200.225/32 is directly connected,
Loopback2
```

b. On R1, issue the command **traceroute 10.2.0.1**. The output should show that the next hop is 192.168.1.2.

```
R1# traceroute 10.2.0.1
Type escape sequence to abort.
Tracing the route to 10.2.0.1
VRF info: (vrf in name/id, vrf out name/id)
  1 192.168.1.2 1 msec *  2 msec
```

c. On R1, issue the command **traceroute 209.165.200.193**. The output should show that the next hop is 172.16.1.2.

```
R1# traceroute 209.165.200.193
Type escape sequence to abort.
Tracing the route to 209.165.200.193
VRF info: (vrf in name/id, vrf out name/id)
  1 172.16.1.2 2 msec *  3 msec
```

d. Issue the **shutdown** command on R1 G0/0/0.

```
R1# config terminal
R1(config)# interface g0/0/0
R1(config-if)# shutdown
R1(config-if)# end
```

e. Demonstrate that the floating static route is working. First, issue the **show ip route static** command. You should see two static routes. A default static route with an AD of 80 and a static route to the 10.2.0.0/24 network with an AD of 1.

```
R1# show ip route static
Codes: L - local, C - connected, S - static, R - RIP, M -
mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF
inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA
external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1,
L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U -
per-user static route
       o - ODR, P - periodic downloaded static route, H -
NHRP, l - LISP

S*    0.0.0.0/0 [80/0] via 192.168.1.2
      10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
```

```
S        10.2.0.0/24 [1/0] via 192.168.1.2
```

f. Demonstrate the floating static route is working by issuing the **traceroute 209.165.200.193** command. The traceroute will show the next hop as 192.168.1.2.

```
R1# traceroute 209.165.200.193
Type escape sequence to abort.
Tracing the route to 209.165.200.193
VRF info: (vrf in name/id, vrf out name/id)
  1 192.168.1.2 1 msec *  1 msec
```

g. Issue the **no shutdown** command on R1 G0/0/0.

```
R1# config terminal
R1(config)# interface g0/0/0
R1(config-if)# no shutdown
R1(config-if)# end
```

Configure and verify static and default routing for IPv6 on R1 and R2

In Part 4, you will Configure static and default routing on R1 and R2 to enable full connectivity between the routers using IPv6. Once again, the static routing being used here is not meant to represent best practice, but to assess your ability to complete the required configurations.

Step 12: On R2, configure a static route to R1's Loopback1 network, using R1's G0/0/1 address as the next hop.

a. Use the **ping** command to ensure that R1's G0/0/1 interface is reachable.

b. Configure a static route for R1's Loopback1 network via R1's G0/0/1 address.

```
R2(config)# ipv6 route 2001:db8:acad:10::/64
2001:db8:acad:1::1
```

Step 13: On R2, configure a static default route via R1's G0/0/0 address.

a. Use the **ping** command to ensure that R1's G0/0/0 interface is reachable.

b. Configure a static default route via R1's G0/0/0 address.

```
R2(config)# ipv6 route ::/0 2001:db8:acad:2::1
```

Step 14: On R2, Configure a floating static default route via R1's G0/0/1 address.

Configure a floating static default route with an AD of 80 via R2's G0/0/1 address.

```
R2(config)# ipv6 route ::/0 2001:db8:acad:1::1 80
```

Step 15: On R1, Configure a static default route via R1's G0/0/0 address.

a. Use the **ping** command to ensure that R2's G0/0/0 interface is reachable.

b. Configure a static default route via R2's G0/0/0 address.

```
R1(config)# ipv6 route ::/0 2001:db8:acad:2::2
```

Add page

Step 16: Verify that the routes are operational.

a. Use the **show ipv6 route** command to ensure that R2's routing table shows the static and default routes.

```
R2# show ipv6 route
IPv6 Routing Table - default - 11 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user
Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1


       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS
summary, D - EIGRP
       EX - EIGRP external, ND - ND Default, NDp - ND
Prefix, DCE - Destination
       NDr - Redirect, RL - RPL, O - OSPF Intra, OI - OSPF
Inter
       OE1 - OSPF ext 1, OE2 - OSPF ext 2, ON1 - OSPF NSSA
ext 1
       ON2 - OSPF NSSA ext 2, a - Application
S   ::/0 [1/0]
     via 2001:DB8:ACAD:2::1
C   2001:DB8:ACAD:1::/64 [0/0]
     via GigabitEthernet0/0/1, directly connected
L   2001:DB8:ACAD:1::2/128 [0/0]
     via GigabitEthernet0/0/1, receive
C   2001:DB8:ACAD:2::/64 [0/0]
     via GigabitEthernet0/0/0, directly connected
L   2001:DB8:ACAD:2::2/128 [0/0]
     via GigabitEthernet0/0/0, receive
```

```
S   2001:DB8:ACAD:10::/64 [1/0]
     via 2001:DB8:ACAD:1::1
C   2001:DB8:ACAD:11::/64 [0/0]
     via Loopback1, directly connected
L   2001:DB8:ACAD:11::1/128 [0/0]
     via Loopback1, receive
C   2001:DB8:ACAD:210::/64 [0/0]
     via Loopback2, directly connected
L   2001:DB8:ACAD:210::1/128 [0/0]
     via Loopback2, receive
L   FF00::/8 [0/0]
     via Null0, receive
```

b. On R2, issue the command **traceroute 2001:db8:acad:10::1**. The output should show that the next hop is 2001:db8:acad:1::1.

```
R2# traceroute 2001:db8:acad:10::1
Type escape sequence to abort.
Tracing the route to 2001:DB8:ACAD:10::1

  1 2001:DB8:ACAD:1::1 6 msec 1 msec 1 msec
```

c. On R2, issue the command **traceroute 2001:db8:acad:209::1**. The output should show that the next hop is 2001:db8:acad:2::1.

```
R2# traceroute 2001:db8:acad:209::1
Type escape sequence to abort.
Tracing the route to 2001:DB8:ACAD:209::1

  1 2001:DB8:ACAD:2::1 1 msec 2 msec 1 msec
```

d. Issue the **shutdown** command on R2 G0/0/0.

```
R2# config terminal
R2(config)# interface g0/0/0
R2(config-if)# shutdown
R2(config-if)# end
```

e. Demonstrate the floating static route is working. First issue the **show ipv6 route static** command. You should see two static routes. A default static route with an AD of 80 and a static route to the 2001:db8:acad:10::/64 network with an AD of 1.

```
R2# show ipv6 route static
Codes: C - Connected, L - Local, S - Static, U - Per-user
Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS
summary, D - EIGRP
       NDr - Redirect, RL - RPL, O - OSPF Intra, OI - OSPF
Inter
       OE1 - OSPF ext 1, OE2 - OSPF ext 2, ON1 - OSPF NSSA
ext 1
       ON2 - OSPF NSSA ext 2, a - Application
```

	`S ::/0 [80/0]`
	`via 2001:DB8:ACAD:1::1`
	`S 2001:DB8:ACAD:10::/64 [1/0]`
	`via 2001:DB8:ACAD:1::1`
	f. Lastly, demonstrate that the floating static route is working by issuing the **traceroute 2001:db8:acad:209::1** command. The traceroute will show the next hop as 2001:db8:acad:1::1.
	`R2#` **`traceroute 2001:db8:acad:209::1`**
	`Type escape sequence to abort.`
	`Tracing the route to 2001:DB8:ACAD:209::1`
	1 2001:DB8:ACAD:1::1 2 msec 1 msec 1 mse	

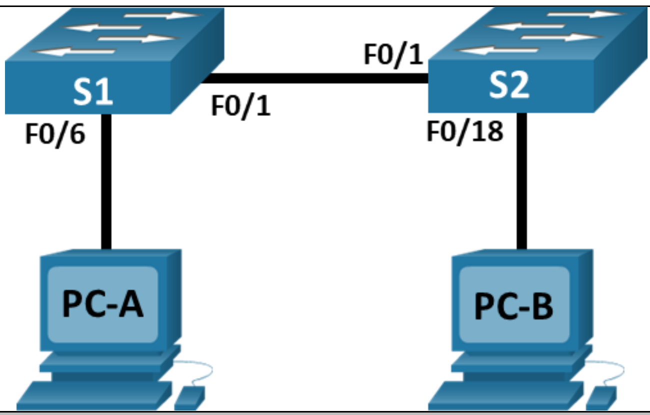
Add Page		
Add Section	**Results**	
Add Text Box	Run **Packet Tracer**,	
Add Text Box	Snapshot your results **percentage and assessment items** from using "Take A snapshot" from VRL	
Add "Take Snapshot from VRL"	Allow student to take snapshot from running VRL	Add Grade
Add Text Box	Save Packet tracer file and submit it using "Submit file into VRL"	
Add "Submit file into VRL"	Allow Student to submit file from VRL	Add grade
Add page		
Add Section	**Reflection Questions**	
Add Open Question	Issuing the command **show cdp neighbors** at this point on R1 or R2 results in an empty list. Explain.	Add Grade

7) Creation for a LLO for Experiment #7

"Lab - Basic Switch and End Device Configuration"

Action	Content	Settings
Add Title	**Basic Switch and End Device Configuration**	
Add Section	**Objective**	
Add Text Box	Configure IPv4 and IPv6 Static and Default Routes **Packet Tracer** Set Up the Network Topology	

<table>
<tr><td></td><td>Configure PC Hosts
Configure and Verify Basic Switch Settings</td><td></td></tr>
<tr><td>Add Section</td><td>Introduction</td><td></td></tr>
<tr><td>Add Text Box</td><td>In this lab, you will build a simple network with two hosts and two switches. You will also Configure basic settings including hostname, local passwords, and login banner. Use show commands to display the running configuration, IOS version, and interface status. Use the copy command to save device configurations.

You will apply IP addressing for this lab to the PCs and switches to enable communication between the devices. Use the ping utility to verify connectivity.</td><td></td></tr>
<tr><td>Add Table</td><td>
<table>
<tr><th>Device</th><th>Interface</th><th>IP Address</th><th>Subnet Mask</th></tr>
<tr><td>S1</td><td>VLAN 1</td><td>192.168.1.1</td><td>255.255.255.0</td></tr>
<tr><td>S2</td><td>VLAN 1</td><td>192.168.1.2</td><td>255.255.255.0</td></tr>
<tr><td>PC-A</td><td>NIC</td><td>192.168.1.10</td><td>255.255.255.0</td></tr>
<tr><td>PC-B</td><td>NIC</td><td>192.168.1.11</td><td>255.255.255.0</td></tr>
</table>
</td><td></td></tr>
<tr><td>Add Section</td><td>Required Resources</td><td></td></tr>
<tr><td>Add Text Box</td><td>2 Switches (Cisco 2960 with Cisco IOS Release 15.0(2) lanbasek9 image or comparable)
2 PCs (Windows with terminal emulation program, such as Tera Term)
Console cables to Configure the Cisco IOS devices via the console ports
Ethernet cables as shown in the topology</td><td></td></tr>
<tr><td>Add Image</td><td>
</td><td></td></tr>
<tr><td colspan="3">Add Page</td></tr>
<tr><td>Add VRL</td><td>Select Packet Tracer from VRL tool list</td><td></td></tr>
<tr><td>Add Text Box</td><td>Click Start to open Packet Tracer</td><td>Add Time</td></tr>
</table>

Add Section	Basic Switch and End Device Configuration	
Add Text Box	**INSTRUCTIONS** **SET UP THE NETWORK TOPOLOGY** In this step, you will cable the devices together according to the network topology. Step 17: Power on the devices. **Power on all devices in the topology. The switches do not have a power switch; they will power on as soon as you plug in the power cord.** Step 18: Connect the two switches. **Connect one end of an Ethernet cable to F0/1 on S1 and the other end of the cable to F0/1 on S2. You should see the lights for F0/1 on both switches turn amber and then green. This indicates that the switches have been connected correctly.** Step 19: Connect the PCs to their respective switches. **Connect one end of the second Ethernet cable to the NIC port on PC-A. Connect the other end of the cable to F0/6 on S1. After connecting the PC to the switch, you should see the light for F0/6 turn amber and then green, indicating that PC-A has been connected correctly.** **Connect one end of the last Ethernet cable to the NIC port on PC-B. Connect the other end of the cable to F0/18 on S2. After connecting the PC to the switch, you should see the light for F0/18 turn amber and then green, indicating that the PC-B has been connected correctly.** Step 20: Visually inspect network connections. **After cabling the network devices, take a moment to carefully verify the connections to minimize the time required to troubleshoot network connectivity issues later.** **CONFIGURE PC HOSTS** Step 21: Configure static IP address information on the PCs according to the Addressing Table. **In PC-A, navigate to the Control Panel. In the Category view, under the Network and Internet heading, click View Network status and tasks > click Change adapter settings.** **Note: There are other ways in Windows to navigate to the adapter settings.** **Right-click the desired network adaptor and select Properties.** **Select the Internet Protocol Version 4 (TCP/IPv4) and click Properties.**	

	Select Use the following IP address. Enter the IP address for PC-A (192.168.1.10) and subnet mask (255.255.255.0) as listed in the IP addressing table. You can leave default gateway blank at this time because there is no router attached to the network. Click OK to continue. Click Close to exit the Properties window. **Repeat the previous steps to assign the IP address information for PC-B.** Step 22: Verify PC settings and connectivity. **From PC-A, open a Command Prompt to verify the PC settings and connectivity using the ipconfig /all command at the prompt.** **To test the connectivity to PC-B, enter ping 192.168.1.11 at the prompt. The ping should be successful. If not, troubleshoot as necessary.**	
Add Page		

	CONFIGURE AND VERIFY BASIC SWITCH SETTINGS
	
	Step 23: Console into the switch. Enter the global configuration mode.
	Open Configuration Window
	
	Establish a console connection to the switch from PC-A using Tera Term.
	
	You can access all switch commands in privileged EXEC mode. The privileged EXEC command set includes those commands contained in user EXEC mode, as well as the Configure command through which access to the remaining command modes are gained. Enter privileged EXEC mode by entering the enable command.
	
	`Switch> enable`
	`Switch#`
	
	The prompt changed from Switch> to Switch# which indicates privileged EXEC mode.
	
	Use the configuration terminal command to enter configuration mode.
	
	`Switch# Configure terminal`
	`Enter configuration commands, one per line. End with CNTL/Z.`
	`Switch(config)#`
	
	The prompt changed to reflect global configuration mode.
	
	Step 24: Give the switch a name according to the Addressing Table.
	
	Use the hostname command to change the switch name to S1.
	
	`Switch(config)# hostname S1`
	
	Step 25: Prevent unwanted DNS lookups.	

To prevent the switch from attempting to translate incorrectly entered commands as though they were hostnames, disable the Domain Name System (DNS) lookup.

```
S1(config)# no ip domain-lookup
```

Step 26: Enter local passwords. Use **class** as the privileged EXEC password and **cisco** as the password for console access.

To prevent unauthorized access to the switch, Configure passwords.

```
S1(config)# enable secret class
S1(config)# line con 0
S1(config-line)# password cisco
S1(config-line)# login
S1(config-line)# exit
```

Step 27: Configure and enable the SVI according to the Addressing Table.

```
S1(config)# interface vlan 1
S1(config-if)# ip address 192.168.1.1
255.255.255.0
S1(config-if)# no shut
```

Step 28: Enter a login MOTD banner to warn about unauthorized access.

A login banner, known as the message of the day (MOTD) banner, should be Configured to warn anyone accessing the switch that unauthorized access will not be tolerated.

The banner motd command requires the use of delimiters to identify the content of the banner message. The delimiting character can be any character as long as it does not occur in the message. For this reason, symbols, such as the #, are often used.

```
S1(config)# banner motd #
Enter TEXT BOX message. End with the character '#'.
Unauthorized access is strictly prohibited and
prosecuted to the full extent of the law. #
S1(config)# exit
```

Step 29: Save the configuration.

Use the copy command to save the running configuration to the startup file on non-volatile random access memory (NVRAM).

```
S1# copy running-config startup-config
Destination filename [startup-config]? [Enter]
Building configuration...
[OK]
S1#
```

Step 30: Display the current configuration.

The show running-config command displays the entire running configuration, one page at a time. Use the spacebar to advance paging. The commands Configured in Steps a - h are highlighted below.

```
S1# show running-config
Building configuration...
```

Add Page

Step 1: Display the IOS version and other useful switch information.

Use the show version command to display the IOS version that the switch is running, along with other useful information. Again, you will need to use the spacebar to advance through the displayed information.

```
S1# show version
Cisco IOS Software, C2960 Software (C2960-LANBASEK9-M), Version 15.0(2)SE, RELEASE SOFTWARE (fc1)
Technical Support: http://www.cisco.com/techsupport
Copyright (c) 1986-2012 by Cisco Systems, Inc.
Compiled Sat 28-Jul-12 00:29 by prod_rel_team
```

Add page

Step 2: Display the status of the connected interfaces on the switch.

To check the status of the connected interfaces, use the show ip interface brief command. Press the spacebar to advance to the end of the list.

```
S1# show ip interface brief
Interface              IP-Address      OK? Method Status
Protocol
Vlan1                  192.168.1.1     YES unset  up
up
FastEthernet0/1        unassigned      YES unset  up
up
FastEthernet0/2        unassigned      YES unset  down
down
FastEthernet0/3        unassigned      YES unset  down
down
FastEthernet0/4        unassigned      YES unset  down
down
FastEthernet0/5        unassigned      YES unset  down
down
```

```
FastEthernet0/6        unassigned      YES unset  up
up
FastEthernet0/7        unassigned      YES unset  down
down
FastEthernet0/8        unassigned      YES unset  down
down
FastEthernet0/9        unassigned      YES unset  down
down
FastEthernet0/10       unassigned      YES unset  down
down
FastEthernet0/11       unassigned      YES unset  down
down
FastEthernet0/12       unassigned      YES unset  down
down
FastEthernet0/13       unassigned      YES unset  down
down
FastEthernet0/14       unassigned      YES unset  down
down
FastEthernet0/15       unassigned      YES unset  down
down
FastEthernet0/16       unassigned      YES unset  down
down
FastEthernet0/17       unassigned      YES unset  down
down
FastEthernet0/18       unassigned      YES unset  down
down
FastEthernet0/19       unassigned      YES unset  down
down
FastEthernet0/20       unassigned      YES unset  down
down
FastEthernet0/21       unassigned      YES unset  down
down
FastEthernet0/22       unassigned      YES unset  down
down
FastEthernet0/23       unassigned      YES unset  down
down
FastEthernet0/24       unassigned      YES unset  down
down
GigabitEthernet0/1     unassigned      YES unset  down
down
GigabitEthernet0/2     unassigned      YES unset  down
down
```

Close Configuration Window.

Step 31: Configure switch S2.

Repeat the previous steps for Switch S2. Make sure the hostname is Configured as S2.

Step 32: From a PC, ping S1 and S2. The pings should be successful.

Step 33: From a switch, ping PC-A and PC-B. The pings should be successful.

Add Page

<table>
<tr><td>Add Section</td><td>Results</td><td></td></tr>
<tr><td>Add Text Box</td><td>Run Packet Tracer,</td><td></td></tr>
<tr><td>Add Text Box</td><td>Snapshot your results <u>percentage and assessment items</u> from using “Take A snapshot” from VRL</td><td></td></tr>
<tr><td>Add “Take Snapshot from VRL”</td><td>Allow student to take snapshot from running VRL</td><td>Add Grade</td></tr>
<tr><td>Add Text Box</td><td>Save Packet tracer file and submit it using “Submit file into VRL”</td><td></td></tr>
<tr><td>Add “Submit file into VRL”</td><td>Allow Student to submit file from VRL</td><td>Add grade</td></tr>
<tr><td colspan="3">Add page</td></tr>
<tr><td>Add Section</td><td>Reflection Questions</td><td></td></tr>
<tr><td>Add Table Question</td><td>Step 1: Record the interface status for the following interfaces.
<table>
<tr><th>Interface</th><th>S1 Status</th><th>S1 Protocol</th><th>S2 Status</th><th>S2 Protocol</th></tr>
<tr><td>F0/1</td><td>Up</td><td>Up</td><td>Up</td><td>Up</td></tr>
<tr><td>F0/6</td><td>Up</td><td>Up</td><td>Down</td><td>Down</td></tr>
<tr><td>F0/18</td><td>Down</td><td>Down</td><td>Up</td><td>Up</td></tr>
<tr><td>VLAN 1</td><td>Up</td><td>Up</td><td>Up</td><td>Up</td></tr>
</table></td><td>Add Grade</td></tr>
<tr><td>Add Open Question</td><td>What could prevent a ping from being sent between the PCs?</td><td>Add Grade</td></tr>
</table>

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