D5.7 Sustainability plan

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1. SUMMARY

Problem-based learning is an emerging pedagogical approach in which knowledge is developed by solving complex, open-ended problems often inspired by the real world. Problem-based learning offers significant advantages. It helps link education to the real-world, it promotes the transferability of knowledge from the academic environment to professional activities, and it builds soft skills such as analytical and critical thinking, collaboration capacity, and entrepreneurial mindsets. Despite these advantages, active- and problem-based learning is not fully exploited in higher education. The reasons for this include the lack of or inadequate infrastructures, lack of openly available digital content that can support problem-based learning, and need for instructor training.

Project ALIEN [1] aims at fostering the adoption of active- and problem-based learning as a strategic educational approach in engineering higher education. This is pursued through a holistic learning intervention that aims to address the challenges that hinder the broad deployment of problem-based learning. ALIEN builds digital problem-based learning labs, a digital problem-based platform and related educational activities, and instructor capacity to deploy problem-based learning through training and community building.

This report constitutes the sustainability plan of the ALIEN project. The document introduces a strategy that paves the way for the broad adoption of ALIEN outcomes beyond the completion of the implementation period within ALIEN partner organizations and at external to the consortium educational institutions. The sustainability strategy is based on enabling open access to project outcomes for all and promoting the capacity of educators and educational institutions to adopt problem-based learning by sustaining developed labs and digital services and by continuing training and community building activities.

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2. THE TARGET SECTOR NEEDS

The project targets directly the engineering higher education sector that benefits from the proposed active- and problem-based learning approach. However, additional groups stand to gain from the ALIEN objectives and outcomes. The following image demonstrates a map of ALIEN direct and indirect stakeholders.

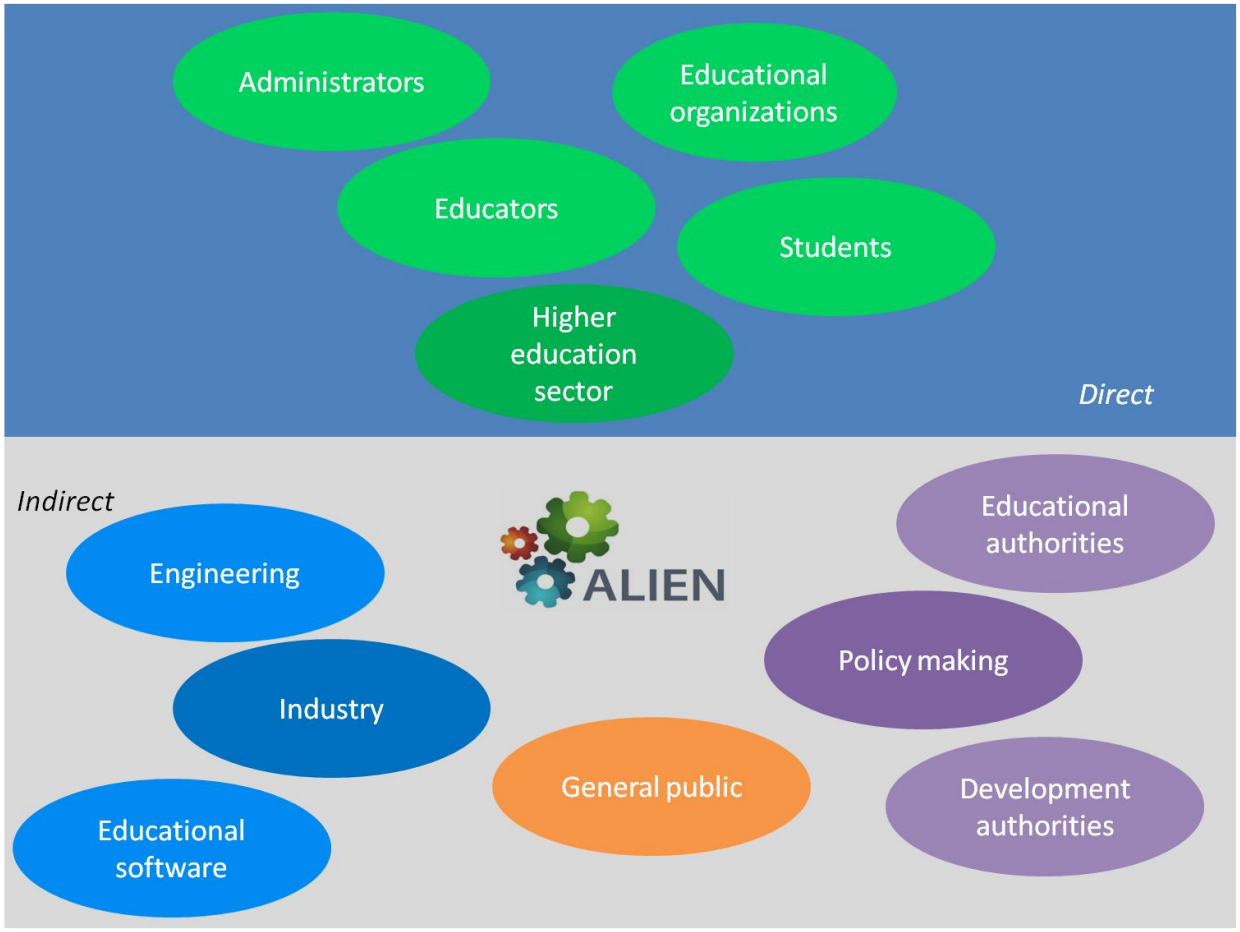

Figure 1. ALIEN direct and indirect stakeholders.

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Direct stakeholders, namely individuals that are engaged with ALIEN solutions, include educational organizations as well as the individuals they engage, namely students, educators, and supporting personnel. Indirect stakeholders include groups and sectors that do not engage actively with ALIEN outcomes but stand to gain from the project results. This includes the industry, policy makers, and the general public that benefit from a better prepared young generation that possesses the skill sets and knowledge that industry and society need for addressing 21st century challenges.

More specifically, the needs of direct stakeholders are:

Higher education institutions are in need of modernizing educational practices, building the knowledge and skills that society and industry need for modern challenges. The new political, economic, social, and environmental realities do not leave the educational sector unaffected. In order to cope with an ever-changing world, old routines and habits need to be reconsidered along with worldviews through the constant pursuit of self-evaluation and self-improvement. They need to adapt to new situations that eventually force the re-examination of systems and the introduction of self-improvement paths in order to discover new methods for approaching knowledge. This requires the complete reorganization of teaching and learning processes, as well as supporting administrative practices, the main aim of which must be the systematic cultivation of students' critical thinking through approaches that allow them to discover, transform, and evaluate knowledge. They must build their capacity to deploy emerging pedagogical design and to bring their learning practices into the digital age.

Higher education students are tomorrow's problem solvers. They need to develop skill sets that empower them to introduce innovative solutions to real-life problems within limited resources and timelines. Problem-based learning offers avenues through which students may combine knowledge from diverse subjects to address complex challenges while at the same time they build analytical and critical thinking soft skills demanded by industry. Students can benefit from

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their exposure to learning scenarios that are inspired by real-life and simulate situations they will face in the future as professionals. They further need to build collaboration capacity that enables them to effectively work with peers to research, analyse, review, evaluate information, and synthesize solutions through explorative methods and the deployment of digital tools. Students can benefit from educational design that encourages them to think critically and to brainstorm collaboratively in the context of commonly owned projects and goals. They are further in need of developing decision-making skills. ALIEN promotes the transition of students from the academic environment to the labor market creating the appropriate conditions for the emergence of new researchers.

Higher education instructors need to develop their skills to integrate into their teaching practices emerging pedagogical design, such as active- and problem-based learning for better preparing their students for their professional life. They need to build among students' knowledge that society and industry demand. Instructors can benefit from lifelong training on maximizing the positive impact of innovative learning design for enriching their already well-developed educational practices. In addition, while instructors do understand the need for integrating digital technologies, such as videos, the internet, simulations, games, and more, in learning they can benefit from good practice guidelines on deploying technology for enriching the interactivity, exploration, and collaboration in the classroom. Educators need to inspire students to be open-minded and to build student self-confidence in their ability to tackle modern challenges.

Educational administrators support learning delivery activities. For this reason, they are in need of understanding the benefits of emerging pedagogical design, such as active- and problem-based learning. They are further in need of building their capacity to support instructional processes based on innovative learning design. For this reason, educational administrators can benefit from life-long training and exposure of good practices in relation to deploying modern educational approaches supported by digital technologies, similarly to educators.

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The needs of indirect stakeholders are:

Industry is in need of highly skilled professionals that possess both foundational knowledge as well as soft skills, such as critical, analytical, and innovative thinking, for pursuing emerging business opportunities. This is particularly important in engineering, a sector that heavily relies on problem-solving skills for introducing solutions to broad challenges. Indirectly, industry can benefit from emerging active- and problem-based learning design that contributes to the development of desired skill sets in a manner that allows their transferability to the work environment. Furthermore, the **educational software industry**, which designs and develops digital learning services, applications, simulations, games, and more, can benefit from the insights developed through the ALIEN project based on evaluation activities that engage actual groups of students in Europe and Asia on the benefits of the proposed active- and problem-based learning design that is supported by digital technologies. The feedback received through the ALIEN implementation is publicly available.

Educational and development policy makers, similarly to industry, are in need of information on the benefits of emerging pedagogical design, including active- and problem-based learning, and how its practical application in real-life educational contexts contributes to the development of skills and knowledge that are in-line with industry and societal needs. They can benefit from analyses, research results, and reports on experiences from the deployment of emerging pedagogical design in order to make policy decisions related to educational and development initiatives.

The general public benefits from a young generation that has the knowledge and skills to address the pressing issues that society faces, leading to increased quality of life, sustainable development, and social cohesion.

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3. EMERGING PEDAGOGICAL DESIGN FOR ENGINEERING

Learning requires attention, observation, memorization, comprehension, goal-setting, and responsibility. These cognitive activities cannot exist without the active participation of students in the educational process. Teachers should avoid turning their students into passive listeners and enrich teaching with practical activities, such as experimentation and synthesis. They should also encourage students' participation in discussions and collaborative activities as well as encourage them to set clear learning goals in line with their interests. Finally, the promotion of learning through collaboration, communication, social learning, and meaningful educational activities offers benefits towards the development of basic knowledge and soft skills.

In order to achieve the basic principle of active participation of students in the learning process, it is important for educators to be able to manage team dynamics. Educators contribute to the formation of a positive environment in the classroom, assume a supportive-facilitating-animating role, and select the appropriate educational methods and techniques that promote interaction, exchange of experiences, and knowledge discovery.

3.1 Problem-based learning

A typical lesson organized according to problem-based learning has as a starting point the presentation of a complex open problem or a question that sets the framework of the project of the students. [2] A well-designed problem engages students in a rigorous learning path that leads to knowledge synthesis. Some key stages in problem-oriented learning are:

- Definition of the problem or question to be introduced into the classroom.
- Classroom discussion and collaboration on potential approaches towards solving the problem.

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- Recognition of the required knowledge that will contribute to the solution of the problem or the answer to the question and identification of the relevant objectives.
- Research on related information or data.
- Brainstorming.
- Synthesis of a solution.

While problem-based learning started from medical education, it is applied in various fields such as STEM education, law education, humanities, and engineering where it offers advantages in terms of fostering the transferability of knowledge to the real world.

3.2 Active learning

Active learning refers to educational offerings that build knowledge by means other than listening and observing. [3] Learners build knowledge by doing; this may involve researching, presenting, visiting sites of interest, role playing, group problem solving, hands-on workshops, discussion, and more to help students connect with lesson content. Active learning helps students avoid passive attendance of a lecture; it helps students participate, learn, and apply lesson content. Strategies that promote active learning have the following common features:

- They encourage student engagement in analysis, synthesis, and evaluation through which knowledge is synthesized.
- They build student values and positive attitudes.
- They help students establish connections between learning and their daily lives.
- They promote creativity in problem solving, fostering true learning.

Active learning gives students the opportunity to reflect on their own experiences and seek answers for themselves, often revealing that reality can be perceived from different perspectives, as opposed to simply providing a clear answer that the teacher seeks.

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3.3 Experiential learning

Experiential learning is an alternative way of building knowledge that is often studied along with problem-based and active learning. [4] It aims at the direct contact of students with the learning object through research, field work, observation, interviews, role-playing, and other activities. The experiential method seeks the active participation of students. The method focuses, in addition to the learning material, on the emotional reactions, questions, and queries of students that are freely discussed in class. In experiential learning students work in groups, communicate their experiences, work out their reactions together, set their own goals, express ideas, and create. Finally, learners learn to reflect and wonder about their experience and to develop the ability for critical reflection.

Experiential learning suggests and applies some specialized techniques, such as use of audiovisual media, experiential representations and games, speech techniques including diary, storytelling, creative writing, and more, artistic creation activities, role play, and theatrical creations.

3.4 Constructivist learning

Constructivism is an educational philosophical theory and argues that experience is the best way to acquire knowledge. [5] The best way to understand something is through the senses and interaction. It is not just an educational method, but it is an educational content theory that encourages students to take responsibility for their own learning. In constructivism, the educator introduces students into a learning environment and allows students to discover answers on their own through experimentation. The role of the educator is to guide and build student confidence. A course of activities may include practices such as:

- Experimentation.
- Investigation.
- Modeling.

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- Discussion.
- Argumentation.
- Representation of phenomena and ideas.

Constructivism is the basis of educational practices that are based on serious games and simulations through which learners digitally experiment towards building knowledge.

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4. MARKET ANALYSIS: RELATED AND COMPLEMENTARYSERVICES

Following is an analysis of related market initiatives.

4.1 MOOCs

MOOCs (Massive Open Online Courses) are courses specially designed for a large number of participants, to which learners have access everywhere and always - as long as they have access to the internet -, are open to all without restrictions and offer a full course experience, free of charge. They are e-courses, which are offered mainly by higher education institutions and cover a wide range of educational subjects, from all scientific fields. They are based on the model of free and open access to knowledge and therefore attract a huge number of learners from around the world. MOOCs are classified as non-formal education, because education is provided in an organized educational framework outside the formal education system and can lead to the certification of nationally recognized certificates. [6]

Higher education institutions have shown particular interest in offering high quality MOOCs to the general public. MOOCs have emerged relatively recently. They are gaining ground and tend to become part of the education system of European countries. They address many areas of the free market, such as employee training, human resource development and marketing. MOOCs today are considered flexible and innovative training solutions, focusing on the acquisition of the necessary skills by the workforce.

MOOCs, are divided into 2 distinct types, known as cMOOCs and xMOOCs. Connectivist MOOCs (cMOOCs) are based on the connectivist theory of learning and advocate the development of informal learning networks, while extensive MOOCs (xMOOCs) are content-based and take a more behavioral approach. The cMOOC educational model provides a platform for exploring young people pedagogical methods beyond traditional classroom teaching and, therefore, tend

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to be adopted by the most radical groups in higher education. On the other hand, the xMOOC educational model provides learning content through short video presentations, quizzes and tests.

Through MOOCs students have accessibility to learning without being eliminated because of geographical, age, or educational restrictions. MOOCs provide them with flexibility in learning time, space, and pace. In addition, MOOCs offer learning on a variety of topics, which helps students enrich their skill sets; MOOCs may act as complementary learning resources to formal educational channels. Furthermore, through MOOCs teachers can receive direct and indirect feedback on the quality of their work, for example by watching their video lectures and reviewing students' comments. There is also possibility for postgraduate and doctoral students to become assistant professors engaging in the organization of a course, its implementation, evaluation, and counseling of a large number of students.

4.2 Serious games and simulations

Educational games aim to impart or evaluate knowledge in a fun way or even to develop and practice specific skills. They are aimed at all ages and their content can cover topics of history, physics, mathematics, chemistry, and language. Educational games should not be confused with educational software, although the similarities between the two types are significant. Recognizing the great value that games offer, the manufacturers of educational software incorporate learning in playful activities. [7] They further design educational modules in the form of a digital game in order to make their product more attractive and to fulfill more effectively and in a fun manner their educational goals. Educational games follow the structure of typical entertainment games. Often, they may use adventure models, embellishing the script and plot with the information, knowledge, or skills that the creator wants learners to acquire.

Serious games are characterized as games with educational purposes, supported by entertainment. Their goal is the same as entertainment games. However, they are more

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complex as control of the fun that leads to participation and the educational elements that lead to the educational experience and learning must be maintained. They are also defined as digital games with serious purposes, such as teaching or training, the main purpose of which is education. Serious games involve combining digital games with academia and the world of simulation in order to immerse the player in a safe and fun learning environment. Because of their unique features, serious games have the power to motivate and engage young people. Serious games aim to impart or evaluate knowledge in a fun way and to develop and practice specific skills. They are addressed to all ages and cover topics on language, physics, chemistry, mathematics, history, and a lot more.

A simulation is a method of studying a system, such as an object, a phenomenon, an activity, or a process, with the help of another system. It is a representation or a model. It is designed to represent the operation of a system leading to its better understanding. [8] The simulation system "imitates" the behavior of what it represents and therefore allows someone to get familiar with its features and better understand its functions.

An educational simulation is based on the model of a phenomenon, device, or process that the student learns to manipulate by interacting with the simulation system. Educational simulations are mainly based on a conceptual model designed to relate to the real world, enabling training and experiential learning. Users can repeat the simulation to test and develop models and theories. In this way simulations provide learning opportunities that are not readily available in the real world. In most cases, simulations simplify reality by omitting or transforming details. Thus, learners have the opportunity to solve problems and learn procedures, reaching understanding of the characteristics of phenomena as well as necessary actions that must be followed in various situations.

Simulation games are becoming more and more popular for both entertainment and educational purposes, as they enhance the learning process which emanates from fun situations

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based on the user experience. In addition, simulation games allow training in a safe environment while avoiding the risk of injury or purchasing high-cost equipment. In fact, they are a simulated depiction of real-world events and processes. Through simulation games users have the opportunity to develop new knowledge and skills.

4.3 Virtual reality

At a time when modern pedagogical trends have a clear orientation towards the use of new technologies, virtual reality is strongly attracting interest. According to modern educational practices, virtual reality is very promising tool for various cognitive fields and provides opportunities to greatly achieve the expected goals as it helps encourage student. [9] It further promotes collaborative and exploratory learning and pedagogical support with the ultimate goal of better learning results. Virtual reality is a new, exciting dimension where someone can enter and experience a situation beyond the possibilities they are given in daily life and beyond the limits of space-time. Virtual environments can significantly support learning through exploratory learning of concepts in the form of simulation.

Virtual reality technology seems to be a powerful educational tool to support teaching practices. Through virtual reality students can explore existing objects and places that are not accessible to them. Moreover, students are able to study real objects that are impossible to understand in a different way due to their size, location, or properties as well as to interact with real people in distant natural places or imaginary places in real or unreal ways. Virtual reality contributes to the understanding of abstract representations.

However, in complex problem-solving processes the support and presence of teachers, who provide guidance and feedback in the form of questions, instructions, and advice, is considered necessary as well. Teachers have a critical role in the learning process as they help students articulate their thoughts in ways that make sense within a particular practice. Teachers also

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address the best use of the technical characteristics of virtual reality designing a defined learning experience that best meets the pedagogical needs of the student.

4.4 Problem-based learning oriented platforms

Following is a description of popular problem-based learning platforms.

4.4.1 ProjectPals

ProjectPals (https://www.projectpals.com/) is an online platform that supports problem-based learning in the following stages:

- Creating an original project or choosing a template from the existing catalogue of Common Core-aligned projects, or co-authoring and co-managing projects with other teachers on interdisciplinary inquiries. Once a project is created, the teacher can form teams and assign tasks.
- Creating original project assets and import assets, including media files and Google docs. Students can also drag-and-drop assets within the workspace, visually arranging content in meaningful ways, and tag assets to classify and organize information.
- Teacher monitoring of student progress in the workspace updated in real time, plus commenting on student work, chatting with teams, and evaluating proficiency using a built-in rubric tool. The teacher has access to project data for insight into individual and team contributions.
- Teacher publishing of student projects and portfolios for building a learning hub and sharing work with peers and parents. Students can present findings to an audience by designing a deck or digital poster board.

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4.4.2 Headrush

HEADRUSH (https://www.headrushlearning.com/) is a learning management platform built specifically for learner-centered schools and project-based programs. Students start learning from different levels. They learn best through doing and through effective feedback loops that lead to better learning.

4.4.3 Edio

Edio is an online platform that offers the following functionality:

- User friendly experience on a human focused platform.
- Remote coaching in PBL for teachers.
- Demonstrated growth with highly visual reporting features.
- Easy tracking and managing of multiple projects.
- Tracking engagement, project progress, and academic standard completion.

4.4.4 Workbench

Workbench (https://edu.workbencheducation.com/) is a problem-based learning platform. It is licensed software-as-a-service to districts with per school pricing. Compared to DIY problem-based learning, where teachers typically need to design the entire project, Workbench offers easy to use authoring tools and a big library of projects to adopt, adapt, and integrate into a bigger project-based learning experience. It provides support to the engineering design process. The platform is already used in over 10,000 schools around the world making the creative and collaboration power strong.

4.4.5 Project Foundry

ProjectFoundry (https://www.projectfoundry.com/) is an online (SaaS), collaborative workflow, portfolio, and reporting solution for student-centered learning. Project Foundry scaffolds the

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learning process while embracing voice and choice in both teacher-guided and student-led learning experiences.

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5. THE OPPORTUNITY: ALIEN GOALS AND OUTCOMES

ALIEN aims at the development of a learning intervention that promotes the adoption of problem-based and active learning as strategic educational approaches in engineering higher education. Through problem-based and active learning ALIEN aims to improve the quality of higher education by providing more motivating, stimulating, and effective learning contexts based on active learning and problem-based learning that prepare students for their professional life through the development of industry desired competences.

Figure 2. Overview of ALIEN solution.

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The ALIEN learning intervention:

WHAT: An integrated approach for fostering the adoption of active- and problem-based learning as a strategic educational methodology.

WHO: For engineering higher education, students, educators, and educational organizations.

HOW: Through the institution of physical infrastructures, digital learning services, training, and communities.

The ALIEN educational framework introduces a vertical approach in integrating problem-based and active learning by developing:

Infrastructure: ALIEN develops physical PBL labs at 12 partner universities in Asia and more specifically in Malaysia, Pakistan, Nepal, Vietnam, and Cambodia.

Digital services: ALIEN develops digital learning platform that promotes student collaboration in active and problem-based learning contexts towards developing problem-solving capacity. The platform introduces a series of features that promote problem-based and active learning including:

- **A digital learning repository** for publishing, accessing, sharing, and re-using problem-based and active learning educational activities that exploit digital technologies for enriching interactivity in the classroom, promoting collaborating, and enriching student learning experiences.

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Figure 3. ALIEN problem-based learning laboratory at the Hanoi University of Science and Technology, Vietnam.

- **Communication elements** through which educators, students, and others may exchange articles, thoughts, experiences, suggestions, and good practices on the deployment of active learning.

Instructor training and community building: ALIEN delivers instructor training for facilitating the adoption of active and problem-based learning in classrooms. It further builds builds a community of educators, students, and others for exchanging experiences towards maximizing the positive impact from the deployment of active and problem-based learning in engineering higher education. Special interest groups examine specific aspects of problem-based and active learning such as general methodologies and tools, deployment in specific courses such as software engineering, and integration with emerging technologies including learning games and artificial intelligence.

The above outcomes are informed by analyses performed for ensuring that project outcome address actual needs in engineering higher education.

State of the art analysis: This involves current practices and policies on the deployment of problem-based and active learning in participating institutions and more generally in countries represented in the consortium through project partners.

Institutional strategies: Strategies on the adoption of problem-based and active learning in participating organizations.

Project outcomes are deployed in real-life educational contexts in participating organizations. Experiences and findings that present the project impact are documented in two reports:

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A use in courses report: The report summarizes the use of the ALIEN labs and digital services in problem-based and active learning at partner sites.

An instructor capacity building report: The report summarizes instructor training activities at participating organizations that aim at building their knowledge and skills towards adopting digitally enriched problem-based and active learning design in engineering higher education.

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6. ALIEN COMPARATIVE ADVANTAGES

6.1 Comparative strategic benefits

The advantages of the ALIEN active and problem-based learning in engineering higher education are many. On a high level, they include:

It modernizes learning: ALIEN promotes the integration into higher education practices of emerging, innovative problem-based and active learning pedagogical design supported by digital technologies. This is aligned with ET2020 objectives that include the modernization of higher education practices through innovative learning practices.

Figure 4. ALIEN instructor training activities in Kuala Lumpur, Malaysia.

It fosters the transition of education to the digital age: The ALIEN digital services and learning content may act as good practice examples of how technology can foster exploration, experimentation, and collaboration anywhere and anytime promoting the integration of digital technologies in educational offerings. Again, this is in-line with ET2020 objectives and the Digital Agenda for Europe that promotes digital integration into all aspects of the economy, including education.

It builds foundational knowledge: The ALIEN labs and digital services promote the development of foundational knowledge in engineering principles that are in demand by industry and society in an active manner that fosters knowledge retention and the ability of students to apply new knowledge in the real world.

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It builds soft skills: Problem-based and active learning fosters the development of transversal skills such as critical thinking, analytical thinking, collaboration capacity in multidisciplinary international teams, and entrepreneurial mindsets.

It fosters transferability of knowledge: Problem-based and active learning promotes the development of knowledge based on challenges that are inspired by industry and society. Active learning in the form of digital games and simulations promotes the use of new knowledge in a manner that simulates real-world practices preparing students to transition from the academic environment to the world of work.

It develops the problem solvers of tomorrow: The ALIEN learning intervention develops problem-solving capacity among engineering higher education students for tackling the urgent and significant challenges of the 21st century as these are identified by the OECD sustainability goals which include growth, health for all, quality education, responsible production and consumption, clean and affordable energy, fighting poverty, mitigating climate change, and more.

6.2 SWOT analysis

Following is a SWOT analysis of the ALIEN learning intervention that aims to establish its comparative position as a solution that promotes problem-based learning in engineering higher education.

6.2.1 Strengths

ALIEN introduces a rich repository of educational activities: The ALIEN digital services act as a portal to rich educational activities developed by educators, students, and engineers from 10 countries in Asia and Europe. Content is available in English and in the national languages of project partners. This offers rich possibilities for external interested parties to draw inspiration and practical advice on integrating problem-based and active learning into classrooms.

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It introduces highly interactive problem-based learning labs: The ALIEN labs developed at universities in Asian countries have been designed specifically to promote problem-based and active learning. The labs have been designed taking into account the institutional strategies, educational missions, and student needs at each partner site. They promote experimentation, exploration, and collaboration through the selection of specific equipment and the setup of the labs that fosters group work and sharing. This makes the labs ideal spaces for building problem-solving skills through peer learning under the guidance of educators.

It promotes the re-use of digital educational content: The ALIEN digital learning repository fosters a community environment in which educators may re-use educational content developed by their peers and adapt to their needs. This approach maximizes the impact of ALIEN educational content by allowing it to be transferred with adaptations to additional learning contexts addressing learning objectives of additional groups of learners.

It follows a low entry high ceiling approach in learning activity publication: The ALIEN digital services support even novices to well structure problem-based and active learning activities through a well-defined and easy to use process that guides them to define learning goals and context, instructions that an educator can provide to students for implementing tasks, and further instructions that support educators in learning delivery. In addition, through content reuse, ALIEN allows educators to start with available activities and to edit them for designing their own. Once they gain experience, educators may structure their own well-developed activities and share them with their peers.

Success stories: The ALIEN learning intervention, including the digital services and problem-based learning labs, has been deployed at 17 universities 12 of which are located in Asia and 5 in Europe. The intervention was applied in over 150 courses. The results are very positive in terms of student and educator engagement and are documented in corresponding report.

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These success stories are leverage for further deployment of the services in higher education contexts.

Affordability: The consortium plans to make the ALIEN digital solution openly available to interested organizations and individuals, allowing access to quality educational services and content in learning contexts. Given that more commercial than open services are available the ALIEN digital tools will provide a platform that can enrich educational experiences. In addition, the high initial cost for setting up the labs at participating organizations has been covered by the project. Naturally, the organizations will need to update the laboratory equipment in the future, however the ALIEN project has provided a significant opportunity for upgrading physical infrastructures.

Collaboration and interactivity: The ALIEN problem-based learning labs and digital services have been designed for promoting group work in problem-based learning scenarios. Collaboration is facilitated through the setup of the labs that fosters group work through round table workspaces. It is further facilitated through the knowledge sharing and educational content re-use features of the digital learning platform. The hybrid solution that is based on labs and digital services activities raises the interactivity among students, whether they work together in the same room or from a distance. ALIEN learning activities published through the platform are designed for group collaboration strengthening peer learning in a manner that simulates real life problem-solving practices.

6.2.2 Weaknesses

Resources required: The sustainability of the ALIEN labs will require technical maintenance as the value of equipment depreciates. This means that participating organizations will need to invest resources in hardware upgrades in the future.

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Skills required: The maintenance of the ALIEN digital services will require software upgrades and technical support. Partners will need to invest in highly skilled professionals that have the capacity to keep the digital services up to date as underlying software and hardware evolves.

The face-to-face use of the ALIEN problem-based learning labs may be limited due to Covid-19: The current pandemic situation inhibits the deployment of the problem-based learning labs built through ALIEN. Until conditions for face-to-face instruction are safe students and educators will need to rely on the ALIEN digital services bypassing the use of the labs.

Internet connectivity: The deployment of the ALIEN digital collaborative platform from home by students requires reliable network connections. While internet connectivity in large cities in Asia is available, this is not the case for rural communities and villages. In the Covid-19 pandemic students moved back to their home towns as they were not able to attend face-to-face classes. Unfortunately, many of them did not have access to technical infrastructure that allowed them to connect reliably to the internet from a distance.

6.2.3 Opportunities

Collaboration between Europe and Asia: ALIEN provides a great opportunity for knowhow exchange between universities in Europe and Asia on good practices towards the deployment of problem-based and active learning in higher education. Participating and external organizations have the opportunity to see what worked in other cultural, educational, and economic environments and to draw inspiration for setting up their own related activities.

Promoting problem-based and active learning in additional educational sectors: The ALIEN problem-based and active learning intervention is applicable beyond the higher education sector. The ALIEN learning intervention can be deployed with adaptations to address the needs of additional learner groups ranging from school to vocational and adult education.

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Technological advances facilitate problem-based and active learning: The rapid evolution of digital technologies can increasingly support exploration, experimentation, and collaboration by enabling students to access increasingly robust software applications and services. The increases on internet speeds allow access to richer content supporting pervasive learning that takes place anywhere and anytime.

Transformation of education in all aspects: Technological advances support the integration of emerging learning design modernizing educational practices as well as institutional governance.

Low costs of running the ALIEN digital services: The requirements for running the ALIEN digital are low. A user simply needs an internet connection. ALIEN services run over common internet browsers. The cost of running the services is related to maintaining an internet connection and is low.

6.2.4 Threats

Completion rates for activities: In order to achieve the desired learning advantages students must complete the activities presented in the ALIEN digital learning platform. As with all on-line learning platforms, such as MOOCs, completion rates are critical for building knowledge. The ALIEN community introduces a supportive environment that encourages student engagement and participation.

Reluctance to use the services: Educators with low digital skills may be reluctant to use the ALIEN digital learning intervention. Educator negative perceptions on distance learning and technology as a learning tool may reduce their confidence in the efficacy of the ALIEN methods and tools. The overcome this obstacle ALIEN organizes continuous instructor training at all participating organizations.

Investment required by educators to create content: Educators must invest time in order to structure meaningful problem-based and active learning activities for their students. Due to

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time limitations educators may be reluctant to commit to activity development. To overcome this difficulty ALIEN supports the re-use of content. Educators may be inspired by activities published by others. They may also copy activities and tailor them to their own needs thus foregoing the necessity to build activities from scratch.

Expenditures for updating equipment in the future: While ALIEN has made a significant investment in purchasing equipment for building problem-based and active learning labs participating organizations will need to come up with additional resources in the future for updating the equipment as technology evolves.

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7. SUSTAINABILITY STRATEGY

Following is a plan of action towards ensuring the sustainability of ALIEN project outcomes.

7.1 Open access

ALIEN aims at providing open access to the digital problem-based and active learning platform and the educational content published through the services. This is in-line with Erasmus+ program objectives of making project outcomes freely available to interested parties.

Open accessibility to project results will maximize the impact of ALIEN on the target higher education sector by providing high quality educational services that promote the development of problem-solving skills.

Educators will be able to create accounts, review suggested educational activities, use the activities in the classrooms, adapt them, and create innovative activities of their own.

7.2 ALIEN server sustainability

The consortium will keep the ALIEN services operational for the foreseeable future. More specifically, the services will be maintained at the University of Malaya. Moving the services to Asia at project completion is a strategic decision that demonstrates the consortium's commitment in supporting problem-based learning in partner countries.

Maintaining the ALIEN services can be achieved with low cost for the following reasons:

- The ALIEN services have been developed in a manner that does not make them dependable on 3d party software that would require continuous licensing costs into the future.

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- The ALIEN services will be installed on servers at the University of Malaya hardware. These servers support the on-going educational process of the university and are maintained through normal, everyday operations.
- Internet hosting will take place internally, eliminating external hosting costs.
- Technical support of the ALIEN services will be undertaken by the ICT team of the University of Malaya with the support, when the need arises, of the ICT of the coordinator and the ICT team of the University of Porto. These teams are already in place and no additional staff will be necessary.

7.3 Creative Commons

The software code for the ALIEN services will be made openly available to interested parties as open source. This goes a step further than making the use of the services freely accessible. Making the software code open source will enable external to the consortium organizations to reuse it, to modify it, and to adapt it for addressing diverse educational needs for broad groups. For example, the software code could be modified and complemented to address educational objectives for the secondary, the vocational, or the professional education sectors. This is a conscious choice of the ALIEN consortium that adds value to project outcomes and maximizes their impact by allowing them to be reused in additional learning settings.

Open sourcing the software code will be achieved through Creative Commons licenses. Creative Commons is a framework that enables and encouraging sharing of work and open access to knowledge. It provides a “free, simple, and standardized way to grant copyright permissions to creative and academic works” [10]. Creative commons allow others “to copy, distribute, and make use of these works” in a straightforward way. The non-profit organization further provides services that allow the discovery of openly available work and knowledge.

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Creative Commons offers 6 types of license schemes to choose from, with varying degrees of restrictions on use. The varying schemes allow or restrict modifications, require users to credit the creator, allow or restrict commercial use, and may require the distribution of adaptations of open work to be on the same terms as the original.

A fitting type of license for ALIEN would be:

BY: Attribution required, namely crediting of the creators, in this case the ALIEN Consortium.

NC: Only non-commercial use of the work permitted.

SA: Share alike, namely all derivative work must be shared under the same terms.

7.4 Human resources

Maintaining the ALIEN services beyond the completion of the project, or installing the services at additional higher education organizations, will require at each institution an effective execution team for supporting the services. This team will need to include:

- **A training coordinator** that will support other instructors on adopting the ALIEN problem-based and active learning solution, the structuring, and the delivery of ALIEN problem-based and active learning activities. The training coordinator will be a member of the ALIEN implementation team at each participating institution with experience on the design and deployment of the ALIEN methodologies and tools.
- **ALIEN project ambassadors**, namely educators that will further integrate the ALIEN learning solution into their courses creating at the same time additional educational content to be published through the ALIEN platform. Each participating organization already has a team of 5 to 10 educators in place that have deployed the project outcomes in real-life conditions into their courses. Furthermore, each participating organization has trained at least 30 educators on the deployment of the ALIEN solution. These educators will become the initial ALIEN ambassadors transferring their knowledge

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to their peers and colleagues towards the continuous expansion of the deployment of project results.

- **A technical support team** that will engage members of the ICT support groups at each partner site. The technical support team will provide technical assistance to educators that deploy the ALIEN digital labs and digital learning services. In addition, a technical support team at the coordinator site will maintain the project portal and the ALIEN digital learning platform, which will be centrally hosted and openly accessible for all interested educational institutions.

The team is presented in the following image.

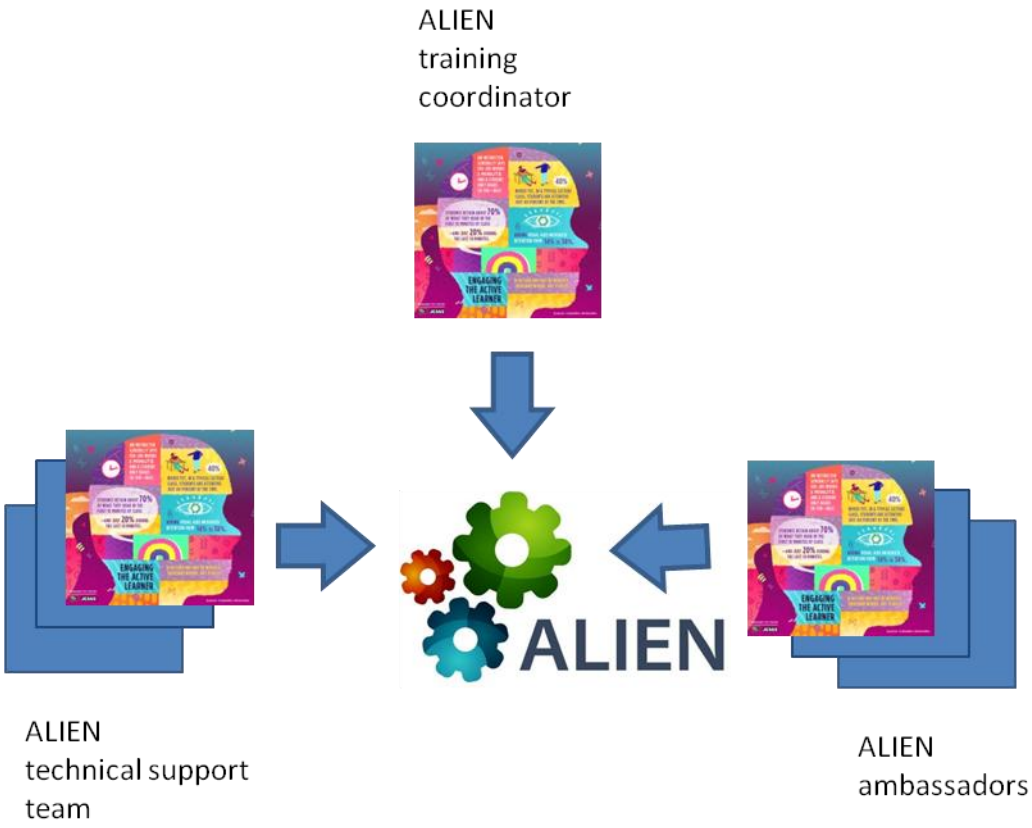

Figure 5. ALIEN implementation team at each participating institution.

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7.5 Institutionalization

The outcomes of the ALIEN project have been deployed in 7 – 10 courses per partner organization. This includes the problem-based learning laboratories, the digital problem-based learning platform, and the over 300 educational activities published through the digital platform. The outcomes of the project have been deployed in over 130 courses at all partner sites reaching over 10.000 students. Notably, each partner has used the project outcomes in 7 – 10 different courses impacting a broad number of students. The deployment of project outcomes will continue post project completion at partner universities and external organizations with the number of courses in which the project outcomes are being deployed increasing on a yearly basis as a result of continued instructor training activities that will enrich the instructional capacity of educators to integrate the proposed problem-based learning design (ALIEN Evaluation of the Implementation Phase Report, 2021).

7.6 Leveraging the ALIEN network of partners in Europe and Asia

The sustainability strategy of the project focuses not only on the growing deployment of ALIEN services within participating organizations but also beyond. This will be pursued through the vibrant network of higher education partners that participating institutions have developed in Europe and Asia through educational and research initiatives and collaborations. The partners have already engaged external organizations in their countries and beyond in dissemination and uptake initiatives, including the contribution of learning activities published through the ALIEN digital platform, the engagement in community events, and more. Following is a characteristic list of external organizations already exposed to the ALIEN learning intervention through dissemination activities, events, or the signing of MoU's on future collaboration in countries represented in the consortium through partners and beyond:

In Greece:

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- The University of Crete.
- The Hellenic Open University.
- Diofantos Center, a consulting body to the Greek Ministry of Education.
- The Greek Mathematical Society, an organization of mathematics secondary educations, with which an MoU was signed by the University of Thessaly.
- Secondary education authorities in the region of Thessaly, that have an interest in promoting emerging learning design, such as problem-based learning.

In Estonia:

- The International Evaluation Team of Tallinn University.

In Bulgaria:

- The Bulgarian Ministry of Education.
- The Gabrovo Chamber of Commerce.
- The VET sector, through participation of the University of Gabrovo in the VET exhibition 2020.
- The Gabrovo Chamber of Commerce.

In Portugal:

- Conselho Coordenador da Instalação dos Estabelecimentos de Ensino Superior Politécnico (CCISP) is the Association that gathers all the Portuguese Polytechnics.
- The Higher Education Commission.

In the UK:

- The University of Hertforshire.

In Malaysia:

- Universiti Malaya Kelatlan.

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- Kolej Universiti Islam Zulkilfi Muhammad.
- Univesiti Technology Petronas.
- Universiti Malaya Pahang.

In Cambodia:

- The Bacamp organization and the KOOMPI® brand engaged in community building.

In Nepal:

- The Nepal Engineering Association.

In Vietnam:

- The Vietnamese Ministry of Education, with which the Hanoi University of Science and Technology organized joint training for secondary education teachers.
- HCL, an Indian company, with which Hanoi University signed an agreement for delivering active learning through the ALIEN laboratory.

In Pakistan:

- Bahria university Islamabad- higher education institute.
- National university of technology- higher education institute.
- The C@SHE student society.

Networking and community building activities will continue post project completion in the context of regular academic activities of partner organizations in their communities.

7.7 Promoting to the end users: educators, students, decision makers

Project outcomes will continue to be promoted after the completion of the implementation period through events, extending project current practices. These may include:

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7.7.1 Webinars

Webinars allow reaching broad audiences in an on-line format that is suitable for international dissemination of project activities while containing costs. Webinars may focus on:

- The ALIEN methodological learning framework of the project, namely the proposed active- and problem-based learning approach that helps build skills that industry and society need.
- The ALIEN digital tools and more specifically maximizing the positive impact from the deployment of the ALIEN digital learning platform and repository of over 200 problems in several languages.
- The ALIEN problem-based learning labs and more specifically integrating the proposed equipment setup into educational practices for encouraging exploration, collaboration, and innovative thinking.
- Scientific areas that may be deployed in combination with active- and problem-based learning, such as artificial intelligence, gamification, design thinking, and more.
- Practical issues related to getting the most out of problem-based learning.

This activity will continue related initiatives that took place over the project implementation period. Webinars have already been delivered on a bi-monthly basis over the second half of the implementation period. A total number of 9 webinars were organized during the ALIEN project duration on topics such as (ALIEN webinars, 2021):

- Problem-based learning methodologies and tools.
- Deploying problem-based learning with large groups of students.
- Gamification and problem-based learning.
- Digital services that promote student on-line collaboration in problem-based learning.
- Using the ALIEN problem-based learning labs in educational activities.
- Design thinking and problem-based learning.

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- Education in the new era.
- Experiences with problem-based learning.
- And more.

7.7.2 Regional events

In addition to the webinars, which may be delivered to international audiences, project partners will continue initiatives on organizing regional events that promote the project objectives and outcomes. This work will continue partner initiatives that took place during the implementation period and aimed at building regional communities for fostering the adoption of the ALIEN learning intervention.

Regional events may take several forms, such as:

- Using ALIEN methodologies and tools in courses.
- Delivering presentations to instructors and other stakeholders, such as policy makers.
- Delivering presentations to broader audiences, including the general public.
- And more.

This activity will continue related actions that took place during the project implementation period, in which over 100 instructor training and community building events took place at all ALIEN partner sites.

7.8 Financial analysis on sustaining the ALIEN solution

The following table introduces an analysis of the costs expected for sustaining the ALIEN learning intervention post project completion.

ALIEN operation costs yearly	**Euros/year**	**Explanation**
Domain name registration	7 €	Typical cost

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Hosting of ALIEN portal	0 €	To be internally hosted by coordinator
Hosting of ALIEN digital platform	0 €	To be internally hosted by the University of Malaya
Maintenance of ALIEN portal	2.448 €	24 work days per year to be covered by existing technical personnel at the University of Thessaly
Maintenance of ALIEN digital platform	792 €	24 work days per year to be covered by existing technical personnel at the University of Malaya
Instructor training	3.928 €	4 work days per year per partner to be covered by existing academic staff
Upgrading of laboratory equipment per partner	3.600 €	This estimate assumes a 5 year depreciation of the laboratory equipment, which originally cost 18.000 per partner

Figure 6. Operational costs for maintaining the ALIEN solution.

The table makes the following assumptions:

- Hosting of the portal and digital learning services will take place internally by the coordinator and the University of Malaya on existing servers, introducing no operational cost. The services will continue to be openly available for all project partners after the completion of the implementation period.
- The maintenance of the project portal will require the publication of information on events and other activities. The workload is calculated to 2 staff days per month at typical rates in Greece. This work will be executed by technical support personnel already in employment by the coordinator. For this reason, the real cost of this activity for each partner is 0.
- Similar argument can be made for the maintenance of the digital learning services, using typical rates in Malaysia where the digital learning platform will be hosted.
- Instructor training will be delivered by existing academic staff at partner sites. The calculations assume 4 staff day per year per partner at typical rates for each country.

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This work will be executed by academic personnel already in employment by each partner. For this reason, the real cost of this activity for each partner is 0.

- Depreciation of laboratory equipment will take place over 5 years. This means that after 5 years the equipment will need to be updated or replaced. Given that the original cost was 18.000 Euros per partner, the cost per year for updating the equipment is calculated at approximately 3.600. This is the only significant cost for sustaining the ALIEN solution, which partners will need to undertake.

Notably, these costs address the continued operation of ALIEN at all partner sites, and in this sense they are very reasonable and manageable. The costs will be covered by the internal operations and existing organizational budgets.

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8. REACHING THE HIGHER EDUCATION MARKET

The higher education market will be reached in a bottom-up manner.

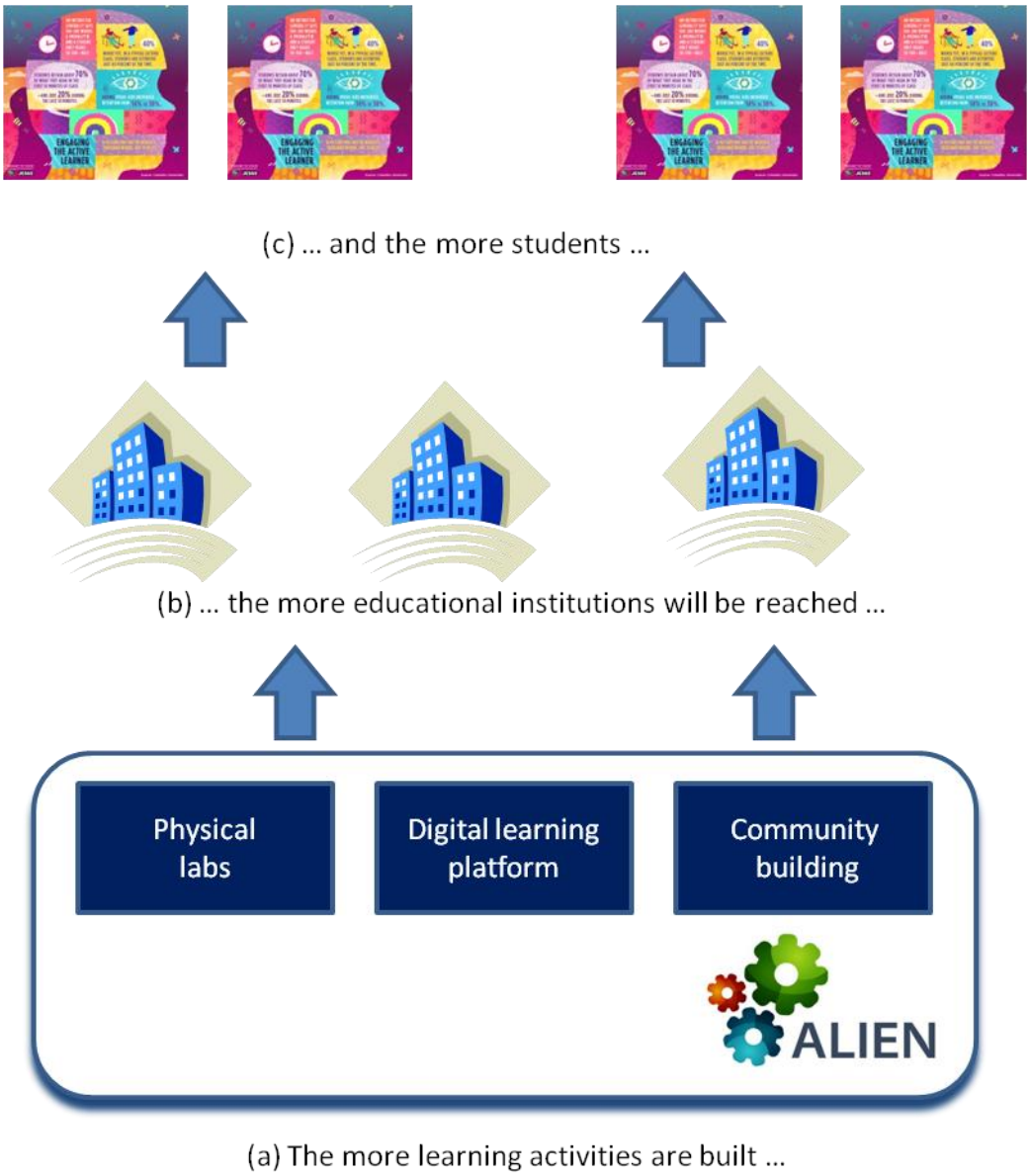

Figure 7. Reaching the higher education market bottom-up.

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The number of organizations benefitting from the ALIEN solution will be built by focusing initially on consortium organizations that will continue to develop educational content for the ALIEN digital learning platform.

As a second step, the consortium will pursue the gradual expansion of its network to external to the consortium educational providers in which ALIEN has project partners and beyond. This will be achieved by continuously enriching the educational content of the ALIEN digital learning services and instructor support activities which will raise the added value of the ALIEN solution in an on-going manner thus attracting additional educational institutions.

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9. MARKETING RECOMMENDED ACTIONS

The following actions are recommended for promoting the ALIEN problem-based learning solution beyond the completion of the project.

- **Position the ALIEN outcomes as an integrated solution for promoting active- and problem-based** learning that addresses the need for digital services availability, open educational content availability, and instructor capacity building.
- **Develop the role of ALIEN Ambassador** for educators that deploy and active- and problem-based learning and who act as instructor trainers for building the capacity of their peers on using the same methodologies.
- **Leverage the digital learning platform** by presenting the advantages it provides a single point of access o rich educational activities available in several languages. The platform already provides access to over 200 learning scenarios that are implemented through the support of digital simulations, games, and applications. By making the platform openly available and promoting its adoption through dissemination and events there is a great potential for increasing significantly the number of activities published, raising the added value of the repository.
- **Leverage the network of educators and educational institutions** for the sharing of knowledge and experiences on how to maximize the positive impact from the deployment of the ALIEN learning intervention. This may be achieved by sustaining the community services on the ALIEN digital learning platform through which stakeholders may build on each other's knowledge by communicating in forums. It may further be achieved by continuing the organization of training and community events at the regional and international level both through face-to-face activities and through webinars.

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- **Focus on the needs of the final end users**, namely students and educators, and highlight the benefits of ALIEN towards building industry demanded problem-solving skills, analytical, and critical thinking. Highlight the potential offered by ALIEN for linking education to the world of work through problems that are inspired by real life.
- **Building a network of alumni** that have completed their studies engaging in ALIEN active- and problem-based learning. The network is expected to further promote project results and the benefits of the proposed learning intervention for building industry demanded skills.
- **Focus on the needs of educational organizations** and highlight the benefits of ALIEN towards modernizing educational practices through emerging didactical design that is supported by digital technologies for building skills needed by industry and society.

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10. ANTICIPATED IMPACT

The impact on ALIEN on direct stakeholders, namely students and educators, as well as educational organizations is analyzed below.

10.1Impact on students

10.1.1 Short term

- **Exposure to improved didactical processes and learning delivery** through the deployment of problem-based learning labs, digital services, and digital educational content.
- **Enriched educational experiences** through higher interaction, collaboration, and engagement in the classroom resulting from active- and problem-based learning design.
- **Enriched problem-solving capacity** as a result of being exposed to emerging problem-based digitally enabled learning design.
- **Better placement possibilities** in the job market as a result of skill sets tailored to industry needs. ALIEN develops both foundational knowledge and soft skills such as critical and analytical thinking, project management, collaboration in diverse groups, and more.
- **Enhanced motivation to engage in learning** as a result of enriched educational activities.
- **Ability to use new knowledge in the real world** as a result of ALIEN active learning design that simulates industry problem-solving practices.

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10.1.2 Long term

- **Better return on investment** in education as a result of the improved learning design that lead to enhanced skill and knowledge development.
- **Better value for money** for tuition fees, where applicable.
- **Improved position** in the job market as a result of the higher perceived value developed skills sets and, as a result, of academic degrees achieved.

10.2 Impact on educators

10.2.1 Short term

- **Improved capacity to design active- and problem-based learning activities** for their students as a result of ALIEN instructor training through their engagement in ALIEN activities.
- **Improved capacity to act as mentors and facilitators in student-centered educational design**, such as active- and problem-based learning, in which the responsibility of learning is shifted to students.
- **Improved capacity to deploy digital technologies in learning** as result of ALIEN instructor training.
- **Affiliation with an international community of peers** through which they can exchange experiences and good practices on the deployment of active- and problem-based learning.

10.2.2 Long term

- **Enhanced career satisfaction** as a result of professional growth and specifically capacity building on emerging learning design.

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- **Opportunity to become mentors** to peers transferring their experiences from their engagement in ALIEN problem-based learning design in engineering education.

10.3 Impact on educational organizations

10.3.1 Short term

- **Raising the quality of educational offerings through modern educational practices**, such as active- and problem-based learning, and through motivating, stimulating, and effective learning contexts, establishing active- and problem-based learning as strategic educational approaches in engineering higher education.
- **Transitioning education into the digital age** through the installation of problem-based learning labs, the availability of digital learning services, and access to open digital educational content.
- **Receiving positive response from students** seeking effective and focused knowledge development.
- **Integration of good practices that help reach organizational educational goals** through active- and problem-based initiatives.

10.3.2 Long term

- **Increasing enrolment** as a result of quality educational practices that link knowledge development to the needs of industry.
- **Helping fight unemployment** by developing skills that promote the employability of graduates.
- **Supporting the introduction of new learning programs** that may take advantage of flexible learning delivery to address the development of targeted skills through short and focused programs.

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- **Enhancing the applicant pool** as the expected perception of didactical innovation among prospective students is expected to attract skilled applicants and additional learner groups. Furthermore, increase in the diversity of the applicant pool by reaching individuals that wish to extend their skill sets through flexible learning offerings. The statistics of the applicant pool will improve as a result of better recognition of effective learning delivery in a few years.
- **For private institutions, increasing revenues from learner tuition** as a result of the increased enrolment and the reaching of additional educational market segments.
- **Better placement of graduates in the job market** as a result of enriched skill sets in-line with industry needs.
- **Raising the perception of quality among students and peer institutions** as better instructional processes, program diversity, and better job placement of graduates will have an impact in the institutions' image.

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11. MONITORING SUSTAINABILITY

The following table demonstrates expected growth of the ALIEN outcomes beyond the completion of the project. More specifically, it demonstrates:

- The targets foreseen to be achieved at the end of the project implementation period in the proposal.
- The achievements at the end of the implementation period (2021).
- The forecast target for a period of 5 years after the implementation period.

Projections for monitoring sustainability	Proposal target	2019 - 2021	2022	2023	2024	2025	2026
Students enrolled in active learning courses	1.500	10.000	11.000	13.200	15.840	19.008	22.810
Educators trained on ALIEN methods	510	1.100	1.155	1.213	1.274	1.338	1.405
Courses deploying ALIEN	125	130	137	144	152	160	168
Participants in community ALIEN building events	1.250	3.400	3.570	3.749	3.936	4.133	4.339
Activities published in ALIEN platform	45	300	574	862	1.166	1.486	1.822

Figure 8. Forecast growth on ALIEN outcomes in the 5 years after the project completion.

The table is based on the following data and hypotheses:

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- The number of courses in which ALIEN outcomes were used during the project implementation period is over 130, exceeding the proposal target of 125. A 5% growth on the number of courses using ALIEN is forecast yearly after the completion of the project. This number is deemed realistic as ALIEN services will continue to expand within partner departments, additional organizational departments, and external organizations.
- The number of problem-based and active learning activities published through the ALIEN digital services during the project implementation period is over 300, exceeding the proposal target of 45. The good performance is expected to continue after the completion of the project. The forecast numbers on yearly activity publications are based on the conservative hypotheses that for each course 2 activities will be published on a yearly basis. More publications are very likely.
- The number of individuals participating in ALIEN community building events was approximately 3.400, exceeding the proposal target of 1.250. A 5% rate increase per year is calculated.
- The number of instructors trained on ALIEN methodologies and tools at the end of the project implementation period over 1.100, exceeding the proposal target 510. The table demonstrates the number of instructors to have received training at the end of each year assuming a 5% growth rate.
- The number of students that will be engaged in active- and problem-based learning is expected to increase at a rate of 10% per year as more courses apply the methodology while the number of educators engaged is expected to grow slower at a rate of 5% given that in some departments already 50% of the academic staff already applies the ALIEN solution.

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12. INDIVIDUAL PARTNER LABORATORY EXPLOITATION PLANS

In addition to the present exploitation strategy that addresses the future deployment of ALIEN project outcomes, each partner located in Malaysia, Pakistan, Nepal, Cambodia, and Vietnam has designed an exploitation plan for the laboratory that was developed through the ALIEN project.

The individual laboratory exploitation plans include information on:

- The name of the ALIEN laboratory.
- The faculty or department in which it belongs.
- The position of the laboratory in the institution's organogram, demonstrated in a graph.
- Guidelines for the use of the laboratoryoratory.
- Activities that take place in the laboratory.
- Resources, including equipment and software.
- Financial and staffing planning for the continued use of the laboratory.

Specifically, laboratory exploitation plans have been developed for:

- The University of Malaya, Malaysia.
- Universiti Tenaga Nasional, Malaysia.
- ISRA University, Pakistan.
- National University of Future and Emerging Sciences, Pakistan.
- Mean Chey University, Cambodia.
- University of Battambang, Cambodia.
- Institute of Technology Cambodia.
- Hanoi University, Vietnam.
- Hanoi University of Science and Technology, Vietnam.

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- Von Neumann Institute, Vietnam.
- Kathmandu University, Nepal.
- Tribhuvan University, Nepal.

The laboratory exploitation plans have been published on the organizational portals of the project partners. In addition, they are available on-line on the ALIEN project portal at http://projectalien.eu/index.php/physical-pbl-labs/ (ALIEN laboratory exploitation plans, 2021).

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13. MoU's signed among partners and with external bodies

ALIEN partners have signed a series of MoU's aiming at the continuation of activities on the promotion of problem-based learning post project completion.

13.1 Bilateral MoU's signed among ALIEN project partners

Bilateral MoU's between project partners have been signed for promoting the following:

- The exchange of information on their respective educational systems and policies to assist in ongoing education reform and to facilitate the adoption of emerging learning design.
- The exchange and professional development of officials, academics, scholars, teachers, experts, students and administrative staff.
- Collaboration in joint delivery and research programs/activities and publications, including exchange of research materials, publications and educational literature, or any other activity of mutual interest.
- The organization of joint conferences, exhibitions and symposia on matters in common areas of interest; and other forms of cooperation in mutually determined and targeted areas.

Bilateral MoU's were among signed between European and Asian ALIEN partners aiming to promote international collaboration beyond Europe:

- Hanoi University of Science and Technology and Porto Polytechnic.
- Hanoi University and Porto Polytechnic.
- ISRA University and Porto Polytechnic.
- Von Neumann Institute and Porto Polytechnic.

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- National University of Future and Emerging Sciences and Porto Polytechnic.
- Tribhuvan University and Porto Polytechnic.
- University of Battambang and Porto Polytechnic.
- Hanoi University and the University of Thessaly.
- ISRA University and the University of Thessaly.
- Institute of Technology Cambodia and the University of Thessaly.
- Von Neumann Institute and the University of Thessaly.
- Tribhuvan University and the University of Thessaly.
- University of Battambang and the University of Thessaly.
- National University of Future and Emerging Sciences and the University of Thessaly.
- University of Malaya.
- Hanoi University and the University of Gabrovo.
- Von Neumann Institute and the University of Gabrovo.
- University of Battambang and the University of Gabrovo.
- National University of Future and Emerging Sciences and the University of Gabrovo.
- Mean Chey University and the University of Gabrovo.

The agreements are available on the ALIEN project portal (MoUs among project partners, 2021).

13.2 Bilateral MoU's signed between ALIEN project partners and external bodies

The following MoU's on promoting problem-based learning were signed between ALIEN project partners and external bodies:

- University of Thessaly and the Hellenic Mathematical Association, Magnesia Division.
- Tribhuvan University and the Nepal Engineering Association.
- The University of Gabrovo and the Gabrovo Chamber of Commerce.

The agreements are available on the ALIEN project portal (MoUs with external bodies, 2021).

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The MoU's demonstrate project partner commitment on continuing the established collaboration on problem-based learning among them and with external bodies post project completion through the signing of formal agreements.

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14. ALIEN impact as described by project partners

Finally, project partners have summarized as follows in a single sentence the single, most important benefit of ALIEN on their organizations, demonstrating the added-value of the project:

John Von Neunmann, Vientam

“Through the ALIEN project, the active learning and problem-based learning methods have become more prevalent in our educational institution. The approach of faculty and students has had a great positive change in the way they communicate and work together in posing and solving subject-related problems. Following the activities identified in the project, many fruitful results can be found and expanded in the Vietnamese pedagogical environment.”, Dr. Nguyen Ngoc Truong Huy, Deputy Director of John von Neumann Institute – Vietnam National University of Ho Chi Minh City.

National University of Future and Emerging Sciences, Pakistan

“Project ALIEN has immensely changed our perspective of problem-based blended learning which is the utmost need of the time.”, Dr. Irum Imayat.

Porto Polytechnic, Portugal

“For the Porto Polytechnic, ALIEN had a major impact on two aspects: firstly, on the systematization of the adoption of Active Learning in our courses and programs – ALIEN helped moving from a causistic approach to a generalized support thanks to the examples and best practice resulting from the project; secondly, on the internationalization of the institution – ALIEN has definitely contributed to expand the network of collaborations into other regions of the world and paved the way for future mobilities of students and teachers into Asia.”, Dr. Carlos Vaz de Carvalho.

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Tallinn University, Estonia

"Western people have many stereotypes when they think about the Asian education system. Stereotypes like – teaching in Asian universities is authoritarian (it's one-directional and teacher-oriented), students never ask questions because this is not polite and they don't want to put a teacher into a difficult situation. The ALIEN project demonstrated that teachers are using active learning methods in all over the world, and students are the same everywhere.", Dr. Martin Sillaots.

Technical University of Gabrovo, Bulgaria

"ALIEN project positively affected the teaching/learning process at the Technical University of Gabrovo. It introduced active learning techniques, especially problem-based learning, in the education of engineering students, which on one hand made the engineering classes more interesting and attractive and, on the other hand, helped engineering students improve their analytical and critical thinking, creativity, team work and communication skills thus meeting the demands of industry. In addition, it appeared a good basis for expanding its application to other target groups and in different context. The University is now working on a EU Project where active learning tools are introduced into a training for upskilling technicians and engineers employed in the sector of Machine Building and mechatronics (allCUTE project). Furthermore, the University academic staff were able to improve their teaching competence so as to provide better education opportunities.", Dr. Tsvetelina Petrova.

Kathmandu University, Nepal

"ALIEN Project has created an environment whereby the students not only have a clear understanding in their subject matter but also able to apply their gained knowledge for problem solving.", Dr. Dhiraj Shrestha.

Institute of Technology Cambodia, Cambodia

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"For the Institute of Technology of Cambodia, ALIEN helped ITC to involve more lecturers to practice and adopt the Active Learning in the classroom. The lecturers at ITC also learn new methods of AL and PBL through example, best practice, and experience sharing from partners in the Consortium.", Mr. Heng Lay.

University of Malaya, Malaysia

"Active learning through our Technology Enabled Learning Space (TEALS) made learning more meaningful, enjoyable and catalytic improvement in academic performance contributing to the future excellence of our nation.", Dr. Rajah Jamilah Rajah Yusof.

University of Thessaly, Greece

"ALIEN reinforced the deployment of active learning in a wide number of courses, increased instructor awareness on active learning, and significantly contributed to internationalization through a network of Asian and European Universities.", Dr. Hariklia Tsalapatas.

University of Central Lancashire, UK

"The best thing that we gained most from ALIEN was to be part of a cross national community in the discussion of learning at higher education level. We felt this two way communication and dialogue was very valuable.", Dr. Janet Read.

ISRA University

"ALIEN had a positive impact on both the faculty members as well as the students. The faculty members were able to incorporate problem-based learning (PBL) practices in their teaching which improved students' level of motivation, understanding, problem-solving skills, and grades. ALIEN also helped in establishing a PBL laboratory and increasing the resources (equipment) that can be used by the faculty members and students for teaching and research".

University of Battambang

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“ALIEN has contributed in upgrading teaching pedagogy via active learning and problem based learning in our existing engineering curriculum”.

Universiti Tenaga Nasional, Malaysia

"ALIEN project has given us the opportunity to collaborate closely with other international institutions in reaching for the common goal of enhancing the teaching and learning experience through active learning and problem-based learning techniques that were systematically introduced, implemented and monitored.”, Dr. Hazleen Aris.

Tribhuvan University, Nepal

"Active learning practices which were new for us in the beginning have significantly contributed to our academic environment in our university by developing industry demanded skills among students and at the same time, it built instructor capacity on innovative learning design.", Dr. Tri Ratna Bhatacharya.

Mean Chey University

" ALIEN project has impact with academics study and changed the norms of students study from individual to group and sharing ideas, experience, knowledge through active learning to solves in PBl ' s lab and display the finding." Mr. Veasna Pich.

Hanoi University

“ALIEN provides our teachers with important knowledge and skills to develop effective and satisfying teaching and learning experience in engineering education ". Dr. Nguyen Xuan Thang, Dean of FIT, Hanu.

Hanoi University of Science and Technology

“The biggest impact of the ALIEN project is that we have leveraged the experience of universities in Europe and Asia in applying active learning when designing new training

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programs as well as when developing learning materials for courses of School of ICT. The PBL lab sponsored by ALIEN is a model for us to deploy more PBL labs for other training programs at HUST.", Dr. Vu Van Thieu.

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APPENDIX 1: Exploitation plan for problem-based laboratory at the University of Malaya

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A1.1 Name of the laboratory

The name of the laboratory is Technology Enabled Learning Space (TEALS). TEALS was established under the Active Learning in Engineering (ALIEN) Project funded by the Erasmus+ implemented in the period 2017-2020. The project gave funding to establish an active learning laboratory. The funding was in total Euro 18 500 equivalent to around RM 85 000. This funding was used to buy equipment such as movable workstations, programmable drones, autonomous cars, 3D printer, Raspberry Pi, Arduino, and writable surfaces. The equipment belongs to the University of Malaya after the project ends in April 2021 and does not belong to the individual grant holder.

The furniture of TEAL, however, was provided by the faculty. It is in-line with a futuristic learning space. At the end of the project, a sustainable plan of action is required to be established in all the partnering universities of the ALIEN project including the one in University Malaya under the Software Engineering department.

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A1.2 Faculty in which the laboratory belongs

TEALS is located at the Faculty of Computer Science and Information Technology (FCSIT).

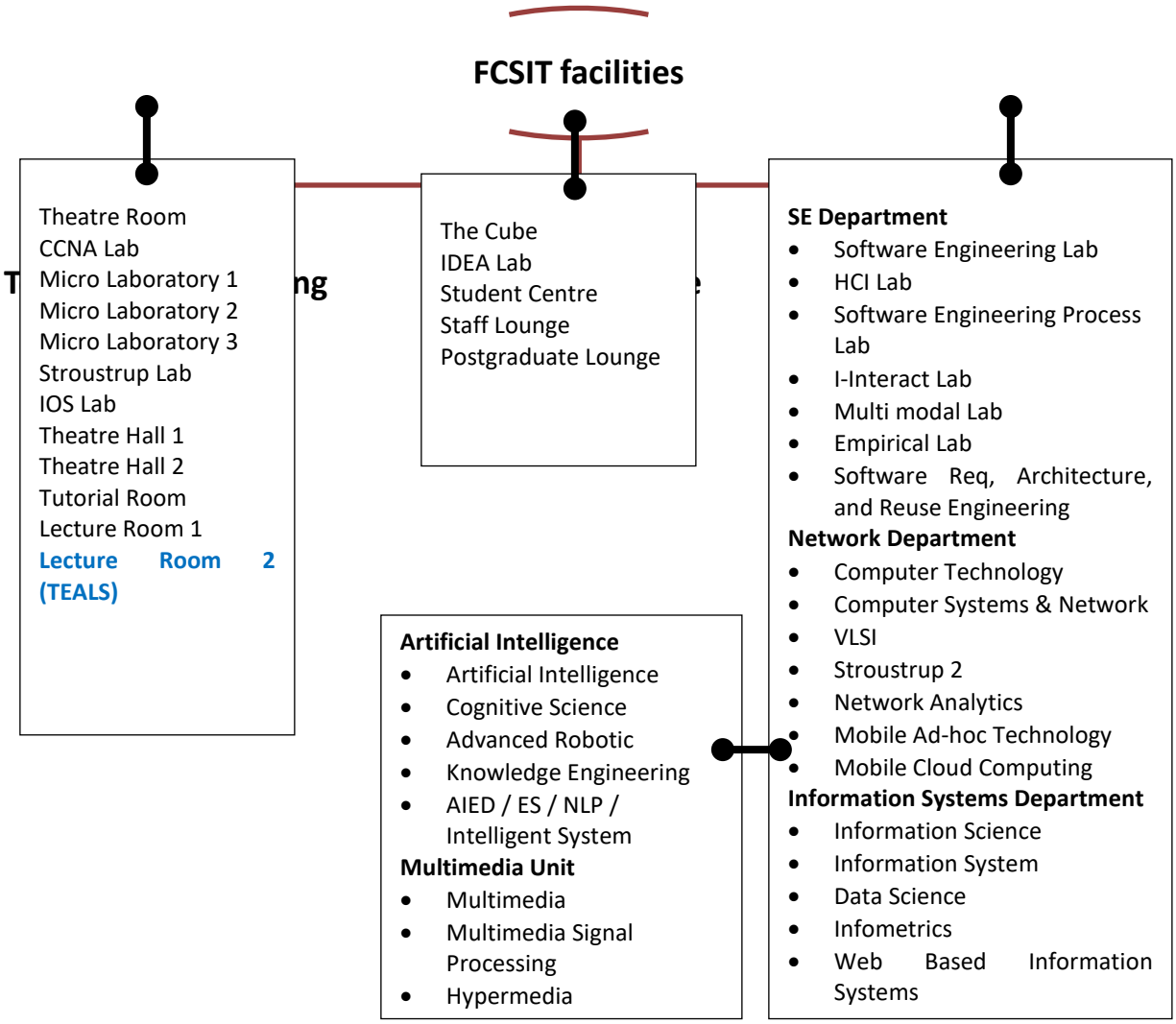

Figure 9. University of Malaya organogram, demonstrating the TEALS laboratory.

It is one of the teaching and learning spaces commonly shared among all members of the faculty. The organogram of FCSIT includes the TEALS laboratory.

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It is one of the teaching and learning spaces commonly shared among all members of the faculty. The organogram of FCSIT includes the TEALS laboratory as shown in the following figure.

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A1.3 Purpose of the laboratory

The purpose of the laboratory is to instill innovative skills in context of cognitive, psychomotor, and affective to FCSIT students and the general public to ignite the potential of students for futuristic skills needed to drive the Malaysian economy to a greater height.

Therefore, it is the purpose of this paper to outline a feasible sustainable model for TEALS that can be used to generate income to the department specifically and generally to the faculty. It is the intention to align this sustainable goal to the concept of Maker's Laboratory.

TEALS is a learning space designed under the ALIEN Erasmus+ project for conducting active learning classes in the Software Engineering Department, Faculty of Computer Science and Information Technology, University of Malaya. The aim of creating the learning space is to equip software engineering students specifically or computer science students in general forthe workplace to solve future problems and to improve the psychomotor, cognitive, and affective skills in teaching and learning software engineering courses. To achieve this aim, hardware and software are used in the active learning process tostrike a good balance between emphasizing knowledge and application of the knowledge.

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A1.4 Guidelines for use of the laboratory

TEALS is designed as a multipurpose laboratory for:

I. Conducting collaborative active learning classes and sessions.
II. Delivering training session to individuals outside of the faculty and University of Malaya.
III. Designing and developing ideas of innovative products.

In order to use the TEALS lab, individuals need to follow the process identified below:

I. Any lecturer in the Faculty of Computer Science and Information Technology could request to conduct classes in TEALS. Every semester, the faculty's time-table committee assigns a random course to be conducted in TEALS. Special request could be made to conduct classes in TEALS so that the lecturer involved will be able to use TEALS equipment to conduct active learning.
II. Students and lecturers from the faculty could also book to use TEALS for any event through the e-booking system of Faculty of Computer Science and information. http://eroom.fsktm.um.edu.my/Web/?
III. Interested persons outside of the faculty would have to write a letter to the Deputy Dean of Research and Development and send the request to rent the usage of TEALS. The letter should be emailed to tdp_fsktm@um.edu.my. The contact numbers are as follows:

    Tel: +603 7967 6305
    Fax: +603 7957 9249
IV. Cost of usage and target users

    The following guidelines apply:

No		

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1.	Software engineering students • At least 3 subjects for each semester	Up to 100 students
2.	Students from other departments • At least 1 subject for each semester	Up to 50 students
3.	The general public • At least 2 events per year	Up to 50 participants
	TOTAL target users per year	At least 200 individuals using the lab

Figure 10. Target users of the TEALS Laboratory.

A.1.4.1 Software and hardware availability and price for rental

For example: Package with training through workshop, one day training, play time with drones, and others.

A1.4.2 Rental Services

	Space	**80/hour**	**min 4 hours**		
Weekdays	Technical	First 3 hours RM50, RM50 every subsequent hour		4 hours	8 hours
Sat/Sun		First 3 hours RM65, RM65 every subsequent hour		950	1465

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Public Holidays		First 3 hours RM70, RM70 every subsequent hour			
	Equipment	**Unit**	**RM**		
	Drone	5	100		
	Workstation	7	100		
	Arduino kit	7	100		
	Rasp pi + kit	7	100		
	Auto Car w/O rasp pi	7	100		
	3D Printer	1 g	1.5		

Figure 11. Equipment available for rental in the TEALS laboratory (price rate may vary and usage may be free of charge or with discount for educational, charitable non-profit events).

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A1.5 The following is an example of the use of TEALS

A1.5.1 Course description

Course Human Computer Interaction (WIF2001) is part of the Software Engineering curriculum. The course covers both human factors and technical methods for the design and evaluation of interactive systems. The course is structured along 4 main topics: overview of human computer interaction (HCI), essential interaction design principles, user interface development process, and interface design and programming.

Overview of human computer interaction introduces humans, computers, and interactions; user interfaces (UI); usability and user experience (UX).

Essential interaction design principles include topics on psychopathology of everyday things, psychology of everyday actions, knowledge in the head and in the world, knowing what to do, understanding and designing for error.

User interface development process includes topics on iterative design, user-centered design, design discovery, design exploration and evaluation of user interfaces.

Interface design and programming includes topics on visual information design, forms design, interface design patterns, prototyping and construction tools, and responsiveness issues.

Three types of applications are covered: graphical user interfaces, the web, and mobile devices.

The number of students engaged in 2020 was 159.

A1.5.2 PBL activities in the course

This scenario describes the active learning conducted in the Human Computer Interaction course and the Mobility Program.

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In the 2020 session of the course, a project was assigned to students, who were challenged to implement it through active learning, specifically project-based learning with the intention to cover the following topics: design principles, conceptual design method, storyboarding, personas, and usability testing. The context of application of these topics is embedded in the following objectives of the project:

- To design, prototype and evaluate an interactive game.
- To apply the knowledge and content of the HCI course in real-life situations using Arduino/Raspberry Pi, 3D printer, and writable surfaces.

The project website is available at http://alien.fsktm.um.edu.my, which illustrates the use of TEALS, the equipment, and the outcomes of the project, namely:

- The conceptual design.
- The game prototypes.
- The persona.
- The usability evaluation.

A1.5.3 Educational material (books, scenarios, etc. and sources)

The following educational material is used. It is downloadable from the Internet.

A1.5.3.1 Active learning – project-based

Two examples of research papers referred to during the course are by Sedelmaier & Landes (2015) and Sibona, Pourreza, & Hill (2018).

The full bibliography information is as follows:

Sedelmaier, Y., & Landes, D. (2015). Active and Inductive Learning in Software Engineering Education. 2015 IEEE/ACM 37th IEEE International Conference on Software Engineering. 5, pp. 418-427. IEEE. doi:10.1109/ICSE.2015.174

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Sibona, C., Pourreza, S., & Hill, S. (2018). Origami: An Active Learning Exercise for Scrum Project Management.: EBSCOhost. Journal of Information Systems Education, 29(2), 105-116.

A1.5.3.2 HCI project description

https://drive.google.com/file/d/1DqoscHXtWMtpN4qN5BPnPyWafu9eX4OV/view?u sp=sharing.

A1.5.3.3 Raspberry Pi reference - what is inside the starter kit

https://www.dexterindustries.com/product/grovepi-starter-kit-2/.

Port Description https://www.youtube.com/watch?v=gbJB3387xUw

https://www.dexterindustries.com/GrovePi/engineering/port-description/

Some Projects: https://projects.raspberrypi.org/en/

A1.5.3.4 Arduino reference - getting started

https://www.youtube.com/watch?v=64oEr1zTlOg.

Downloads (Arduino IDE) and resources:

https://www.arduino.cc/.

https://create.arduino.cc/.

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A1.6 Activities and courses implemented in the laboratory

The list of courses that used TEALS and conducted active learning sessions with the specialized equipment from Semester 2, 2018/2019 to Semester 2, 2020/2021 is as follows:

- Human Computer Interaction (HCI).
- Software Modeling.
- Control Flow Mobility Program.
- Real Time Programming.
- Agile software development.
- Design and Analysis of Algorithms.
- Advanced Algorithms.
- Software Testing.
- Project Management.
- Final Year Project.

Other courses were also conducted in the TEALS laboratory using only the collaborative setup with one workstation per island. TEALS is a common teaching and learning space in the faculty. In addition to collaborative work, the laboratory is also used for normal lectures or presentations. The laboratory is included in the time-table as one of the rooms in which lectures are conducted. The time-table committee may assign the room to a random course as long as the number of students does not exceed the capacity of 49 students.

One of the plans in relation to the usage of TEALS is to make it a specialized laboratory to conduct any course in the Faculty of Computer Science and Information Technology in line with the University and Government policy. Research equipment from expired research projects held by specific lecturers can be put in TEALS to be used in teaching and learning. Consequently, TEALS may provide other equipment then listed in the equipment section. The courses listed at the beginning of this section are the most likely subjects to use TEALS. The courses are part of the Software Engineering curriculum. Other courses from other

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departments are also likely to deploy TEALS. Examples of other departments that may use the laboratory include:

- Artificial Intelligence Department.
- Networking and Computer Systems Department.
- Information Systems Department.
- The Multimedia Unit.

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A1.7 Resources

The following resources are available in the TEALS laboratory.

A1.7.1 Equipment

The following table demonstrates the equipment available in TEALS.

Equipment	Features			Brief description
Workstation	8th GenerationIntel® Core™i5-8400 Processor Windows 10 Home 64bit	8GB DDR 4 2666MHz 16GB Intel®Optane™ memory accelerated 1TB 7200 RPMHDD	Premier Wireless Keyboardand Mouse	One workstationper island

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32" LED Monitor Display	with HDMI Cable Portable Stand for LED TV Display Moveable stand with Adjustable shelf height for storage space	Integrated cable management system Heavy gauge columns constructed Resolution 1366 x 768	HDMI/USB /Compone nt In (Y/Pb/Pr)/ Composite In (AV) Connectivity Slim Type LED Type Wide Color Enhance Slim edge Mold Design	One monitor perisland
Heavy-duty casters	Max load capacity: 46 kg Power Extension Socket Tower Type-2-Tier	With reinforced design support the equipment weight while allowing for swift maneuverability		
Computer	Professional HDMI Cable 2M			

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Peripherals	Asus RT-AC58U AC1300 Dual-Band Gigabit Wireless Router	
Drones	Programmable Drones with accessories	To support programmable hardware projects, which can be related t o software engineering and the Internet of Things (IOT), Machine Learning, and CloudComputing
Raspberry Pi	Raspberry Pi Learning Kit come with user module training/manual	
Arduino	Arduino Learning & Development Kit (complete sensors/modules)	
Autonomous car	Smart Video Car Kit for Raspberry Pi Compatible with RPi 3, 2 and RPi 1 Model B+	
3D Printer	With extra filaments	To facilitate analysis, design, development, andevaluation stagesof software development

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Samsung Galaxy Tab A	A with S-Pen come with Miracast device		For teachers to control lecture materials in an active learning environment
Writable surface	Materials: Acrylic Glass -Background: Avery White	-Size & Thickness: 90 cm x 60 cm x 5 mm	To support brainstorming and discussion sessions with sketches and diagrams to facilitate active learning

Figure 12. TEALS equipment.

A1.7.2 Software

The following software are being used and they are downloadable from the Internet

- Arduino IDE.
- Raspberry Pi OS with all peripherals.
  - Python editor.
- Software for wireless connection to wireless projector.
- 3D Studio to print 3D object.

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A1.7.3 Staffing

The maintainability of the equipment is proposed to be under:

- Technician working in the FCSIT.
- SE department specific technician.
- SE department coordinator lecturer (TEALS Maker's Laboratory coordinator).
- FSKTM-Technovation.

The above staff is already employed by the university.

Maintenance of the website is to be assigned to a web developer and administrators. Below is a list of student project based on classes using TEALS. This project information can serve as an advertisement to display completed projects implemented in TEALS.

- http://alien.fsktm.um.edu.my/
- http://alien.fsktm.um.edu.my/woa7001/group1/group1.html
- http://alien.fsktm.um.edu.my/woa7001/group2/
- http://alien.fsktm.um.edu.my/sem1_2020/group3/g3.html

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A1.7.4 Financial support

Financial support from the University of Malaya will be needed to maintain the laboratory. Essential needs to maintain the usage of the equipment would be:

- The battery for the wireless mouse and keyboard.
- The refill of the 3D printer.
- The replacement of broken Arduino and RaspberryPi and sensors.

It is also possible to buy these through other research funding related to teaching and learning.

The ALIEN equipment bought for TEALS will be maintained as University of Malaya equipment and devices.

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APPENDIX 2: Exploitation plan for problem-based learning laboratory at Universiti Tenaga Nasional

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A2.1 Name of the laboratory

The proposed name of this laboratory is 'Active Learning Lab'. It is used for any activities related to the promotion of active learning in technological courses, be it research or academic activities. It is the extension of the existing problem-based learning lab, with the additions of the workstations and other facilities bought under this grant.

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A2.2 Faculty in which the laboratory belongs

The laboratory is currently located at Level 2, BM building at the College of Engineering, Universiti Tenaga Nasional (UNITEN). Shown below is the organogram of the organization in which the laboratory fits.

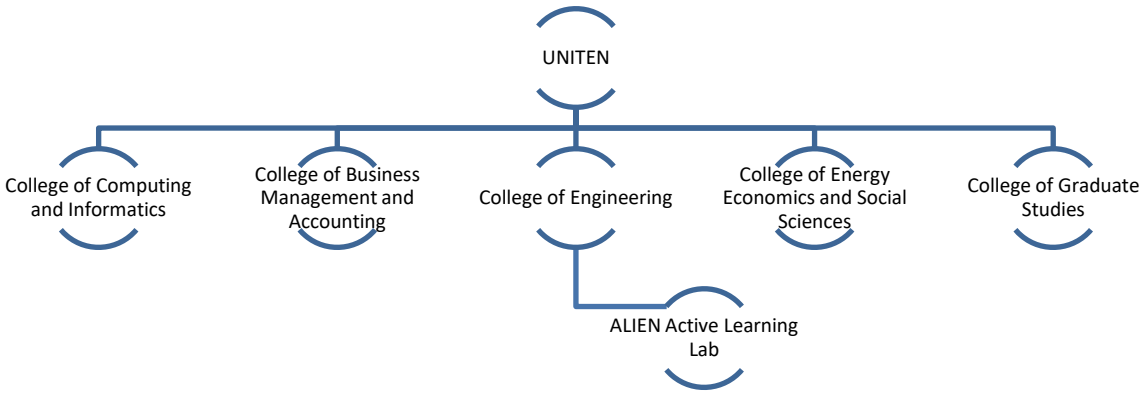

Figure 13. UNITEN organogram, demonstrating the location of the ALIEN laboratory in the organization.

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A2.3 Purpose of the laboratory

The laboratory will be used to facilitate teaching and learning activities. It will also be used to conduct trainings, workshops and AL/PBL activities during classes.

A2.3.1 Guidelines for use

The followings are the instructions for educators who wish to use the laboratory.

- Apply existing booking procedure, fill up online approval form. The educators should provide purpose, brief description of the activities, and number of students. The laboratory can be used once permission is obtained from the Deputy Dean's office.
- During the laboratory sessions, educators are responsible to maintain a good housekeeping.
- Upon completion of use, the educators and students are to fill up online feedback forms
- The scenario of how the laboratory can be used can be found in the ALIEN project Institutional Strategy, available at http://projectalien.eu/index.php/project-reports/ .

A2.3.2 Activities and courses

The table below shows a list of courses in which the laboratory is currently used and will be used in the future.

	Course name	Current	Future	Description
1.	Software Quality	✓	✓	Students are divided into groups to accomplish tasks obtained from the ALIEN PBL platform. The computers are used by the groups to access resources needed to perform the tasks.
2.	Fundamental of Software Engineering		✓	Students work in groups to play a digital serious game developed by UNITEN to train them on requirements gathering and analysis. The computers are used to play

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	Course name	Current	Future	Description
				the game.
3.	Requirement Engineering	✓	✓	Students work in groups to play the digital serious game developed to train them on requirements gathering and analysis. The computers are used to play the game.
4.	System Analysis and Design		✓	Students work in groups to play the digital serious game developed to train them on requirements gathering and analysis. The computers are used to play the game.
5.	Fundamental of Software Engineering (Diploma)		✓	Students work in groups to play the digital serious game developed to train them on requirements gathering and analysis. The computers are used to play the game.
6.	System Analysis and Design (Diploma)		✓	Students work in groups to play the digital serious game developed to train them on requirements gathering and analysis. The computers are used to play the game.
7.	Power System (Diploma)	✓		PBL activities on per-unit topic. Students are divided into groups to solve assigned problems. The computers are used to obtain resources from the internet.
8.	Power Electronics (Diploma)		✓	MATLABORATORY Simulink is installed on the computers. The students design and build converter models as per requirements given. Then, they present their findings in the class.
9.	Mechanics II: Dynamics	✓		Demonstrations for kinetic motion are conducted in the laboratory. Students are to solve the problems based on the mechanism shown during the activity.
10.	Manufacturing Processes Laboratory		✓	Welding activity via augmented reality is introduced to students in the laboratory. At the end of the session, students produce a report based on the activity.
11.	Object-oriented Programming	✓	✓	Students are divided into groups and upon confirming a topic/problem to be solved, students are asked to identify system requirements by referring to existing systems the description of which can be

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	Course name	Current	Future	Description
				discovered on the internet using the computers in the laboratory. The group then is asked to write a program to implement the identified requirements to produce the system solution by using the IDE installed in the laboratory.
12.	Fundamentals of Data and Information	✓		[During pandemic COVID-19: virtual learning] Using Telegram as main communication channel for announcements and discussions, flipped classroom method, peer reviewing, and active learning using online discussion tools such as Padlet.
13.	Algorithmic Problem Solving	✓		[During pandemic COVID-19: virtual learning] Students are assigned a problem to be presented in pairs through a video, in a game-playing method instead of a formal presentation. Prior to that, students are to sit in a lecture session on algorithm techniques. A pre-recorded video is also available in the university LMS so that students can refer to the techniques at their own time. The problem question is uploaded onto the Moodle LMS platform and MS Teams assignment so that students can easily access the question.
14.	Data Communication and Network	✓		[During pandemic COVID-19: virtual learning] One of the topics is network planning for IPv4 where students are to design a network based on some criteria and requirements in groups. One group consists of four to five students. The problem is shared on the official LMS platform, Moodle, Padlet and also uploaded onto the ALIEN PBL platform so that the students can conveniently access the problem.

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	Course name	Current	Future	Description
15.	Physics for Engineering			[During pandemic COVID-19: virtual learning] One of the topics chosen to be covered using active learning methods is thermodynamics where students are given learning resources in the form of lecture notes or lecture videos. One group comprise of three to four students. The problem is also uploaded onto the ALIEN PBL platform so that the students can easily access the problem and that the problem can also be shared with other instructors. Students are required to complete the given crossword puzzle by actively search for the keywords or descriptions of the terms in either lecture note or lecture video. With the COVID-19 pandemic, the activity is slightly modified such that the students discuss among themselves using virtual communication platforms.
16.	Numerical Methods for Engineers	✓		[During pandemic COVID-19: virtual learning] How a one-hour lecture is conducted: Warm-up exercises and questions (Facebook, Telegram), lecture, answering the given questions, lecture, and conclusion with a short quiz/discussion. Small group project: students are assigned open ended engineering problems to be solved using numerical methods and mathematical software installed in the laboratory. One of the activities in the group project is to present their findings to the class.

Figure 14. Courses in which the laboratory is used at University Tenaga Nasional.

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A2.4 Resources

A2.4.1 Equipment

The equipment available in the laboratory includes the 11 workstations bought for active learning use, a projector, and existing furniture and wall mounted widescreens. Details are as below.

- 1 High-spec game development PC.
- 1 EPSON EB-X05 projector.
- 10 Tower desktop gaming PCs.

A2.4.2 Staffing

An admin executive has been appointed as a manager, to handle the booking, housekeeping, and the well-being of the laboratory. At least 10 trainers are expected to utilize the facilities in the laboratory. Two technicians have also been assigned. They are in charge of maintaining the equipment. All staff is already employed by the organization.

A2.4.3 Financial support

After the project is completed, to sustain the laboratory operations, the OPEX financial resources will be covered by different departments in the university as follows.

- Staff costs will be handled by UNITEN's Human Resource.
- Upgrading of furniture and equipment (where and if necessary) will be handled by the Facility Development and Management Dept.
- Upgrading and updating of hardware and software will be handled by the IT and Multimedia Services Dept.

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APPENDIX 3: Exploitation plan for problem-based learning laboratory at ISRA University.

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A3.1 Name of the laboratory

The name of the laboratory is “Problem-Based Learning Lab”.

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A3.2 Faculty in which the laboratory belongs

ISRA University, Hyderabad campus offers various degree programs in 4 faculties. These faculties are:

1. Faculty of Medicine and Allied Medical Sciences.
2. Faculty of Dentistry and Allied Sciences.
3. Faculty of Commerce, Economics & Management Sciences.
4. Faculty of Engineering, Science and Technology (FEST).

The Problem-Based Learning (PBL) Laboratory is established in Academic Block B of ISRA University, Hyderabad campus and it is accessible to all faculty members of all departments of FEST.

More specifically, the following departments use the lab:

1. Department of Computer Science.
2. Department of Electrical Engineering.
3. Department of Mechanical Engineering.
4. Department of Civil Engineering.

Figure 15. The entrance to the Problem-Based Learning Laboratory.

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A3.3 Purpose of the laboratory

The Problem-Based Learning Laboratory can be used by all faculty members of FEST who intend to use equipment available in the laboratory in their courses, use problem-based learning practices in the courses, or supervise problem-based related projects in the courses that they teach or final year projects.

A3.3.1 Guidelines for use

The faculty members of FEST who intend to use the Problem-Based Learning Laboratory in their courses are expected to inform the departmental subject allocation committee who further informs the timetable coordinating committee to allocate the Problem-Based Learning Laboratory to specific teachers. This will ensure there is no clash in the Problem-Based Learning Laboratory timetable. The Information Technology Support Services (ITServ) department receives a copy of the timetable, allocates the use of available equipment in time slots, and resolves issues (if any) before the start of the semester. The staff that works at the ITServ department is also responsible for opening and closing the Problem-Based Learning Laboratory for the faculty members to use and regularly, before and after the Problem-Based Learning Laboratory use, inspect the equipment record to ensure that units are in working condition. Faculty members will be introduced upon request to the ALIEN digital learning platform by the coordinating person of the ALIEN project so that platform may also used in the courses.

A3.3.2 Activities and courses

The list of courses in which the equipment available in the Problem-Based Learning L was used in the August 2019, January 2019, and August 2020 semesters is as follows:

- Introduction to Algorithms.
- Advanced Computer Networks.
- Final Year project.

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- Object Oriented Software Engineering.
- Basic Electronics.
- Programming Fundamentals.
- Human-Computer Interaction.
- Software Quality Assurance.
- Object Oriented Programming.

A3.3.3 Characteristic use of the laboratory in a specific course

Following is a description of typical use of the laboratory space in a characteristic course, specifically in Design and Analysis of Algorithms.

A3.3.3.1 Description of the course

The Design and Analysis of Algorithms course introduces students to the design and analysis of algorithms and covers topics that include applied theoretical tools and techniques for analysis of algorithms, such as recurrence relations, amortization and counting, computation and reasoning on the upper and lower asymptotic bounds of the performance of algorithms, and selecting appropriate algorithms that are expected to have higher performance in a given situation.

A3.3.3.2 Description of the participants

The course is mandatory for 2nd year students in the Bachelor of Science in Computer Science program. It is also an elective in the Bachelor of Science in Software Engineering and the Bachelor of Science in Information Technology programs. Approximately 50 students are enrolled in the course each academic year. This is an advance level course. Participants of the course have been exposed to the problem-based learning. They apply active learning for the design and analysis of algorithms related to their complexity time and space.

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A3.3.3.3 Description of active learning activities deploying ALIEN methodologies and tools

Students were exposed to active learning in the ALIEN Problem-Based Learning Laboratory. During the course, students performed practical activities. They followed specific steps given by the teacher to solve specific exercises. The goal of the exercises was to develop understanding of sorting and searching concepts in the analysis of algorithms. Firstly, students performed manual sorting on a deck of cards. Students performed sorting by selecting the smallest card in the unsorted pack and moving the card to a second hand. The activity was concluded when all cards have been removed from the unsorted hand; at that time the second hand contained the card in sorted order. Time taken to sort all the cards was recorded.

Steps:

1. Get a hand of unsorted cards.
2. Repeat step 3 and 5 until the unsorted hand is empty.
3. Compare unsorted cards.
4. Select the smallest unsorted card.
5. Move this card to the sorted hand.
6. Stop.

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A3.4 Resources

A3.4.1 Equipment

The following list of equipment is available in the Problem-Based Learning Lab:

1. 2 HTC VIVE virtual reality systems HTC.
2. 3 Oculus rift and touch virtual reality system.
3. 2 LEAP motion VR DEV bundle.
4. 1 PIPO X9s, Box Android TV 8.9-inch Tablet Mini PC.
5. 3 workstations with INTEL core i7, 8700K, 8th Gen, ASUS motherboard ROG Strix B360, 32GB RAM, DVD writer, Corsair 200R casing, Corsair power supply, GIGABYTE GeForce graphing card, Logitech keyboard and mouse.
6. 3 HP Monitors 27 Inches - 27F.
7. 1 Apple MacBook Pro 15.

A3.4.2 Staffing

All labs across the university are managed and maintained by the staff of ITServ department. ITServ staff members are hired by the ISRA University. They regularly inspect the condition of all equipment to ensure that units are in a working condition and fix any issues that may arise. The staff that works at ITServ provides access to the laboratory before the start of a laboratory session and closes the laboratory after the session is over.

A3.4.3 Financial support

The laboratory equipment requires timely maintenance to ensure the working condition of the units. All departments submit foreseen maintenance costs as part of their annual departmental budget for approval by the administration. Each department then uses the allocated

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maintenance budget for the maintenance of the equipment. Similarly, the equipment of the Problem-Based Learning Laboratory will also be maintained from the same organizational budget after the completion of the project. The Problem-Based Learning Laboratory will be taken care of by regular ITServ staff. Therefore, no additional staff will be hired to look after the Problem-Based Learning Laboratory and its equipment.

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APPENDIX 4. Exploitation plan for problem-based learning laboratory at Von Neumann Institute

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A4.1 Name of the laboratory

The laboratory oratory is funded by the ALIEN project and is established at the John von Neumann Institute (JVN). JVN is an institute that directly belongs to Viet Nam National University of Ho Chi Minh City (VNUHCM). It is located at the JVN building in IT Park of VNUHCM, Quarter 6, Linh Trung Ward, Thu Duc District, Ho Chi Minh City, Viet Nam. The laboratory oratory is named “Active Learning Laboratory oratory”. It is identified through the logo of the ALIEN project and is co-located with the laboratory of data science. The server of laboratory oratory is installed in the server room of JVN.

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A4.2 Faculty in which the laboratory belongs

JVN has 2 scientific programs, namely Information and Communications Technology and Quantitative Computational Finance. Each scientific program has a graduate program and a laboratory oratory where JVN's lecturers, students, and researchers can work together in courses or projects. Through this model, JVN's students have a great opportunity to join in more practical projects with their lecturers or researchers, not only from JVN but also from industrial partnerships of JVN with companies.

This laboratory is used by both the scientific programs. Therefore, this laboratory can be the destination of all courses of graduate programs and all projects of JVN. For that reason, from the design phase, JVN introduced the solution of supporting physical and virtual working environments. The students can access the ALIEN active learning platform for their courses through laptops in the laboratory oratory or through an Internet connection from their own location. This solution has demonstrated advantages, especially in the COVID-19 pandemic.

The figure below shows how the laboratory oratory fits in JVN's organogram of departments and programs:

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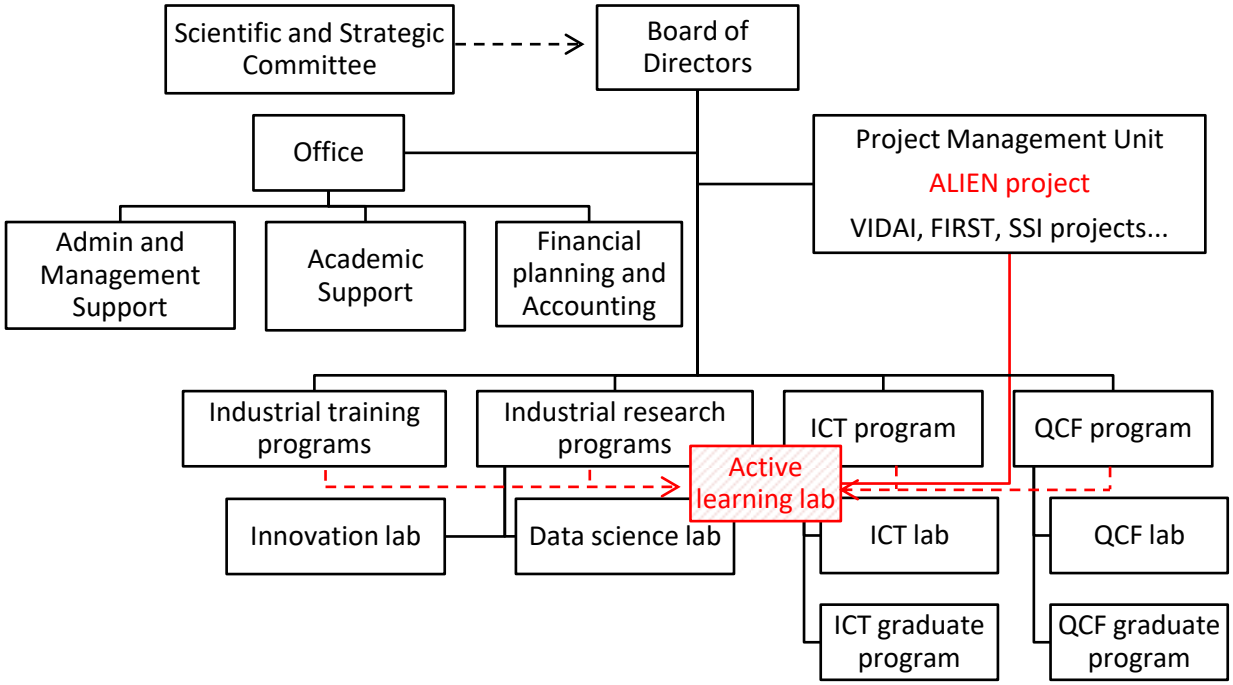

Figure 16. The Active Learning Laboratory in JVN's organogram.

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A4.3 Purpose of the laboratory

The laboratory oratory will be used by students under JVN's lecturers' instruction in the courses of JVN's ICT and QCF graduate programs. With the laboratory oratory's resources, lecturers and students may work together in their courses more interactively and innovatively using the virtual machine enabled server, wireless connection hub, and a large monitor available on site. In the case of remote working, JVN provides a VPN connection through an Internet broadband network and a VMWare installed server.

A4.3.1 Guidelines for use

The guidelines for using the laboratory are:

- Lecturers will register their courses in the laboratory each semester. They will prepare the activities that will take place in the laboratory using laboratory resources such as laptops, servers, connections, and software.
- Students will register for using the laboratory in a registration plan managed by a researcher.
- The registration plan will be approved by the lecturers and the project manager and will be communicated to the researcher for his cooperation.
- After each semester a report how to use the laboratory more effectively and improve active learning for students will be prepared.

A4.3.2 Activities and courses

Following is a list of courses in which the laboratory is currently used:

1. Enterprise Architecture: The course is part of the ICT graduate program at John von Neumann Institute. The course is also offered in the ICT graduate program in Polytechnic University of Ho Chi Minh City. 12 students enrolled in semester 1 of academic year 2019 -

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2020 and 15 students enrolled in semester 1 of the academic year 2020 - 2021. The lecturer of the course is Dr. Huy Nguyen (JVN). Students implemented the following steps and activities:

- Students studied, presented, and discussed the general definition of enterprise architecture.
- Students selected a business scenario to build an enterprise architecture work.
- Students looked for different business reference models to use in their scenario.
- Students reviewed lessons with interactive games using Kahoot®. Students created the games themselves under teacher guidance. After each game, the lecturer posed questions on the wrong or unclear answers, encouraging students to discover more on the missed points.
- Students played scenario games in which they provided input related to the practical application of knowledge and techniques in developing enterprise architectures.
- Students used EA Sparx® and Dropbox® to build and share their results with their classmates and lecturer.
- Students worked in groups to develop models and presented their results to their peers and the instructor.
- Students summarized their results in a shared document that they collectively edited.
- Students raised concerns or interests during the course and engaged in discussions with their classmates in the final session. The lecturer helped students align their points with the framework of the course for developing more effective understanding of concepts and enabling student to apply new knowledge in practice.

2. Decision Analysis: The course is part of the Quantitative Computational Finance graduate program at John von Neumann Institute. This course is also offered in some Applied Mathematics graduate programs in University of Economics and Law - VNUHCM and University of Natural Sciences - VNUHCM. 22 students enrolled in semester 2 of academic

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year 2018 - 2019 and 17 students enrolled in semester 2 of academic year 2019 - 2020. The lecturer of the course is Dr. Brett Houlding (TCD) and Dr. Man Ngo (JVN). Trinity College Dublin (TCD) is the partner of JVN in the VIDAI project funded by Irish Aid.

Students implemented the following steps and activities:

- Students studied analysis techniques and finished the exercises in different contexts given by the lecturer.
- Students selected a topic in a pre-defined list and prepared a data story through which they illustrated the related concepts to the lecturer and their classmates.
- Students researched different data analysis models and data sources applicable in their scenario.
- Students reviewed lessons with interactive games using Kahoot®. Students created the games themselves under teacher guidance. After each game, the lecturer posed questions on the wrong or unclear answers, encouraging students to discover more on the missed points.
- Students played scenario games in which they provided input related to the practical application of knowledge and techniques in decision making.
- Students used R, Python, and Google® Class to build and share their results with their classmates and lecturer.
- Students worked in groups on the analysis of the scenario that they selected and prepared a presentation summarizing their findings for the benefit of their classmates.
- Students summarized their results in a shared document that they collectively edited.
- Students assumed roles of professionals in a data science department. They discussed plans for applying their knowledge and skills in the context set by the lecturer.
- Students raised concerns or interests during the course and engaged in discussions with their classmates in the final session. The lecturer helped students align their points with

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the framework of the course for developing more effective understanding of concepts and enabling student to apply new knowledge in practice.

3. Time Series Analytics and Forecasting: The course is part of the Quantitative Computational Finance graduate program at John von Neumann Institute. The course is also offered in some Applied Mathematics graduate programs in University of Economics and Law - VNUHCM and University of Natural Sciences - VNUHCM. 21 students enrolled in semester 2 of the academic year 2018 - 2019 and 16 students enrolled in semester 2 of academic year 2019 - 2020. The lecturer of the course is Dr. Jason Wyse (TCD) and Dr. An Mai (JVN). Trinity College Dublin (TCD) is the partner of JVN in the VIDAI project funded by Irish Aid.

   Students implemented the following steps and activities:

   - Students studied analysis techniques and executed exercises in different contexts provided by the lecturer.
   - Students selected a topic and data package from a pre-defined list and applied different data analysis techniques for understanding the story in focus. They presented the story to the lecturer and their classmates. The story was used to predict the future of the scenario using evidence from their analysis results.
   - Students reviewed lessons with interactive games using Kahoot®. Students created the games themselves under teacher guidance. After each game, the lecturer posed questions on the wrong or unclear answers, encouraging students to discover more on the missed points.
   - Students played scenario games in which they provided input related to the practical application of knowledge and techniques in their scenario of choice.
   - Students used R and Python to build and share their results with their classmates and lecturer.
   - Students worked in groups on the analysis of the scenario that they selected and prepared a presentation summarizing their findings for the benefit of their classmates.

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- Students summarized their results in a shared document that they collectively edited.
- Students packaged their solutions as an application and demonstrated in a presentation to their lecturer and classmates how to use the application in similar contexts.
- Students raised concerns or interests during the course and engaged in discussions with their classmates in the final session. The lecturer helped students align their points with the framework of the course for developing more effective understanding of concepts and enabling student to apply new knowledge in practice.

4. IT Management: The course is part of the ICT graduate program at John von Neumann Institute. 17 students enrolled in semester 2 of academic year 2018 - 2019 and 21 students enrolled in semester 2 of academic year 2019 - 2020. The lecturer of the course is Dr. Huy Nguyen (JVN).

   Students implemented the following steps and activities:

   - Students studied, presented, and discussed the general definition of and roles in IT management.
   - Students selected a business scenario on which they would build an IT plan.
   - Students looked for different potential IT solutions to apply in their scenario.
   - Students reviewed lessons with interactive games using Kahoot. These games are Students reviewed lessons with interactive games using Kahoot®. Students created the games themselves under teacher guidance. After each game, the lecturer posed questions on the wrong or unclear answers, encouraging students to discover more on the missed points.
   - Students played scenario games in which they provided input related to the practical application of knowledge and techniques in developing and operating an IT solution effectively.
   - Students used Office® software, modeling tools, and Dropbox® to build and share their results with their classmates and the lecturer.

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- Students worked in groups on aspects related to the development, exploitation, and maintenance of an IT solution for a specific scenario and presented their findings to the teacher and their classmates.
- Students summarized their results in a commonly owned shared document.
- Students raised concerns or interests during the course and engaged in discussions with their classmates in the final session. The lecturer helped students align their points with the framework of the course for developing more effective understanding of concepts and enabling student to apply new knowledge in practice.

5. Management Information Systems: The course is part of the ICT graduate program at John von Neumann Institute. However, this course is also offered appropriately in the ICT undergraduate program in Ho Chi Minh University of Technology and the ICT graduate program in University of Economics and Finance. 23 students enrolled in semester 1 of academic year 2019 - 2020 and 27 students enrolled in semester 1 of academic year 2020 - 2021. The lecturers of the course are Dr. Huy Nguyen (JVN) or Dr. Minh Nguyen (IU-VNUHCM).

   Students implemented the following steps and activities:

   - Students studied, presented, and discussed the general definition of management roles and management information systems.
   - Students selected a business scenario on which they would build an IT solution.
   - Students researched different viewpoints in developing and operating an MIS.
   - Students reviewed lessons with interactive games using Kahoot. These games are Students reviewed lessons with interactive games using Kahoot®. Students created the games themselves under teacher guidance. After each game, the lecturer posed questions on the wrong or unclear answers, encouraging students to discover more on the missed points.

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- Students played scenario games in which they provided input related to the practical application of knowledge and techniques in developing and operating an MIS.
- Students used Office® software, modeling tools, and Dropbox® to build and share their results within their classmates and lecturer.
- Students worked in groups on aspects related to the development of an MIS modeling and development plan and presented their findings to the teacher and their classmates.
- Students summarized their results in a commonly owned shared document.
- Students raised concerns or interests during the course and engaged in discussions with their classmates in the final session. The lecturer helped students align their points with the framework of the course for developing more effective understanding of concepts and enabling student to apply new knowledge in practice.

6. Network Programming: The course is part of the ICT undergraduate program at Vietnam Germany University and University of IT - VNUHCM. 35 students enrolled in semester 2 of academic year 2018 - 2019 and 42 students enrolled in semester 2 of academic year 2019 - 2020. The lecturers of the course are Dr. Huy Nguyen (JVN) or Dr. Nam Nguyen (UIT-VNUHCM).

   Students implemented the following steps and activities:

   - Students worked in groups on coding Java programs to fulfill system requirements provided by the lecturer.
   - Students designed their own solutions based on theoretical frameworks and recommendations introduced through lectures.
   - Students researched different models for building effective communication applications.
   - Students reviewed lessons with interactive games using Kahoot®. Students created the games themselves under teacher guidance. After each game, the lecturer posed questions on the wrong or unclear answers, encouraging students to discover more on the missed points.

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- Students played scenario games in which they provided input related to the practical application of knowledge and techniques in developing networks.
- Students used Eclipse®, Java, and Dropbox® to build and share their results within their classmates and lecturer.
- Students worked in groups on aspects related to the development of an MIS modeling and development plan and presented their findings to the teacher and their classmates.
- Students summarized their results in a commonly owned shared document.
- Students raised concerns or interests during the course and engaged in discussions with their classmates in the final session. The lecturer helped students align their points with the framework of the course for developing more effective understanding of concepts and enabling student to apply new knowledge in practice.

7. Methodology and Skill for Scientific Research: The course is part of both the ICT and QCF graduate programs at John von Neumann Institute. This course is also offered in the ICT graduate programs at the University of Natural Sciences - VNUHCM and the Polytechnic University of Ho Chi Minh City. 39 students enrolled in semester 2 of academic year 2018 - 2019 and 32 students enrolled in semester 2 of academic year 2019 - 2020. The lecturers of the course are Prof. Bao Ho (JVN), Prof. Vu Duong (JVN), Dr. Huy Nguyen (JVN), Dr. An Mai (JVN) and Dr. Quang Nguyen (JVN).

   Students implemented the following steps and activities:

   - Students studied the phases of the scientific writing process. They worked in groups on a topic of their choice.
   - Students selected their own approach for writing and presenting their work, which was structured as a research paper.
   - Students researched related scientific articles and other documents. They discussed their findings under the guidance of the lecturer. They prepared and delivered a presentation of their work for the benefit of their classmates and the lecturer.

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- Students reviewed lessons with interactive games using Kahoot®. Students created the games themselves under teacher guidance. After each game, the lecturer posed questions on the wrong or unclear answers, encouraging students to discover more on the missed points.
- Students played scenario games in which they provided input related to the practical application of knowledge and techniques in identifying a research topic of interest, researching the context of the work, and preparing a written research proposal.
- Students used Office® software and Google® class to develop presentations and share their results within their classmates and the lecturer.
- Students worked in groups on selecting a research topic and performing a literature review.
- After each important milestone of the project students prepared and presented a progress report that was evaluated by their classmates and lecturers.
- Students executed exercises and tests for evaluating and improving soft skills in the digital age, such as creative thinking, active listening, and team work.
- Students summarized their results in a commonly owned shared document.
- Students raised concerns or interests during the course and engaged in discussions with their classmates in the final session. The lecturer helped students align their points with the framework of the course for developing more effective understanding of concepts and enabling student to apply new knowledge in practice.

Following is a list of courses in which the laboratory will be used in the next intakes or semesters:

1. Advanced Programming in Finance: The course is offered in the 1st semester of the QCF graduate program. It enrolls 20 students. The course is delivered by 1 lecturer and 1 academic assistant. Both will use the laboratory. The pedagogical approach of this course is learning by examples and practical enhancement through exercises and mini projects.

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2. Numerical Methods in Finance: The course is offered in the 2nd semester of the QCF graduate program. It enrolls 20 students. The course is delivered by 1 lecturer and 1 academic assistant. Both will use the laboratory. The pedagogical approach of this course is increasing direct interaction through practical projects to help students understand better the theoretical issues.
3. Business Process Modeling: The course is offered in the 2nd semester of the ICT graduate program. It enrolls 20 students. The course is delivered by 1 lecturer and 1 academic assistant. Both will use the laboratory. The pedagogical approach of this course is learning by applying the theoretical issues in real contexts and practical enhancement through mini-projects.
4. Data Modeling: The course is offered in the 2nd semester of the ICT graduate program. It enrolls 20 students. The course is delivered by 1 lecturer and 1 academic assistant. Both will use the laboratory. The pedagogical approach of this course is learning by applying the theoretical issues in real contexts and practical enhancement through mini-projects.

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A4.4 Resources

A4.4.1 Equipment

Figure 17. Equipment at the problem-based learning laboratory at Von Neumann Institute.

The laboratory includes equipment was purchased through the ALIEN project as well as equipment purchased through other JVN resources.

The equipment purchased through the ALIEN project is the following:

5. 1 server for computational and storage purposes. This server has VMWare installed to create virtual machine for different platform requirements emerging in courses.
6. 1 switch for high speed and extensible connection between users and servers if required. Typically, it is used when a larger number of students joins a class.

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7. 1 high speed WiFi hub for mobility in working groups.
8. 1 smart board used as a display. It creates a highly interactive working environment in the laboratory.
9. 1 workstation for the lecturer.
10. 4 high performance laptops with touch screens for students.

The following equipment is provided by JVN:

- Working space: Co-location with the data science laboratory in an area of 50m^2. This area is air conditioned and appropriately lit.
- Furniture: The laptops and electronic devices are installed on a table with chairs. It can support a group of 5 - 10 students.
- Internet connection: The laboratory is equipped with a high speed Internet connection with a VPN enabled switch to support remote connection.
- Power supply: The laboratory is equipped with sustainable power supply in the IT Park where JVN is located.
- The laboratory is protected by hardened doors and windows with fingerprint authentication. The laboratory is cleaned daily.

A4.4.2 Staffing

The support team is comprised of:

- A technician who has a clear understanding of the equipment and the usage of the laboratory. The technician is in charge of maintaining equipment as well as supporting laboratory users. When using the laboratory, lecturers are provided with a hotline through which they may contact the technician for help.
- A researcher who has experience in applying active learning. The researcher further has experience on using this laboratory in courses.

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- Lecturers who can flexibly use the equipment and software available in the laboratory in the laboratory to create activities for classes.
- Cleaning staff that keeps the laboratory clean for daily use.

JVN employs a technician and cleaning staff to maintain and ensure good working conditions in the laboratory. For the laboratory operation JVN selected a researcher from the QCF program to support the registration and reporting processes. Moreover, JVN has a culture of self-discipline in using and protecting the working environment for the benefit of all.

A4.4.3 Financial support

The expenses for operating the laboratory include staff costs, Internet connectivity costs, power supply costs, and updating and maintenance of equipment. These costs are managed and controlled according to JVN's regulations on budget registration and payment.

After the completion of the ALIEN project, the laboratory will continue to be used under the management of JVN. All expenses are covered by JVN budget.

Benefits from using the laboratory include quality improvement of the courses, satisfaction enhancement of students, better interaction between lecturers and students, and, most importantly, opportunities for students to become more active and innovative in applying their knowledge and skills in practical contexts. These benefits are significant and justify covering the laboratory expenses through the JVN budget. Each newly admitted class of students is assessed as more competent by companies and JVN's industrial partners as a result of active learning. This helps JVN achieve a better reputation in academics and research.

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APPENDIX 5: Exploitation plan for problem-based learning laboratory at Hanoi University

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A5.1 Name of the laboratory

The laboratory at Hanoi University is named “ALIEN problem-based learning lab”. This name briefly and accurately describes the purpose of the laboratory. Besides, the prefix ALIE indicates that the laboratory is funded by the project ALIEN.

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A5.2 Faculty in which the laboratory belongs

The ALIEN problem-based learning laboratory belongs to the Faculty of Information Technology, Hanoi University. The following is the organogram of Hanoi University which shows where in the university the laboratory fits.

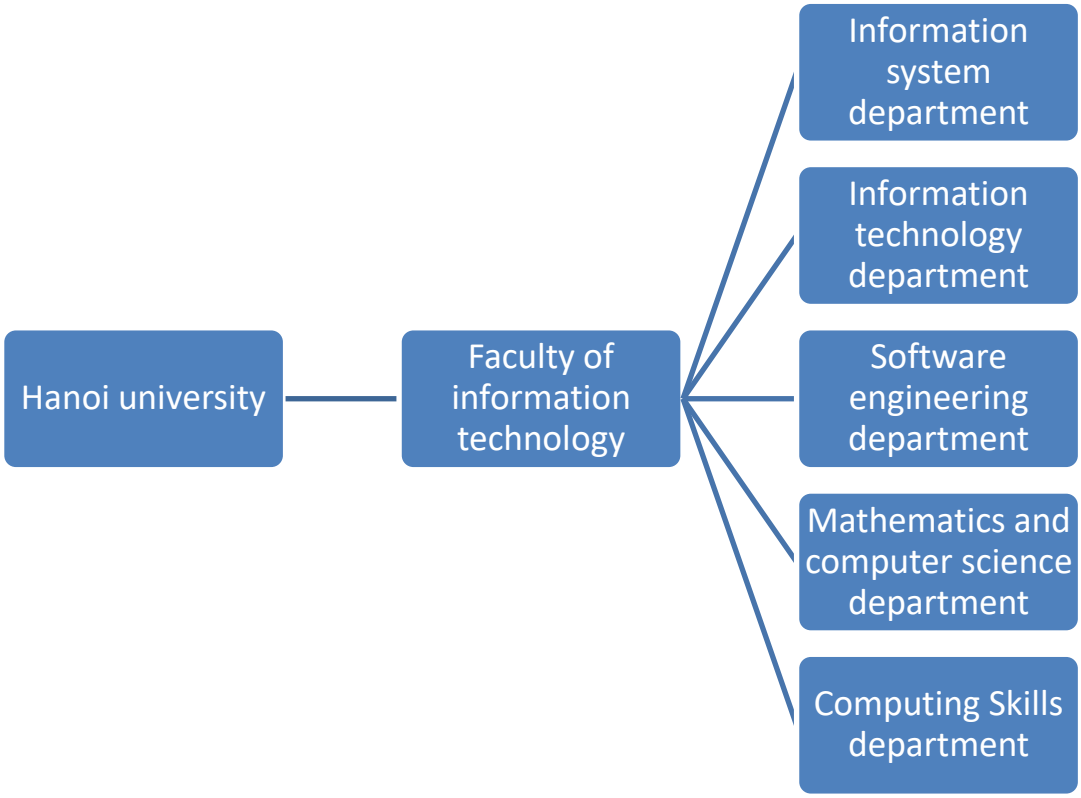

Figure 18. Organogram of Hanoi University.

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A5.3 Purpose of the laboratory

The ALIEN problem-based learning laboratory at Hanoi University is used to promote new pedagogical methodologies such as game-based, and problem-based learning. It is designed specifically for active learning with moveable tables that can be reordered to create flexible space for different games or activities. Moreover, all needed equipment for applying active learning in 3 main courses is installed with reasonable numbers for students to use. The laboratory supports 20 – 25 students at a given session, who can work in groups utilizing the available equipment.

A5.3.1 Guidelines for use

The following guidelines are provided for laboratory users:

- The laboratory includes equipment designed specifically for teaching multimedia design. However, it is also suitable for a wide variety of subjects due to the flexibility of room design and high-quality facilities.
- For teachers who are not experienced in using the lab, the project technician will guide in detail on how to use the equipment and assist when needed. Teachers may call a hotline number provided in advance.
- The laboratory supports approximately 25 students at a given time. It is suitable for classes with a small number of students, and is not designed for classes with large numbers of students.
- Teachers and students can rearrange the configuration of the tables and chairs but are not allowed to disassemble the equipment.
- Besides courses that are assigned to use the laboratory officially with fixed timetable, any teachers or tutors who want to use the laboratory need to inform the support team in the department at least 1 week in advance. The team will arrange a suitable time for each and inform within a day.

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A5.3.2 A scenario for the use of the laboratory

Following is an example of the use of the laboratory. It is provided as inspiration for educators and students on the type of learning activities that may be supported through the laboratory.

Course title: Multimedia design.

Engineering curriculum where it belongs: Multimedia.

Course objectives: To teach the basic elements of multimedia. Specifically:

- To teach how to combine different elements in one multimedia product
- To teach how to leverage text, image, sound, animation and video clip to convey meaningful messages.
- To guide how to design and manage a multimedia project

Number of students to be engaged: 70.

Problem-based learning activities that will be integrated in the course: A series of activities that may be included in the course for helping students understand elements of multimedia, stages, and skills in making multimedia, multimedia tools, and more. A range of different activities and teaching methodologies may be deployed to address the entire range of leaning objectives of the course as these are described above. The following are some examples:

- Analyze different multimedia products to see how they are used in different fields, such as business, education, at home, at market places, and more.
- Revise the lesson using fun and interactive games in Kahoot® (https://kahoot.com/b/) or Quizlet® (https://quizlet.com/latest). After having students play the game, teachers may ask students to identify the benefit of multimedia in education.
- Play a “fonts have feelings” game printing messages using bad font choices, asking students how the fonts and words make them feel. Challenge students to find a better font for the selected message.

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- Have students design their own font using Fontstruct® (https://fontstruct.com/).
- Select 5 different web pages, each from a different web site. Select pages that contain lots of colors and images, both photographs and graphics. View the 5 different pages on both a Macintosh and a PC screen, preferably side by side, as well as on more than one computer on the same platform, for example use one Mac and two Windows computers. Note the differences in how each page appears across platforms and screens. For each page, write a paragraph describing how they differ in terms of color tone, saturation, and any other noticeable characteristics.
- Play a Headsup® game (projector required) to enhance students' memory on the 12 principles of animation.
- Show samples of animation, some of which follow the 12 basic principles and some do not. Ask students to identify the differences among them. Ask students to build their own animation based on the 12 principles. Students may present the final result in class.
- Locate 3 multimedia projects and review the credits. Ask students to identify: How many members were on the team? What were their titles? How many team members performed more than one role? What tasks were "outsourced" to external companies? Ask students to create a table that compares the titles for similar roles among the 3 projects. For each role, discuss how the team related to the product.

Equipment, software, and educational material to be used: Following is a list of course supporting equipment:

- **Equipment:** Computers, multimedia workstations with high-end graphics, 2 laptops, scanner A4, short throw projector, i-board, laser printer A3, Swivl® robot and solution, and project accessories.
- **Software:** MS office®, Audacity®, Adobe Photoshop®, Dreamweaver®, Pencil2D®, Blender®.
- **Educational material:**

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Multimedia: making it work by Tay Vanghau, 8th edition Li, Z. and S. Drew, M. (2004). Fundamentals of Multimedia. 1st ed. Prentice-Hall.

Fit portal: http://fit.hanu.vn/.

- **Other materials:** Google® email, Google® drive, Fontstruct® (online).

A5.3.3 Activities and courses

A5.3.3.1 Courses in which the laboratory was used in the past

Multimedia Design

Students learn the basic components of multimedia communication and how to combine them using existing tools and techniques. The course also helps students understand how to use pictures, sounds, and video clips to convey the message in the most meaningful way. At the same time, students build knowledge on how to design and manage a multimedia communication project.

This is an elective course that targets undergraduate students in the Department of Information System, Faculty of Information Technology, Hanoi University. 51 students enrolled in the course in semester 1 of the 2019-2020 academic year. All students were in the 3rd year of their studies.

Special Subject 01

Students work on research topics under the guidance of the. Topics are related to web design, human-computer interaction, multimedia design, and more.

This is an obligatory course that targets 2nd year undergraduate students from the Department of Information System, Faculty of Information Technology, Hanoi university. Approximately 17 students were enrolled in semester 1 of academic year 2019-2020.

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Special Subject 02

This course is a continuation of Special Subject 01. The course introduces special topics that can be the extended or advanced part of topics addressed in Special Subject 01. Students work in the same groups as in Special Subject 01 and develop an application based on the results of their research in Special Subject 01. Alternatively, students may conduct additional literature review and research on a topic of interest.

This is a 3rd year mandatory course for undergraduate students in the Department of Information System, Faculty of Information Technology, Hanoi University. The course enrolled 20 students in semester 1 of the 2019-2020 academic year.

Information Systems Design and Implementation

The course builds knowledge on how to design and implement an information system step by step. The course addresses the following themes: understanding agile design methodologies, understanding how to specify and analyze the user requirements, being able to deploy design tools, analyzing and designing accurately, implementing, and managing a project.

This is an obligatory course that targets 4th year undergraduate students in the Department of Information System, Faculty of Information Technology, Hanoi university. Approximately 42 students enrolled in the course in semester 2 of the 2019-2020 academic year.

Data Structures and Algorithms

The course aims to equip learners with basic knowledge on algorithms and data structures as well as their practical applications. It builds student capacity to understand and apply algorithms and data structures properly, to evaluate and select appropriate algorithms or data structures for a specific project, and to design and implement algorithms or data structures in the Java® programming language for learning, researching, and working.

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This is an obligatory course that targets 3rd year undergraduate students in the Department of Information System, Faculty of Information Technology, Hanoi university. Approximately 32 students enrolled in the course in semester 2 of the 2019-2020 academic year.

A5.3.3.2 Courses in which the laboratory is currently used

Database Design

The course builds student capacity to design a database system using appropriate relational database design tools. Upon completion of the course students are able to fully design a relational database system for a substantial problem. They are further able to develop a fully functional relational databases system based on an existing design. Finally, students are able to test a database system based on the system requirements.

This is a 3rd year obligatory course. It was taught in semester 1 of academic year. The course engaged 105 students.

System Analysis and Design

The course builds student knowledge on gathering data for analyzing and specifying system requirements, designing system components and environments, building general and detailed morels that assist programmers in implementing a system, designing a database for managing data, designing a user interface for data input and output, and designing controls for protecting systems and data.

This is a 3rd year obligatory course. It was taught in semester 1 of academic year 2020-2021. The course engaged 121 students.

A5.3.3.3 Courses in which the laboratory will be used in the future

Information Systems Design and Implementation

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The course is described above. It is conducted in semester 2 of each academic year. Active learning is being applied in this course starting in academic year 2019-2020. Activities will continue in the 2020-2021 academic year (January – May, 2021). The ALIEN problem-based learning laboratory will be deployed in the course.

Special Subject 02

The course is described above. The course engages 20 – 40 students in each academic year. Active learning has been applied in the course starting in academic year 2019-2020. Activities will continue in the 2020-2021 academic year (January – May, 2021). The ALIEN problem-based learning laboratory will be deployed in the course.

Multimedia Design

The course is described above. Active learning has been applied in the course starting in academic year 2019-2020. Activities will continue in the 2020-2021 academic year (January – May, 2021). The ALIEN problem-based learning laboratory will be deployed in the course.

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A5.4 Resources

A5.4.1 Equipment

- Computers and laptops

Students will work in groups; each group use 1 computer and/or 1 laptop to design their multimedia product in class. It's is important to test the final product on different computers so both desktop computers and laptops must be used.

- Multimedia workstations with hi-end graphics

The multimedia workstations offer high-quality design especially suitable for making animation and video in the course.

- Scanner a4

Scan images and documents when students learn image editing. Besides this one can be used to scan required documents for the course such as leaflet or book covers.

- Printer a4

Students can use printer to print documents or images when they learn image editing and typeface designing. Moreover, this one can be used when students need to see differences between soft version and printed version of an image or documents.

- Short throw projector

The projector is used by teachers and students to deliver presentation or product demonstration, for playing educational games like mentioned above.

- I-Board

Displaying students' multimedia product or idea. Moreover, it can interact with the short throw projector to make an effective presentation.

- Laser printer A3

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Using printer to print documents or images when students learn image editing and typeface designing. There are 2 printers for different requirements of the course

- Swivl robot and solution

This equipment is used to record all lecture delivered by teachers. All recorded files will be used as material for making online class (an example of multimedia in education)

- Accessories for projectors

For the usage of projectors

- Wifi

For laptops and mobile phones to access the internet.

A5.4.2 Staffing

The support team is comprised of a technician who has a clear understanding of the room's equipment and usage of the classroom. The technician is in charge of maintaining equipment as well as supporting users of the laboratory. When using the lab, teachers are provided with a hotline that they can call the technician for help. We also need one teacher who has experience in applying active learning and using this laboratory in courses. The tutor can flexibly use the equipment and software available in the laboratory to create activities for classes. This person is a key staff of the ALIEN project at Hanu and will take on the role of training, sharing room usage experiences with other teachers. In addition, an assistant of the faculty will manage the scheduling of the lab's classes as well as receive registration from teachers.

The individuals are already employed by our faculty.

A5.4.3 Financial support

After the project is completed, the laboratory will continue to be used under the management of the Faculty of Information Technology, Hanoi University. Fees to maintain the laboratory

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include the staff costs for 2 technicians to maintain and support the teachers and student to use the laboratory. Expenses for machinery maintenance, equipment repair in case of damage and equipment supplementation according to the training needs of the faculty.

These expenses will be deducted from the tuition fee paid by students to Hanoi University. In addition, a part of the budget will be deducted from the sponsorship packages of companies that cooperate with the Faculty of Information Technology such as GMO RUN System Company, FPT Corporation, SEPTENI Company, or IFI solution company or company.

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APPENDIX 6: Exploitation plan for problem-based learning laboratory at the National University of Battambang

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A6.1 Name of the laboratory

For the National University of Battambang (NUBB), the name of the laboratory built through the ALIEN project is “the Problem-Based Learning (PBL) Laboratory.” The project implementation team had a discussion with the Rector, who agreed to change the name of Information Technology Laboratory to PBL Laboratory. This laboratory is used by undergraduate and postgraduate students of different faculties and schools. Approximately 150 students use this laboratory for their studies weekly.

Figure 19. The ALIEN PBL Laboratory.

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A6.2 Faculty in which the laboratory belongs

This laboratory belongs to the Faculty of Science and Technology that offers majors on Information Technology and Civil Engineering.

Organizational Structure of National University of Battambang (NUBB)

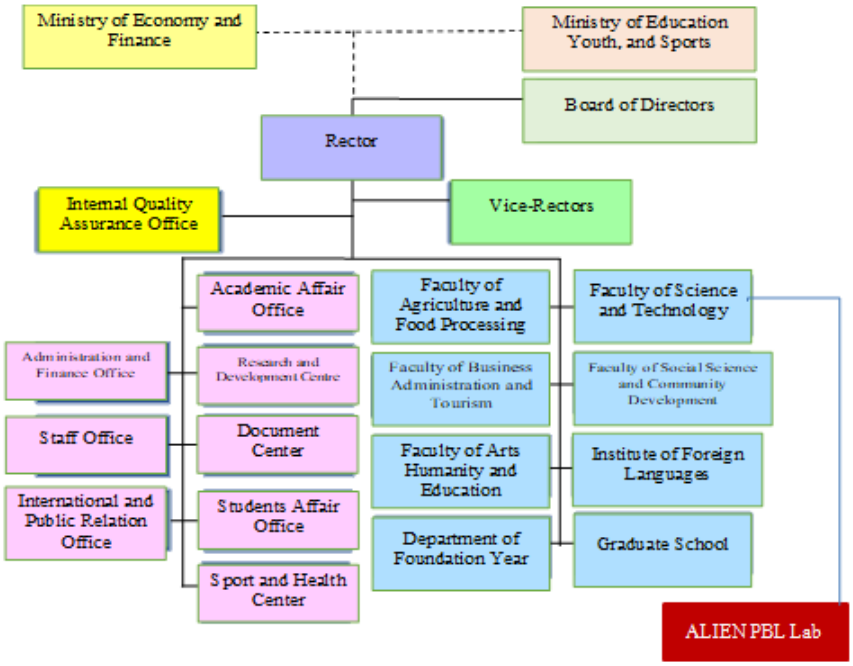

Figure 20. NUBB organogram, that shows the ALIEN PBL Laboratory.

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A6.3 Purpose of the laboratory

This laboratory is purposively used for teaching and learning activities addressing both undergraduate and postgraduate students who may benefit from active learning. Several courses deploy problem-based and active learning since the method was introduced by the ALIEN project. The PBL Laboratory aims at promoting active learning deployment among students. It further offers equipment and software facilities. Lecturers use the PBL laboratory for instructional practices that apply experiences and knowledge acquired from the ALIEN project. Lectures promote active learning by using the PBL Laboratory for introducing problems to students. Students solve the problems in the PBL Lab, increasing their exposure to active learning.

A6.3.1 Guidelines for use

The PBL Laboratory may used for the instruction of any course in the Faculty of Science and Technology. It is further openly available to all lecturers who need to practice and to teach in the Laboratory. Further support is provided by a Laboratory and Network Administrator who is in charge of the maintenance and operation of the laboratory. To use the lab, an instructor is required to contact the administrator to reserve the room. The administrator provides guidelines to the instructor on the use the laboratory. The administrator also supports the instructor for the setup of any necessary additional software on the lab's equipment to support the implementation of active and problem-based learning in his/her classroom. The PBL Laboratory is designed for use by 25 to 30 students working in 5 groups. Each group is allocated one PC and one Smart 42 inches TV that is used as a projector. The equipment is installed on a table with 5 chairs, with a total of 5 tables in the room. A LDC projector may be used to display a problem and explanations to students. The students may display their findings for the benefit of all in the class. All PCs are connected to the internet.

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For example, the PBL Laboratory is used to teach the Course of Scientific Writing and Communication to a group of 60 4th year students. During the course the lecturer displays a problem on the screen and the students solve the problem in groups.

A6.3.2 Activities and courses

Following are subjects that already use ALIEN's PBL Laboratory.

1. JavaScript.
2. Data Communication and Networking.
3. Management Information System (MIS).
4. Scientific Writing and Communication.
5. Creating an HTML Web Page.
6. Safety in Construction.
7. Structural Analysis.
8. E-Commerce.
9. Advanced Calculus.
10. Construction Technology.

Detailed descriptions of course content and the implementation of active and problem-based learning in each is available on the ALIEN project "Evaluation of the Implementation Phase" Report. Activities will continue beyond the end of the ALIEN project implementation.

Activities will be coordinated by the Faculty of Science and Technology and supported by the Information Technology Center and Administrative and Financial Office. The role of the Information Technology Center is maintaining the PBL Laboratory and promoting its use to

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other faculties. This approach allows the continued use of the PBL Laboratory by students in courses even after the completion of the ALIEN project.

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A6.4 Resources

A6.4.1 Equipment

The following figure demonstrates the equipment available in the lab:

The hardware acquired in the framework of the ALIEN project consists of 6 Dell Computers, 5 Mobile Stands, 1 LCD Projector, 2 Laptops, and 1 WiFi Router Link. Specifically, the following equipment is available in the laboratory:

- 6 Dell computers.
- 5 mobile stands.
- 2 computer laptops.
- 1 LCD projector.
- 1 wi-fi router.

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ALIEN Active Learning In Engineering Education

Inventory of NUBB Equipment

Based on the Erasmus+ Partnership Agreement on the project Support of ALIEN project: Erasmus+ **586297-EPP-1-2017-1-ELEPPKA2-CBHE-JP**, NUBB-ALIEN Team would like to put the equipment of ALIEN project which is funded by Erasmus+ Programme below to the National University of Battambang as the inventory equipment:

No.	Equipment	Quantity (unit)
1	Desktop Dell Core i7 Completed Set	6
2	Smart TV 43" Sony and Mobile TV Stands	5
3	D-Link Router WIFI	1
5	Apple MacBook Pro 15" 2018	2
6	LCD Projector (V11H740522 Epson EB-695Wi)	1

Done at Battambang, 10 March 2021

Having seen and approved

Rector

SOK KHORN

Prepared by Project Coordinator

Dr. Sam Rany

Figure 21. Equipment available in the ALIEN PBL Laboratory.

A6.4.2 Staffing

NUBB is a public university. The ALIEN's PBL Laboratory belongs to the Faculty of Science and Technology. The faculty's staff is responsible for the operation and maintenance of all labs and the network infrastructure of the department. The ALIEN's PBL Laboratory is maintained by the faculty's technical and other supporting staff.

A6.4.3 Financial support

Since the ALIEN's PBL Laboratory belongs to the Faculty of Science and Technology, it will be maintained and paid by the faculty based on the annual budget allocated by the university. The cost of operation will be covered by NUBB and the Ministry of Education, Youth, and Sport (MoEYS). The operational cost on the laboratory includes:

- The recruitment of technical staff and administrators for the purpose of maintenance and operation of the laboratory and network infrastructure.
- The equipment maintenance costs and laboratory consumables. Practically, equipment and electronic devices are removed (right off) after 5 years of operations or use. The Ministry of Education, Youth, and Sport and Ministry of Economy and Finance have financed NUBB based on the proposed annual budgets that cover all teaching and learning equipment.

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APPENDIX 7: Exploitation plan for problem-based learning laboratory at the Institute of Technology Cambodia

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A7.1 Name of the laboratory

The name of the problem-based laboratory established in the context of the ALIEN project is "**ALIEN's PBL Laboratory**". The following pictures demonstrate the laboratory space.

Figure 22. Students work on projects in the ALIEN's PBL Laboratory.

A7.2 Faculty in which the laboratory belongs

The ALIEN's PBL Laboratory belongs to the Department of Information and Communication Engineering (GIC), Faculty of Electrical Engineering, Institute of Technology Cambodia. Following is an organogram of Institute of Technology Cambodia that demonstrates the link of the laboratory in the organization's overall activities.

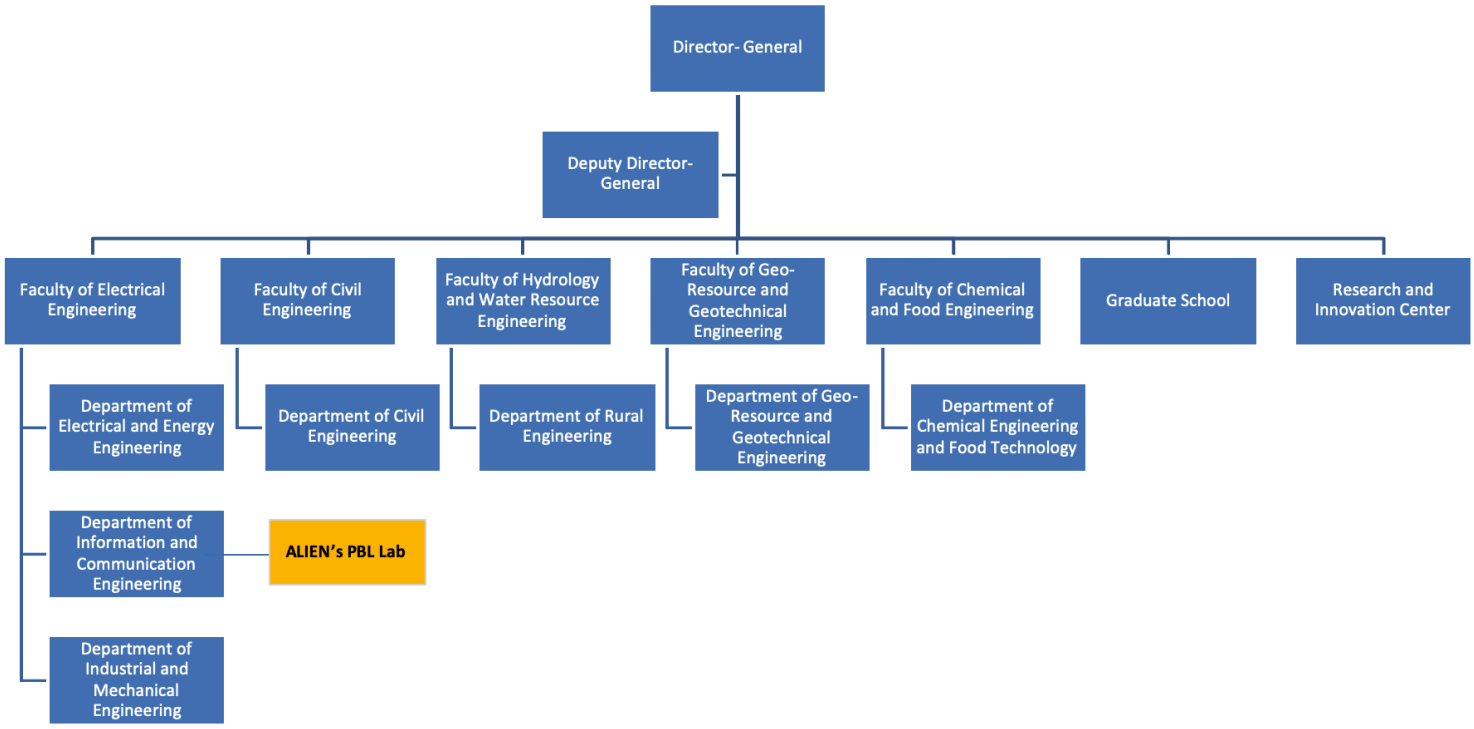

Figure 23. The Institute of Technology Cambodia organogram, with ALIEN's PBL Laboratory integrated.

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A7.3 Purpose of the laboratory

ALIEN's PBL Laboratory aims to promote active learning, and especially the problem-based learning (PBL) in the Institute of Technology Cambodia. The laboratory offers basic facilities and software for supporting the implementation of problem-based learning. The problem-based learning activities are supported by teaching staff from the Department of Information and Communication Engineering who participated in the ALIEN project. The teachers will act as problem-based learning "ambassadors" transferring their knowledge and experience to colleagues for promoting the wider adoption of active and problem-based learning through the deployment of digital infrastructure and software tools that enrich educational experiences, increase interactivity, promote exploration, and foster collaboration.

A7.3.1 Guidelines for use

The laboratory is openly available to all instructors at the Department of Information and Communication Engineering (GIC). It is further openly available to all instructors of all departments in the Faculty of Engineering.

Further support is provided by a Laboratory and Network Administrator who is in charge of the maintenance and operation of the laboratory. To use the laboratory, an instructor is required to contact the administrator to reserve the room. The administrator will provide guidelines to the instructor on the use the laboratory. The administrator may also support the instructor to setup additional software on the laboratory's equipment to support the implementation of active and problem-based learning in his/her classroom.

The ALIEN's PBL laboratory's capacity is about 20 students with 20 laptops and 2 Smart TVs with 55 inches screen size. All devices are connected on a wireless network which allows them to communicate with each other. The TVs may be used as projectors or boards for presenting lessons, assignments, problems, activities, and more. The TVs may also be used to display the results of a discussion among students as well as delivering presentations. The 20 laptops,

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equipped with software tools, are reserved for use by students in the context of problem-based learning activities.

An example of using problem-based learning in the laboratory is as follows. In the Algorithms and Programming course, which targets 3rd year students in the Department of Information and Communication Engineering, the instructor introduces a problem which requires students to work in groups or individually to design a solution algorithm. The problem is displayed on the laboratory screens. Students may work together in groups of 2 - 3 individuals to introduce a solution to the problem. Then, they may use the laptops and programming software installed to implement their solution / algorithm in practice. Each group or individual may present their findings on the screens to receive feedback and comments from instructors and other groups in the class.

A7.3.2 Activities and courses

Following are subjects that already use ALIEN's PBL Laboratory.

1. Algorithms and Programming.
2. Compilers.
3. Computer Networks.
4. Natural Language Processing.
5. Software Engineering.
6. Image Processing.
7. Informatics.
8. Mining Project Management.
9. Ore Microscopy.

Detailed descriptions of course content and the implementation of active and problem-based learning in each is available on the ALIEN project Evaluation of the Implementation Phase report [**Error! Reference source not found.**][**Error! Reference source not found.**].

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Activities will continue beyond the end of the ALIEN project implementation. This will be achieved through the Higher Education Improvement Project (HEIP), which is supported by World Bank. Through this project, the Institute of Technology Cambodia will continue to strengthen and improve the organization's teaching and learning approached. In the short-term, namely the next 1 to 2 years, the organization will involve additional instructors and ensure the use of the laboratory in additional courses in the Department of Information and Communication Engineering and the Department of Geo-Resource and Geotechnical Engineering, which have been involved in ALIEN project, towards the implementation of active and problem-based learning through the ALIEN's PBL Laboratory. In the medium-term, namely the next 3 to 5 years, the organization plans to further promote the adoption of active and problem-based learning to all faculty members.

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A7.4 Resources

A7.4.1 Equipment

The hardware acquired in the framework of the ALIEN project consists of 20 laptops and 2 Smart TVs that are deployed as projectors. Specifically, the following equipment is available in the laboratory:

- 10 laptops Asus X507UF
- 10 laptops Asus S510UN
- 2 LG 55UH8500 Super UHD 4k HDR SMART

A7.4.2 Staffing

The ALIEN's PBL Laboratory belongs to the Department of Information and Communication Engineering (GIC). The department has allocated 2 Laboratory and Network Administrators in GIC who are responsible for the operation and maintenance of all the laboratories and the network infrastructure of the department. The ALIEN's PBL laboratory will be maintained by the 2 Laboratory and Network Administrators.

A7.4.3 Financial support

Given that the ALIEN's PBL Laboratory belongs to the Department of Information and Communication Engineering, it will be maintained under the regular operation costs of the department. The cost of operation will be covered by the Institute of Technology Cambodia and the Ministry of Education, Youth, and Sport (MoEYS). The cost includes:

1. The recruitment of Laboratory and Network Administrators for the maintenance and operation of all laboratory and network infrastructure in the department.
2. The equipment maintenance costs and laboratory consumables.

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Normally, GIC replaces or upgrades electronic devices, and in particular computers, in laboratories after five years of usage. The funds for renewing the equipment come from be provided at the time of replacement by MoEYS.

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APPENDIX 8: Exploitation plan for problem-based learning laboratory at Mean Chey University

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A8.1 Name of the laboratory

The name of the problem-based laboratory installed for the ALIEN project is "**ALIEN's PBL Lab**".

The students be applied practice as following pictures demonstrate the laboratory space.

Figure 24. Installed ALIEN's PBL Laboratory.

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A8.2 Faculty in which the laboratory belongs

This PBL's Laboratory installed for faculty of Science and Technology in Mean Chey University and using for students applied theory and practice. Also, other faculties can be use the PBL's Lab, if they have overall activities related to the subjects. As following is an organogram of Mean Chey University that demonstrate the Link of the PBL' s Laboratory in the organization overall activities.

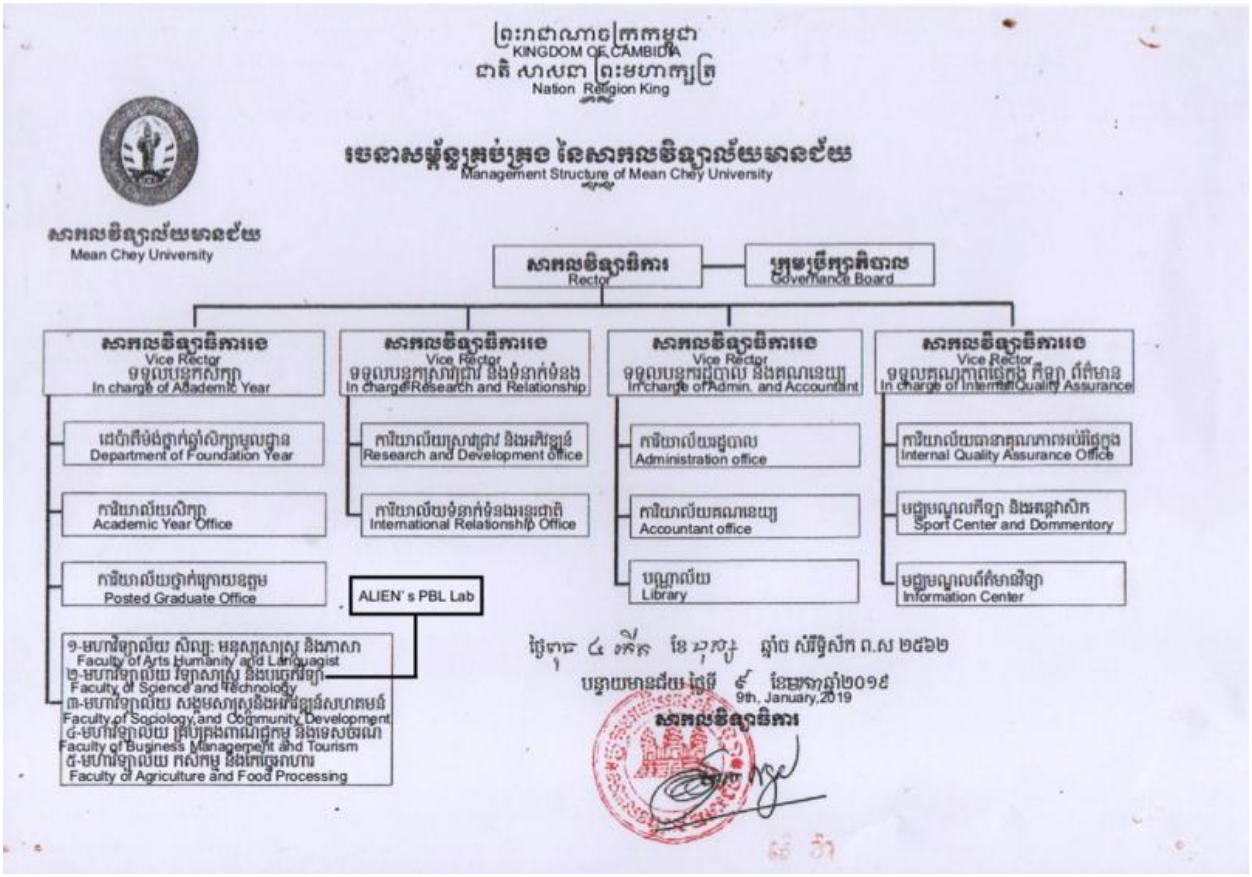

Figure 25. Faculty Science and Information in charge of ALIEN PBL's Laboratory.

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A8.3 Purpose of the laboratory

The PBL's Laboratory to promoting the activities students to study by active learning to increase the student's activities. The PBL's Laboratory offered the facilities related to software supported the implementation by using PBL's laboratory. The staff teaching in the PBL's Lab, they are all knowledge how to transfer their experience to apply PBL's Laboratory supported by ALIEN Project. The teachers can be promoting all activities to use the PBL's Laboratory by provide the problems to students and solve problems in the PBL's Laboratory to increase students' s activities in group work than teachers' s activities.

A8.3.1 Guidelines for use

The laboratory can be used for all instructor of courses. It is further openly available to all instructors of all Information Technology Center (ITC).

Further support is provided by a Laboratory and Network Administrator who is in charge of the maintenance and operation of the laboratory. To use the laboratory, an instructor is required to contact the administrator to reserve the room. The administrator will provide guidelines to the instructor on the use the laboratory. The administrator may also support the instructor to setup additional software on the laboratory's equipment to support the implementation of active and problem-based learning in his/her classroom.

The ALIEN's PBL laboratory's capacity is about 25 students with 5 groups. Each group have one PC, Smart VT 42 inches use instead of monitor screen one table and 5 chairs. One LDC Projector use to display the problem, explain to students or students can display their finding to each group. All PCs has connected with internet.

An example of using problem-based learning in the laboratory is as follows. The subject business statistic for 42 student's year 2, the teacher display problem in screen and the students solved problem in groups.

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A8.3.2 Activities and courses

Following are subjects that already use ALIEN's PBL Laboratory.

10. Visual Basic programming
11. Information System Analysis Design
12. Internet Programming HTML
13. Computer Network
14. Data Structure
15. Data Base System
16. Java Programming
17. Client- Server Computer
18. Applying Statistic
19. Basis Accounting

Detailed descriptions of course content and the implementation of active and problem-based learning in each is available on the ALIEN project Evaluation of the Implementation.

Activities will continue beyond the end of the ALIEN project implementation. We have to organized with Faculty of Science and Technology and responded by Information Technology Center (ITC), The role of ITC is maintaining the PBL's Laboratory and promoting to another faculty are involve to use Laboratory. So all activities still continues event if the ALIEN project has finished the PBL' s Laboratory still used and students has adopted for the next courses.

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A8.4 Resources

A8.4.1 Equipment

The hardware acquired in the framework of the ALIEN project consists of 6 Dell Computers, 5 Mobile Stands, 1 LCD Projector, 2 Laptops, 1 WiFi Router Link Specifically, the following equipment is available in the laboratory:

- 6 Dell Computers
- 5 Mobile stands
- 2 Laptops
- 1 LCD Projector
- 1 WiFi Router

A8.4.2 Staffing

The ALIEN's PBL Laboratory belongs to the Information Technology Center supported by Faculty of Science and Technology. Information Technology Center who are responsible for the operation and maintenance of all the laboratories and the network infrastructure of the department. The ALIEN's PBL laboratory will be maintained by a Laboratory and Network Administrators.

A8.4.3 Financial support

Given that the ALIEN's PBL Laboratory belongs to the Information Technology Center, it will be maintained under the regular operation costs of the department. The cost of operation will be covered by Mean Chey University and the Ministry of Education, Youth, and Sport (MoEYS). The cost includes:

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3. The recruitment of Laboratory and Network Administrators for the maintenance and operation of the laboratory and network infrastructure.
4. The equipment maintenance costs and laboratory consumables.

Normally, the equipment can be replacing or upgrades electronic devices, and in particular computers, in laboratories after five years of usage. The funds for renewing the equipment come from be provided at the time of replacement by MoEYS we call program budget (PB).

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APPENDIX 9: Exploitation plan for problem-based learning laboratory at Tribhuvan University

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A9.1 Introduction

The Central Visualization Systems Laboratory namely Problem Based Laboratory was established in Institute of Engineering, Tribhuvan University under the Active Learning in Engineering (ALIEN) project funded by the Erasmus+ implemented in the period 2017-2020. The project had provision of funding to establish an active learning laboratory which is in total of Euro 18500. This funding was used to buy and establish the laboratory. This laboratory was established in the premises of Centre for Energy Studies (CES), Zero Energy House, Pulchowk Campus complex. The facilities will be used by the faculty, researchers and students of Tribhuvan University. Among the facilities of the laboratory, equipment and accessories were procured under the ALIEN project whereas other facilities were provided by the Centre for Energy Studies, Institute of Engineering, Tribhuvan University. It is in-line with a futuristic learning space. For sustainability of use of the lab, a sustainable plan has been developed.

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A9.2 Purpose of the laboratory

The main purpose of the laboratory is to develop students' practical and transferable skills, as well as their content knowledge and scientific understanding, and also to address the concern expressed in the literature over the effectiveness of the traditional laboratory courses to achieve these objectives.

It is expected to provide students with the opportunity to develop skills related to:

- Working in groups.
- Leadership development and holding leadership roles.
- Better communication, both oral and written.
- Self-awareness.
- Working independently.
- Critical thinking and analysis.
- Applying course content to practical field.
- Researching and information literacy.
- Problem solving across disciplines.

It is expected the Central Visualization facilities will encourage students to prepare for their laboratory sessions in an active and collaborative manner through pre-laboratory exercises. By combining elements of group work, group discussion, practical hands-on activities, and various alternative assessment methods the students will be provided with an environment conducive to meaningful, deep learning.

The following picture is the organizational chart of the Institute of Engineering, Tribhuvan University.

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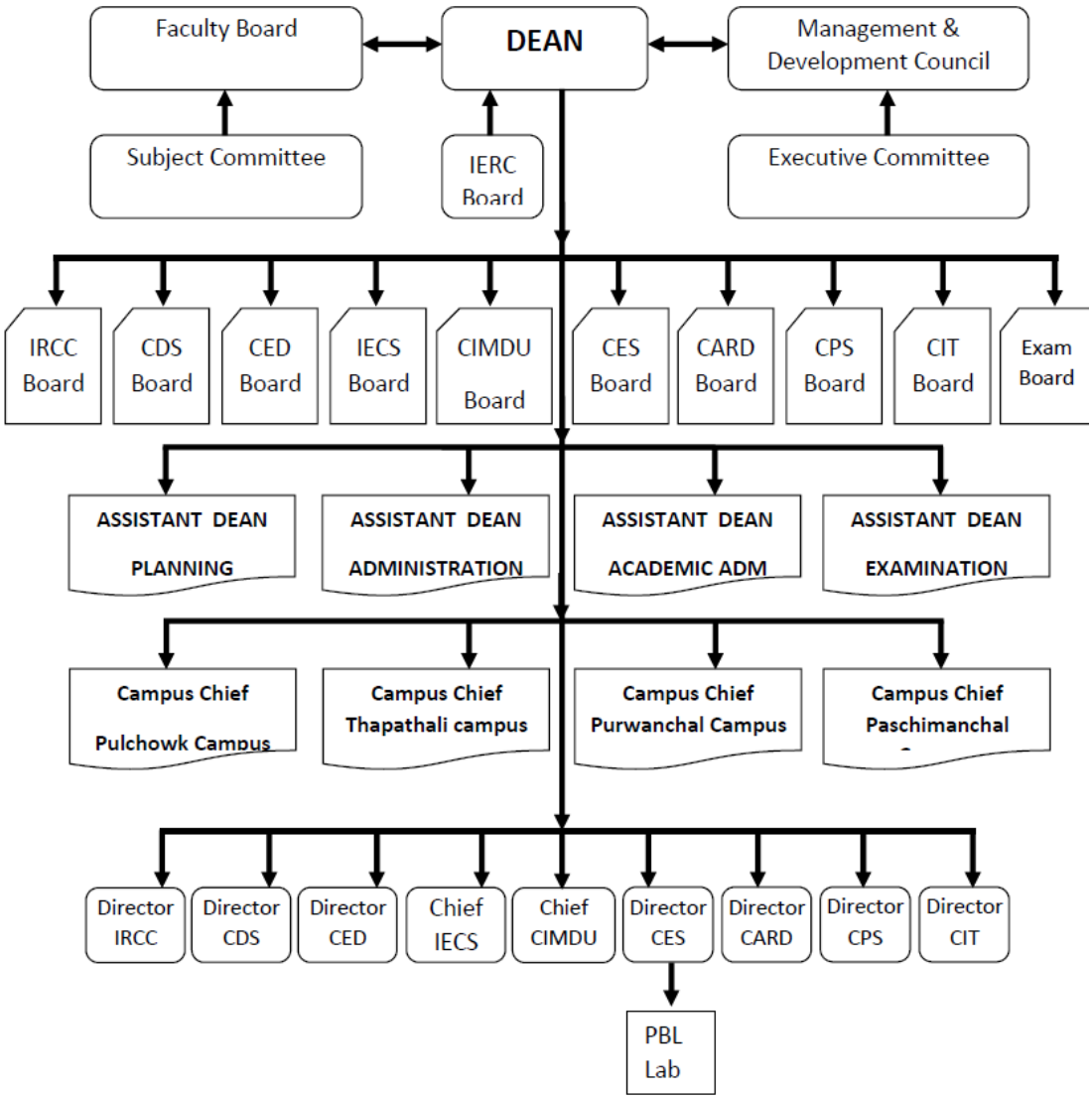

Figure 26. The ALIEN problem-based learning laboratory is part of the Centre for Energy Studies in the Organogram of Tribhuvan University.

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A9.3 Guidelines for use of the laboratory facilities

This facility is designed as a multipurpose working space for supporting the teaching and learning process towards solving real problems in engineering disciplines. Problem-based learning activities were developed by adapting existing student experiences rather than changing the already deployed experiments. Specific engineering problems are assigned to students with a focus on pre-laboratory exercises, associated group work, and assessment methods as well as on actual practical work. Mainly, the laboratory is designed as a multipurpose laboratory for:

- Conducting collaborative active learning classes and sessions.
- Delivering and providing training to institutions and individuals outside of the university.
- Designing and developing ideas of innovative products.

A9.3.1 Process

In order to ensure smooth running of the facilities, user guidelines have been developed. The process is identified below:

- The faculty members of the Institute of Engineering, Tribhuvan University can use the facility of the Central Visualization Laboratory for problem-based learning activities. Prior to using the laboratory they should inform the administration of the Centre for Energy Studies (CES) for scheduling.
- The departments or specific programs of the university can use the facilities on a regular basis by allocating time in their class routine. Any planned used of the laboratory should be communicated to the administration of the Centre of Energy Studies at the beginning of each semester.
- Students who wish to work on projects, implement ideas, or solve problems in this facility can request access by contacting the administration.

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- This facility will also be made available to individuals or institutions in specific timeslots. Parties interested to use the laboratory facility must submit an application in advance. They will be charged as per the rules of the university.

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A9.4 Activities and courses implemented in the lab

The Centralized Visualization System Laboratory under ALIEN project has been used in diverse academic and community contexts. The laboratory has already been used in selected courses offered by the Department of Electronics and Computer Engineering. There is a lot of potential for using the laboratory facility in other disciplines such as Operation Research and Management Science, Multi-Criteria Design Analysis, and more.

To facilitate the smooth use of the facility, 2 training sessions have been organized in 2 different subjects:

- Central Visualization System Laboratory support, maintenance, and troubleshooting.
- Central Visualization System Laboratory for active learning operation.

The trainings were attended by instructors and staff from different departments of the university who are involved actively in teaching and learning process through problem-based learning methodologies.

A9.4.1 Methods and facilities use

The laboratory will be used regularly in courses such as:

- Course title: Operation Research and Management Science.
  The course is a 1st year elective in the curriculum of the M.Sc. in Engineering in Energy Systems Planning and Management (MSESPM) of the Department of Mechanical Engineering.
- Course title: Image Processing.
  The course is a 2nd semester elective course offered in the M.Sc. in Computer Systems and Knowledge Engineering program of the Department of Electronics and Computer Engineering, Pulchowk Campus, IOE, Tribhuvan University.
- Course title: Knowledge Engineering.

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This is a 1st semester introductory core course offered in the M.Sc. in Computer Systems and Knowledge Engineering program of the Department of Electronics and Computer Engineering, Pulchowk Campus, IOE, Tribhuvan University.

- Course title: Social Computing.

  This is an elective course offered in IT related M.Sc. programs of IOE, Tribhuvan University.

- Course title: Information Visualization.

  This is a 2nd semester core course offered in the M.Sc. in Computer Engineering Specialization in Data Science and Analytics program of the Department of Electronics and Computer Engineering, Pulchowk Campus, IOE, Tribhuvan University.

- Problem-based learning methods will also be applied in Robotics Clubs, such as the ROBOCON International and National Competition, which is hosted in the Pulchowk Campus of the Institute of Engineering, Tribhuvan University.
- The facility will also be used for the activities of the Laboratory for ICT Research and Development (LICT).
- Problem-based learning will be regularly deployed for pilot studies on the upgrading of the university examination system by the Examination Control Division.
- The facility will also be used for mutual benefit for members of Nepal Engineers' Association as a result of the MoU that was signed between Tribhuvan University and the association.

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A9.5 Available resources

A9.5.1 Software

The software installed in the Central Visualization Laboratory at the Centre for Energy Studies, Institute of Engineering is VizExperts. It is developed by VizExperts India Pvt Ltd, L-320, 1st Floor, Lane No 9, Mahipalpur Extension, New Delhi, Delhi, India - 110037. Phone : (+91) 11 2678 1491 Fax : (+91) 124 4116643.

The purpose of the software is to provide innovative and easy-to-use software for high end visualization systems, such as:

- High end 2D and 3D visualization.
- Ultra high resolutions.
- Visualization of high volumes of data.
- Visualization of input in different forms, such as video, audio, and text.

A9.5.1.1 Key software features

- Functionality to hot-plug a video source.
- Seamless large display as a combination of single displays of resolution up to 6960 X 2160.
- High resolution full-HD video grabbing.
- Video sources support: VGA, DVI, HDMI, SDI, BNC, S-video, Composite Video, and TV Tuner.
- Support for networked streamed video sources.
- Support for audio.
- Complete control of an entire display wall through a controller application running on a multi-touch table or iPad.
- Preview and control of video sources: resizing, movement, transparency, and refreshing.

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The following figure shows high level software and hardware modules in the application.

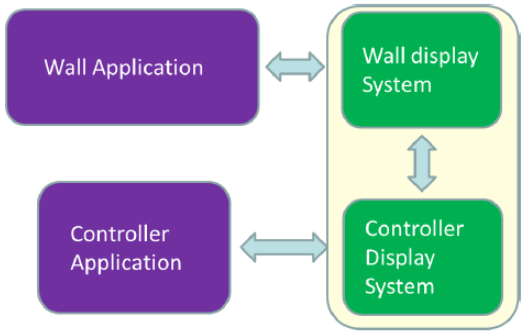

Figure 27. High level software and hardware modules offered by VizExperts.

A9.5.2 System architecture

The hardware system offers the following additional features:

- The administrator can decide whether to display a single video source or all the video sources to the Central Visualization System.
- The media server and central visualization system are connected; the video sources are selected using the IP addresses of the machine.
- The administrator has full privilege to customize the display themes, size of the display, and settings.
- Video sources support: VGA, DVI, HDMI, SDI, BNC, S-video, Composite Video, and TV Tuner.
- Support for networked streamed video sources.
- Support for audio.
- Complete control of an entire display wall through a controller application running on a multi-touch table or iPad.
- Preview and control of video sources: resizing, movement, transparency, and refreshing.

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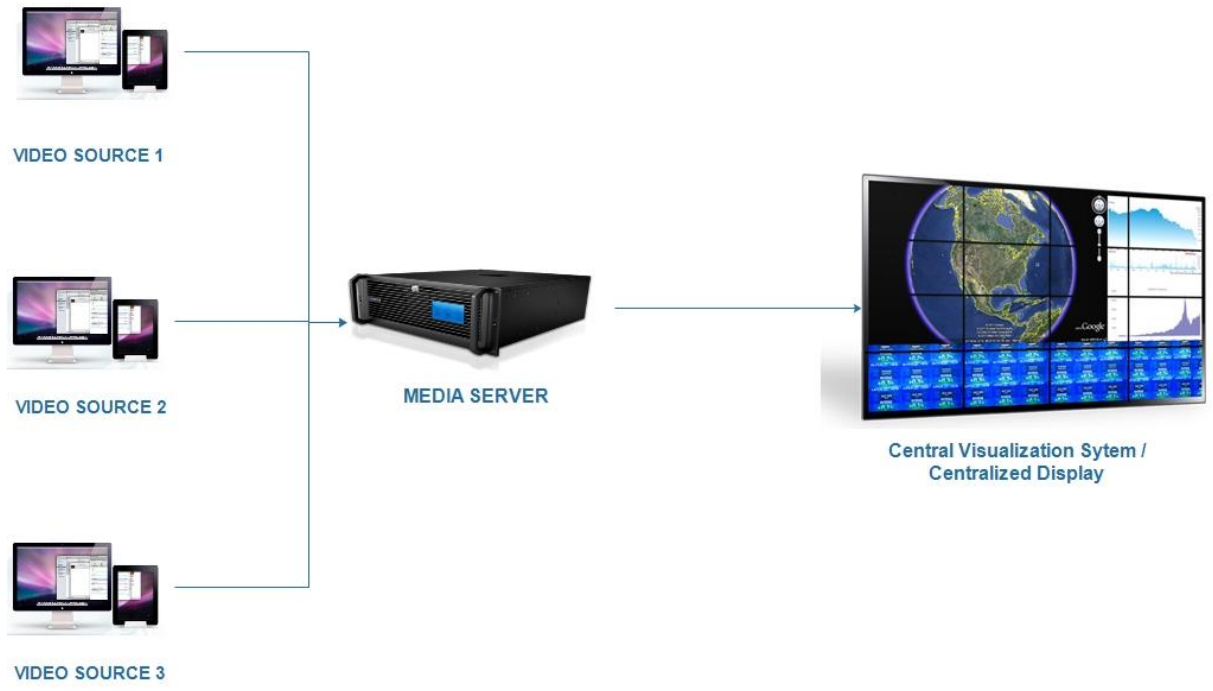

Figure 28. The hardware architecture of the Central Visualization Laboratory.

A9.5.3 Definition of terms used

- Video Source.

  Every single video data fed to the system, be it pc output, DVD player output, camera output or TV input is called a Video Source.

- Wall.

  Wall is the area on which all input video sources will be displayed. This could be a single desktop monitor, a dual monitor computer display, a video wall of various display cubes, or a large, seamless, multichannel edge blended projection wall. The display surface may be curved or flat.

- Controller.

  Controller is the system controlling and managing all video sources. This includes tasks such as dynamically identifying the video sources to be displayed on the wall, the display

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position on the wall, and their size. This system may be a Multi Touch Table, PC, laptop or iPad.

- Session.

  A session starts when the wall and the controller are connected and the controller can be used to modify, add, or remove video sources on the wall. A session supports the loading of layouts and presets.

- Layout.

  A layout is a template defining the video sources, their position, and their size in relation to the wall. This template can be configured and saved so that a particular session can be loaded quickly as per the needs of a given situation. Saving a layout allows retrieving the look and feel of a particular session.

A9.5.4 Operating environment

The operating environment specifications for the software are as follows:

- Thermal conditions.

  The recommended operating environment is a room temperature of 18° C to 22° C with humidity level below 40 %. Non condensing humidity levels should be always maintained.

- Controller configuration.

  The software and hardware requirements for the controller are displayed in the following table.

Component	**Operating System**	**Processor**	**Graphics card**	**RAM**
Requirement	Windows 8.1 64-bit, iOS 8.1	Intel, AMD (preferably	NVIDIA (8xxx series or	Recommended 4 GB

	(For iPad Controller)	multi-core)	higher), AMD (HD 4xxx series or higher)	

Figure 29. Controller software and hardware configuration requirements.

- Wall configuration.

  The wall software and hardware configuration requirements are displayed in the following table.

Component	**Requirement**
Operating System	Windows 8.1 64-bit, iOS 8.1 (For iPad Controller)
Processor	Intel, AMD (preferably multi-core)
Graphics card	NVIDIA (8xxx series or higher), AMD (HD 4xxx series or higher)
RAM	Recommended 4 GB

Figure 30. Display wall hardware and software configuration requirements.

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A9.6 Sustainable operation and maintenance

The operation and maintenance of this laboratory is performed by the Centre for Energy Studies. The Centre for Energy Studies will coordinate with the Dean's Office and campuses of the Institute of Engineering for the year round operation of the facilities. Required support staff will be provided by the university. Supporting facilities exist on the university premises. The scheduling of the laboratory facility will be managed by the Tribhuvan University departments and the laboratory coordinator. The maintenance of hardware and software will be carried out in cooperation with the campus maintenance unit. Maintenance of the website will be assigned to a web developer and administrators. The operation and maintenance budget of the facilities will be allocated from internal resource generation and it will be included in annual budget of the Centre for Energy Studies.

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APPENDIX 10. Exploitation plan for problem-based learning laboratory at Kathmandu University

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A10.1 Name of the laboratory

The name of the Laboratory is Active Learning Laboratory**.** It is situate in Department of Computer Science and Engineering, School of Engineering, Block-9, Room 307.

Figure 31. The laboratory entrance at Kathmandu University.

A10.2 Faculty in which the laboratory belongs

The Active Learning Laboratory is in the Department of Computer Science and Engineering, School of Engineering and the department has assigned Mr. Dhiraj Shrestha, Assistant Professor, Department of Computer Science and Engineering, School of Engineering as the Laboratory Head. Mr. Shrestha will manage the resources available in the laboratory and report to the department.

The following organogram demonstrates that the laboratory belongs to the School of Engineering of Kathmandu University.

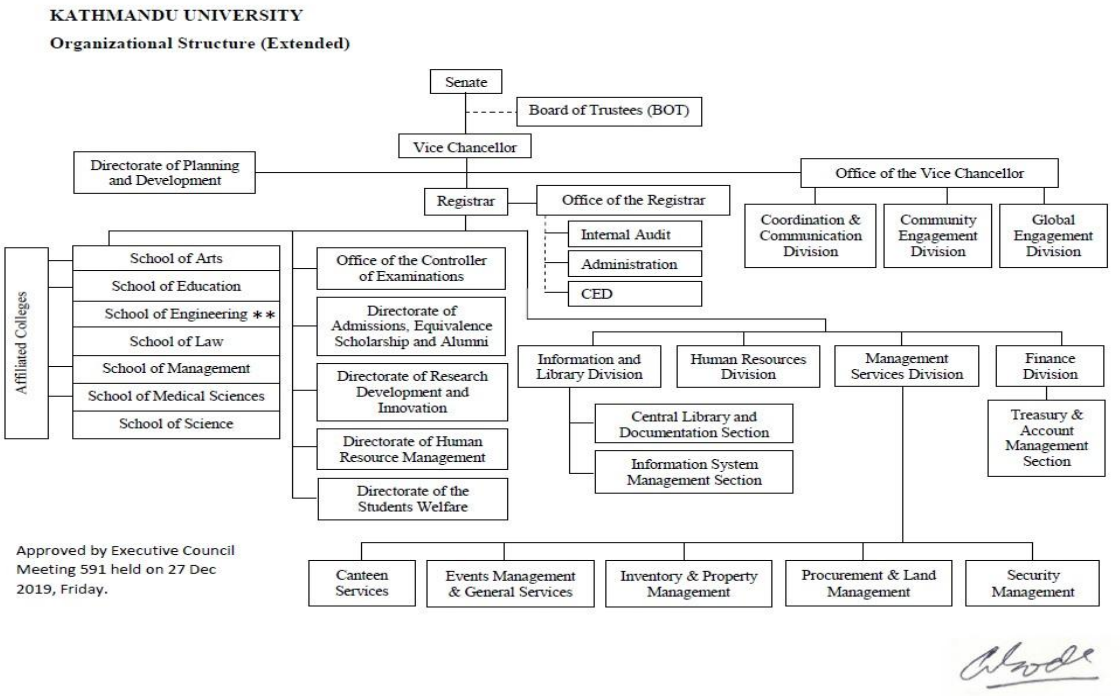

Figure 32. Organogram demonstrating where the laboratory belongs.

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A10.3 Purpose of the laboratory

The Active Learning Laboratory will be used by the School of Engineering, School of Science, and School of Management located in the Dhulikhel Premises. The Active Learning Laboratory will be used for the following purposes:

- Conducting the various courses offered by the school of Engineering, School of Science, and School of Management Dhulikhel Premises through problem-based learning.
- Facilitating groups discussions among students enrolled in the school of Engineering, School of Science, and School of Management Dhulikhel Premises in the context of projects implemented through problem-based learning.
- Conducting tutorial sessions of courses that require group discussions among students enrolled in the school of Engineering, School of Science, and School of Management Dhulikhel Premises.
- Conducting instructor training sessions.

A10.3.1 Guidelines for use

The active learning practitioners in Kathmandu University are allowed to use the laboratory for conducting their courses. The faculties are required to take permission from the Laboratory Head before conducting a course. The faculties who are willing to use the resources of the Active Learning Laboratory need to follow the following instructions:

- The faculties need to take permission from the Laboratory Head before conducting the course.
- The faculties should send the plan and timing 2 weeks before class delivery.
- If found mishandling or harming the laboratory resources students and faculty will be penalized.
- The laboratory resources should be used within the formal university activities time schedule.

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A10.4 Examples of the use of the Active Learning Laboratory equipment in specific courses

A10.4.1 Course title: Computer Graphics (Comp 342)

A10.4.1.1 Engineering curriculum where it belongs

This is a 3rd year undergraduate course offered to students of Bachelor of Computer Engineering and Computer Science.

A10.4.1.2 Course description

The course covers the basic concepts, mathematical foundations, fundamental theory and algorithms, software techniques, hardware and system issues, and application examples on computer graphics.

A10.4.1.3 Number of students engaged

60.

A10.4.1.4 Problem-based learning activities integrated in the course

Students develop mini-projects in groups of 3-4. Students select the topics that they will work on. The selected projects must include concepts from computer graphics.

A10.4.1.5 Equipment, software and educational material used

Equipment

- Multimedia projector.
- Smart TV.
- 6 workstations and3 laptops.

Software

- C / C++.

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- Python compiler.
- OpenGL.

Educational material (books, scenarios, and other sources)

- Computer graphics by Donald Hearn and M. Pauline Baker
- Computer graphics: Principles and Practices by James Foley,S.K Feiner and J.F Hughes
- OpenGL tutorials available on Internet

A10.4.1.6 How the ALIEN equipment is used

Multimedia projector, Smart TV

The projector and Smart TV are used by students for discussion and conducting brainstorming sessions among team members. The equipment is also be used by students for the presentation of their project progress and final work.

6 workstations and 3 laptops

The 6 workstations are used by students working in groups for collaboration on their project work and for programming. The laptops are used by students for the presentation of their work.

C / C++, Python compiler, OpenGL

This open source software is used for the development of student mini-projects.

A10.4.2 Course title: Operating Systems (Comp 307)

A10.4.2.1 Engineering curriculum where it belongs

This is a 3rd year undergraduate course offered to students enrolled in the Bachelor of Computer Engineering, Computer Science, and Computational Mathematics programs.

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A10.4.2.2 Course description

The course aims to build knowledge on:

- Fundamentals of operating systems.
- The mechanisms of operating systems on handling processes, threads, and communication.
- The mechanisms involved in memory management in contemporary operating systems.
- Distributed operating system concepts including architecture, mutual exclusion algorithms, deadlock detection algorithms, and agreement protocols.
- Components and aspects of concurrency management.
- Programming simple operating system mechanisms.

A10.4.2.3 Number of students engaged

75.

A10.4.2.4 Problem-based learning activities integrated in the course

Students are given a problem based on the concepts of operating systems and are asked to solve it in groups through simulations. Simulations are implemented using the C/C++, Python, or Java programming languages.

A10.4.2.5 Equipment, software and educational material used

Equipment

- Multimedia projector.
- Smart TV.
- 6 workstations and 3 laptops.

Software

- C / C++.

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- Python compiler.

Educational material (books, scenarios, etc. and sources)

- Andrew Tanenbaum, “Modern Operating Systems”, 3rd edition, Pearson/Prentice Hall, 2008.
- Avi Silberschatz, Peter Baer Galvin, Greg Gagne, Operating System Concepts, 9th Edition, John wiley & Sons, Inc.

A10.4.2.6 How the ALIEN equipment is used

Multimedia projector, Smart TV

The projector and Smart TV will be used by students for discussion and conducting brainstorming sessions among team members. The equipment will also be used by students for the presentation of their project progress and final work.

6 workstations and 3 laptops

The 6 workstations will be used by students working in groups for collaboration on their project work and for programming. The laptops will be used by students for the presentation of their work.

C / C++, Python, Java Compiler

This open source software will be used for programming simulations.

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A10.5 More activities and courses taking place in the lab

The establishment of Active Learning laboratory has initiated the use of problem-based learning in the School of Engineering. The students' attitudes towards problem-based learning are very positive. Due to the pandemic, the use of Active Learning Laboratory was not possible, but faculties took the initiative and implemented the concept of problem-based learning in virtual mode. Seven courses offered from the department of Computer Science and Engineering have already utilized the concept of problem-based learning.

In course Computer Graphics (Comp 342), students were asked to do the mini projects for implementing graphics concepts. Students selected the project of their choice, implemented it, and presented the work to the course instructor.

In course Operating Systems (Comp 307), students were assigned problems related to different topics of process management, memory management, and deadlocks. Students were asked to simulate the problems by coding them in a programming language of their choice. Through the developed programs and simulations students demonstrated the concepts taught in lecture classes. Practical activities helped students develop a clear understanding of the subject matter.

In course System Analysis and Design (Comp 321), students were asked to work on a case study of their choice, in which they developed documents such as requirements definitions, feasibility analysis, system design, and more. Students worked in groups of 4-5 to prepare the case documents. After completing the documents, students presented their work in an oral exam. This hands-on methodology helped the students implement in practice theoretical concepts.

In course Computer Architecture and Organization (Comp 315), students were asked to design a mini computer. Upon completion, students submitted an implementation report. The project was focused on design and helped students build a clear understanding of the subject matter.

In course Embedded Systems, students were assigned a variety of projects at the end of the semester. Projects were implemented through problem-based learning approaches. Most

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projects focused on socket programming, but other themes of particular interest to students were also welcomed and considered. There was an active participation of students despite the pandemic, with project presentations and demonstrations being conducted online.

In course Algorithm and Complexity, students were asked to develop an efficient approach to solve a problem in the computer. Students used pseudocode. Students were divided into a number of different groups. The solution of every group was thoroughly discussed and explained by group members for the benefit of the whole class. The instructor discussed possible improvements and enhancements which could make the work more efficient, providing valid reasoning. The same approach was deployed in analyzing problems in terms of time and space.

In course Object Oriented Programming, each student was provided with a dedicated computer that run the LINUX operating system. Theoretical knowledge was developed through in depth discussions on probable implementations of specific problems related to the content of each course chapter in the context of problem-based learning.

The positive experience developed through the above courses led faculty members plan for the wider deployment of problem-based learning in additional subjects. The university administration decided that classes will resume in physical mode, which allows the deployment of the Active Learning Laboratory. An active learning workshop was conducted targeting faculty members, which resulted in higher demand by instructors from different departments on using the Active Learning Laboratory. In the coming semester, the following courses will deploy problem-based learning:.

Course Name	Year	Semester	Program	Teacher
Computer Programming	1	1	BE in Mechanical Engineering	Mr. Sameer Tamrakar
Computer	1	1	BE in Geomatics	Mr. Amrit Dahal

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Programming			Engineering	
Software Dependability	4	2	BSc in Computer Science	Prof. Dr. Manish Pokharel
Engineering Economics			BE in Computer Engineering	Mr. Bibhu Ratna Tuladhar
Data Structures and Algorithm	2	1	Bachelor in Business information system	Ms. Praynita Karki
Microprocessor and Assembly Language	2	2	B.SC in Computer Science	Dr. Gajendra Sharma
Human Computer Interaction	3	2	BE in Computer Engineering	Mr. Sushil Shrestha
Software Engineering	4	2	Bachelor in Business Information System	Mr. Sushil Shrestha
Emerging Technologies	1	1	ME in computer Engineering/ MTech in Information Technology	Prof. Dr. Manish Pokharel
Machine Learning	4	1	BE in Computer Engineering	Dr. Bal Krishna Bal

Table 1. Courses in which the laboratory was used at Kathmandu University.

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A10.6 Resources

A10.6.1 Equipment

The laboratory equipment was bought in 3 batches:

1st batch

The 1st batch of equipment was bought following a needs analysis performed by faculty members involved in the project with an interest in problem-based learning. Apple products were brought in this batch because the Apple products are typically sold by dedicated vendors.

2nd batch

The 2nd batch of equipment was bought following a needs analysis performed by faculty members involved in the project. Products from brands other than Apple were purchased.

3rd batch

A 3rd batch of items was bought based on the requirements set by new subjects integrated into the ALIEN problem-based learning intervention.

The equipment purchased is described below.

S.N	Equipment	Quantity
1	All in One PC - HP EliteOne 1000 PC	1
2	Workstation - HP Z4 Gr	1
3	Projector - EPSON EB-X05	1
4	Television set - LG 55in UHD 4K TV (55UJ652T)	1
5	All in One Computer (MNDY2ZP/A-iMac	4
6	Dell i7 Laptop 16GB RAM DDR4	2

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7	Dell i7 Laptop 8GB RAM DDR4	1

Table 2. Laboratory equipment at Kathmandu University.

A10.6.2 Staffing

The Department of Computer Science and Engineering, School of Engineering owns the Active Learning Laboratory. The Department has assigned Mr. Dhiraj Shrestha as the Laboratory Head. His responsibilities include the laboratory maintenance, arranging the schedule for conducting courses in the lab, fixing technical issues with the support of department's Laboratory Assistant, reporting to the department regarding the functioning of lab, reporting to the department of any necessary maintenance.

The department provides Laboratory Technicians for managing and maintaining the resources of Active Learning Laboratory when required. The department's Laboratory Technicians are Mr. Rajendra Banjara and Mr. Bibas Neupane. They will be supporting the Active Learning Laboratory.

A10.6.3 Financial support

The main expenses required for the regular functioning of Active Learning Laboratory are as follows:

- Electricity
- Internet connection
- Regular laboratory maintenance
- Laboratory management
- Upgrading of Laboratory equipment
- Purchasing additional equipment for problem-based learning

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The Department of Computer Science and Engineering, School of Engineering owns the laboratory and all the costs related to the laboratory will be covered by its regular budget. The Active Learning Laboratory will be used for the conduction of courses in problem-based learning mode. The department will not hire separate staff for but assign existing staff members for supporting the laboratory. The department will allocate funds for laboratory maintenance and, when required, additional resources for purchasing new equipment.

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APPENDIX 11. Exploitation plan for problem-based learning laboratory at National University of Future and Emerging Sciences

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A11.1 Name of the laboratory

The name of the laboratory is Problem-Based Learning Laboratory.

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A11.2 Faculty in which the laboratory belongs

The Problem-Based Learning Laboratory belongs to the School of Computing, Department of Software Engineering. The following organogram demonstrates how the laboratory fits into the organizational structure.

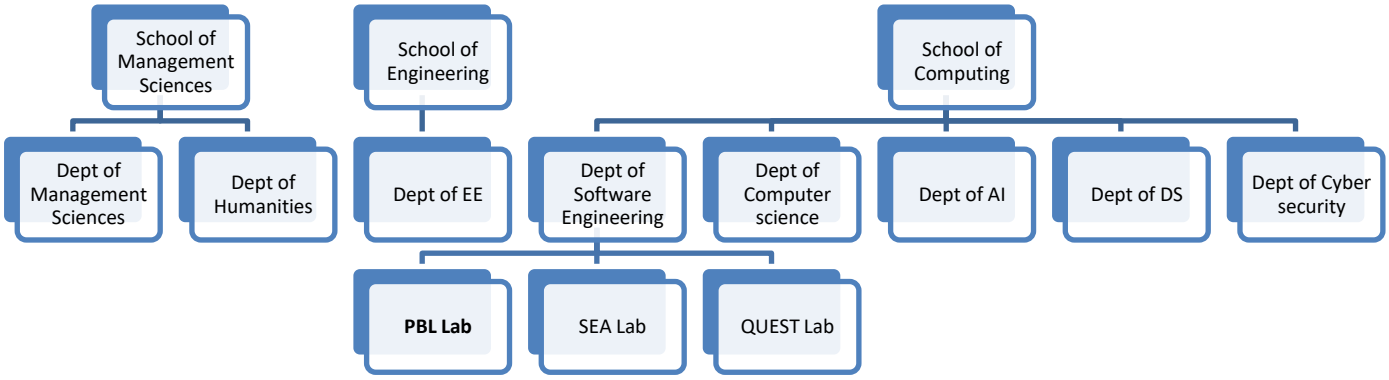

Figure 33. The organogram of the School of Computing, Department of Software Engineering.

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A11.3 Purpose of the laboratory

The Problem-Based Learning Laboratory is being used for different courses and for conducting teacher trainings. The laboratory is used in multiple courses that deploy active learning methods for effectively engaging students. The laboratory allows students to work hands-on with technology towards building their understanding of the course content. The laboratory allows the replacement of the conventional method of teaching that is based on lectures and promotes the broad deployment of active learning among colleagues and students.

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A11.4 Guidelines for the use of the laboratory

The laboratory can be used for conducting group work in courses and laboratory assignments. Along with that, it can be used for conducting teacher trainings.

Two pilot courses that have already been conducted using the lab, as well as the ALIEN digital learning platform, are:

Subject	Number of students	Number of teachers	Equipment	Semester
Software Engineering for Industrial Automation Systems	22	1 teacher	Virtual reality	August 2019
Software Engineering	250	3 teachers and 2 laboratory instructors	Augmented reality	March 2020

Figure 34. Examples of courses in which the Problem-Based Learning Laboratory was used.

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A11.5 Activities and courses that take place in the laboratory

A11.5.1 Course description Software Engineering in Industrial Automation

The course Software Engineering in Industrial Automation (SE593), which is part of the School of Computing, Master's in Software Engineering, Master's in Computer Science, and Master's in Cyber Security, was delivered in the Problem-Based Learning Laboratory.

The main objectives of the course are:

- To develop understanding on the concepts of industrial automation and control systems.
- To be able to use software engineering lifecycle steps for industrial automation and control systems.
- To build knowledge on risk assessment techniques for Industrial automation systems.
- To build knowledge on cyber security of SCADA systems.
- To build knowledge on the standards of cyber security and functional safety in industrial automation.

The course contents are:

- Introduction to Software Engineering principles.
- Industrial Automation Systems: Programmable Logic Controllers (PLC), Motion Control Systems, Computer Numerical Controls (CNC), AC Drives, Human Machine Interface (HMI) Software, Supervisory Control and Data Acquisition (SCADA), PXI, and PC based Systems Automation Software. Categories: Software tools, Manufacturing Systems, Resource, Planning, and Real-time systems.
- Industrial Software Standards: IEC 61131-3, ISA 88/95, IEC 61499, IEC 61804, IEC 61850.
- Requirements Engineering for industrial automation systems, and specifically:
    - Quality requirements industrial automation systems.
    - Requirements patterns for industrial automation systems.

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- Risk management in industrial automation systems analysis, security failure analysis, safely failure analysis, STPA, FMEA, HAZOP, and FTA.
- Industrial Software Design Practices: Model-Driven Engineering (MDE), Component-based software engineering (CBSE), Design Based on Formal Model, Multi-Agent Architecture, Service-Oriented Architecture (SOA), and OO Approach for Industrial Automation Software Development.
- Industrial Software Testing, Management, and Validation: Software Testing, Software Maintenance and Evolution, Software Configuration and Engineering Management, Software Process and Tools, and Software Quality.
- SCADA systems, DCS, and Cyber Security in SCADA Systems Cyber security, SCADA systems, attack models, mitigation techniques, and Security constraints.

The number of students that was engaged in the 2020 academic year was 57.

A11.5.2 Problem-based learning activities that took place in the course

The course was delivered through the flipped classroom learning model.

A11.5.3 Equipment, software, and educational material deployed

A11.5.3.1 Hardware

The following hardware was used in the course:

Equipment	**Features**	**Purpose**
PCs for Development	Ci7 8700, ASUS ROG Motherboard B360, 32 GB DDR4 RAM, 2 TB SATA HDD, 500	Application / Game Development and Usage

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	GB SSD, GeFORCE GTX1080 8GB, DVD RW, Corsair Casing, Corsair 750W Supply, HP27F 27'' LED Display	
PCs for Gaming	Ci7 8700, ASUS ROG Motherboard B360, 16 GB DDR4 RAM, 1 TB SATA HDD, 128 GB SSD, NVIDIA GTX1050Ti 4GB, DVD RW, HP27F 27'' LED Display	Application/ Game Usage
Projectors	Acer Projector Model: X118H	To present lecture slides, play videos, show examples etc.
VR Headsets	Oculus Rift + Touch VR System with Leap Motion	

Figure 35. Equipment used in the Software Engineering in 'industrial Automation course.

A11.5.3.2 Software

- OpenPLC.
- AdvancedHMI.
- JSON API for plant automation.
- SteamVR.

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- OpenVR.

A11.5.3.3 Books

- Industrial Cloud-Based Cyber-Physical Systems, Editors Armando W. Colombo, Springer, Cham
- Title of Book Advanced Industrial Control Technology, By Peng Zhang

A11.5.3.4 How ALIEN equipment is used

The laboratory will be used as a general purpose classroom for multiple problem-based learning courses. The laboratory is designed in such a way that it has all 8 PCs settled in a big room with moveable semi-circular tables and chairs as shown in the following figure. The tables and chairs can be adjusted into any design required by the instructor for the purposes of a particular course. There are no fixed LEDs so the computers can be kept in any required fashion. There is a projector installed to disseminate instruction and share material with the students. This laboratory can also be used for teacher training in problem-based learning.

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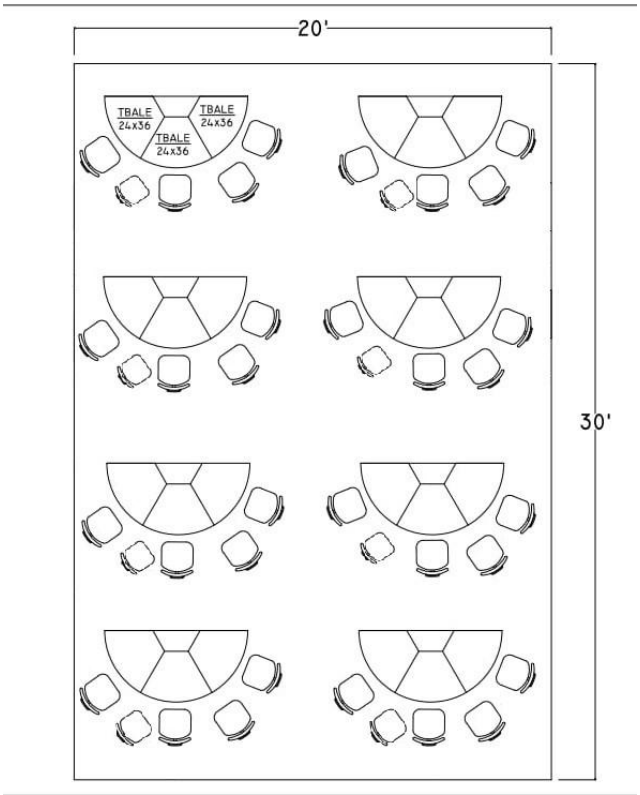

Figure 36. Floor plan of the Problem-Based Learning Laboratory.

A11.5.2 Course description Software Engineering in Industrial Automation

The goal of the project is to build student skills that lower the barrier of malicious entry into industrials control systems. The course deploys active learning principles. During the course, students are asked to practice common attacks like including command injection, man-in-the-middle, and buffer overflows on the PCs and visually see the impact of their attacks in 3D visualization through the VR headsets as shown in the following figure. Users can also practice their defensive skills by properly segmenting the network with strong firewall rules or intrusion detection rules.

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Figure 37. Simulation of ICS.

Upon completion of the course students are familiar with concepts related to ICS simulation, attach simulation, and attach results.

A11.5.3 Courses in which the Problem-Based Learning Laboratory will be used in the future

The laboratory can be used for multiple courses such as:

- User experience engineering.
- Design thinking.
- IOT security.
- And more.

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A11.6 Resources

A11.6.1 Equipment

The Problem-Based Learning Laboratory offers the following equipment:

Item	Qty.	Supplier
Oculus Rift + Touch Virtual Reality System Oculus	2	Superior Elec.
LEAP Motion VR DEV Bundle	2	Superior Elec.
Windows 10 professional	11	Superior Elec.
PC for Development Ci7 8700, ASUS ROG Motherboard 8360, 1 32GB DDR4 RAM, 2 TB SATA HDD, 500GB SSD, GeFORCE GTX1080 8GB, DVD RW, Corsair Casing, Corsair 750W Supply, HP27F 27" LED Display, 2.5" Passport Drive 4TB, Keyboard and Mouse	3	Asktech
PC for Gaming Ci7 8700, ASUS ROG Motherboard 8360, 16GB DDR4 RAM, 1 TB SATA HDD, 128GB SSD, NVIDIA GTX1050Ti 4GB, DVD RW, HP27F 27" LED Display, Keyboard and Mouse	5	Asktech
Acer Projector Model: X118H	2	Asktech

Figure 38. The equipment in the Problem-Based Learning Laboratory.

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A11.6.2 Staffing

The Problem-Based Learning Laboratory will be supported by the following personnel:

- Teachers and lecturers who will
  - Use the laboratory for conducting their courses and labs.
  - Conduct trainings and workshops
- Technicians who will
  - Assist students with equipment use in final year projects and Master's projects
  - Maintain the software and ensure that it is up to the date

A11.6.3 Financial support

The laboratory staff comprises of university staff including lecturers and technicians who are already employed by the university. The staff is already employed by the organization, is part of the organizational organogram and is included in the organizational payroll. For this reason, not additional funding is required for supporting the Problem-Based Learning Laboratory team.

However, a very important part of the laboratory is students (BS, Master's, and PhD students). Student stipends and salaries will be supported through the pursuit of additional research projects.

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APPENDIX 12. Exploitation plan for problem-based learning laboratory at Hanoi University of Science and Technology

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A12.1 Name of the laboratory

HUST has built a modern active learning laboratory named AI and Cyber Security Active Learning Laboratory. The lab's infrastructure is an investment by HUST. The equipments in the laboratory has been purchased through the ALIEN project.

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A12.2 Faculty in which the laboratory belongs

The AI and Cyber Security Active Learning Laboratory belongs to the School of Information and Communication Technology (SoICT), Hanoi University of Science and Technology (HUST). The organogram of SoICT is as follows:

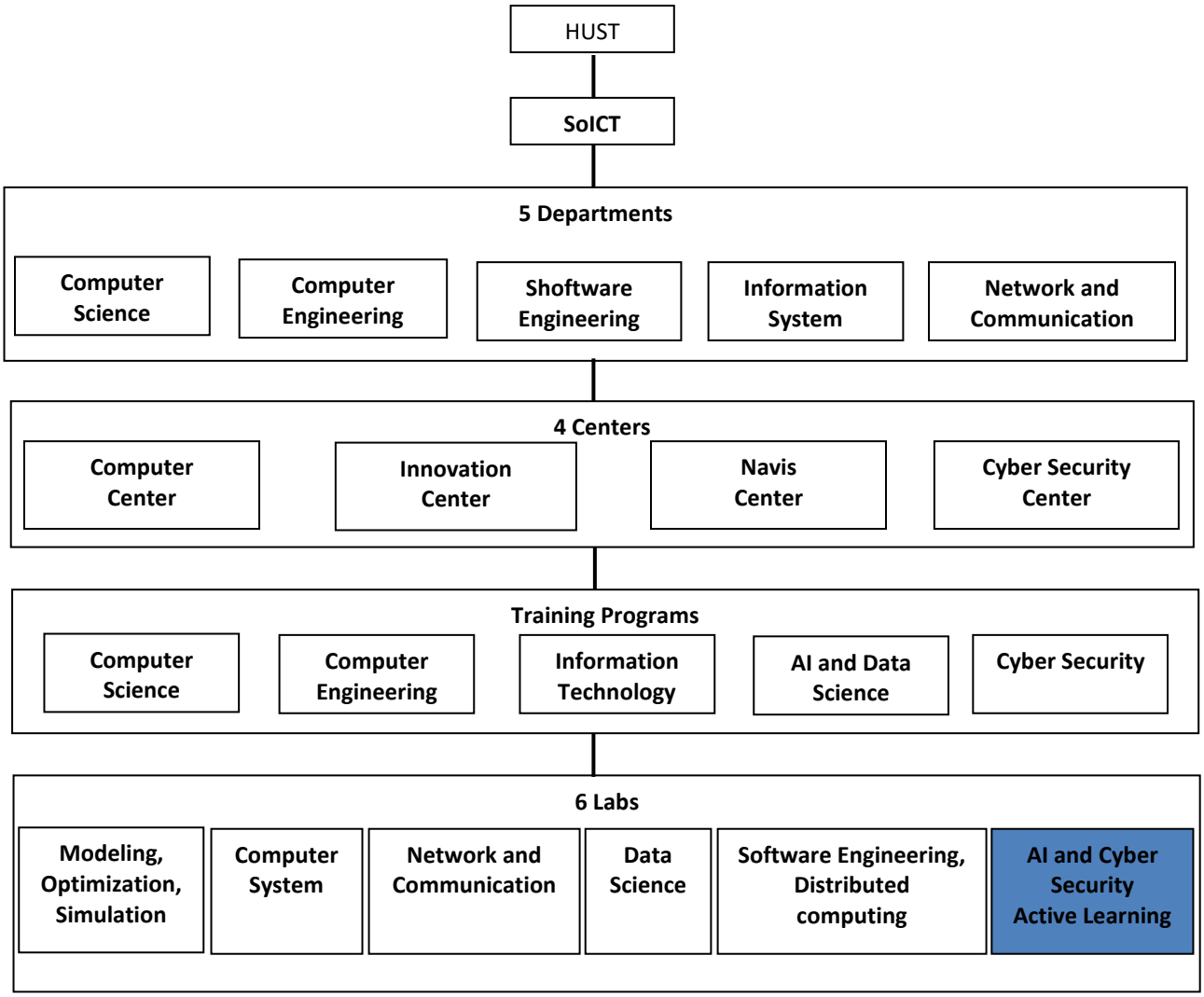

Table 3. Organogram demonstrating where the laboratory belongs.

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A12.3 Purpose of the laboratory

The purpose of the AI and Cyber Security Active Learning Laboratory is to provide a modern practical training environment, applying active learning methods. The laboratory is designed as an open and flexible space so that instructors can easily organize teaching and learning in groups, suitable for active learning. The laboratory is equipped with modern equipment such as a computer for each student, TVs, projectors, screens, whiteboards, an audio system, and more. The laboratory is used to organize practice classes for advanced SoiCT training programs such as AI and Data Science and Cyber Security and to deliver short-term training courses on digital transformation, AI, information security, and more to staff in companies or other organizations.

A12.3.1 Guidelines for use

A12.3.1.1. Instructions for the use of the lab

- Purpose of the laboratory:
    - The laboratory is used for practical activities in courses of advanced training programs such as Cyber Security, Data Science and AI, and Global ICT. The practical courses of these programs will be permanently scheduled to take place in the laboratory.
    - The laboratory is further used to deliver short-term training programs to employees in companies and organizations. In 2020, SoICT organized a number of short-term courses on Cyber Security, AI, Data Science, Digital Transformation.
    - Finally, the laboratory is used to organize events and competitions for students.
- Registration for the use:
    - Lecturers of courses that have been permanently scheduled to take place in the laboratory do not need to register for the use of the laboratory.

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- Lecturers who want to use the laboratory for unscheduled subjects, or use the beyond regular instruction hours, such as in evenings and weekends, or use the laboratory for other purposes such as organizing events or competitions for students, need to register on SoICT's website: https://qldt.hust.edu.vn/ .

- Technical support:
  - The laboratory is designed in a flexible manner. It offers approximately 40 seats for students, divided into 6 round table areas. Trainers who want to change the layout of the laboratory space, or want to add more seats, contact technical support.
  - The laboratory is equipped with computers, TVs, projectors, screens, whiteboards, sound systems, and WiFi. The computers run on Windows, Ubuntu, and Mac OS operating systems. They are further equipped with basic compilers such as for the C and Java programming languages. Teachers who need to add practice equipment or install additional software needed in their subjects, contact technical support.

A12.3.1.2 Laboratory equipment

Hardware

- Computers: Aimed to be used by students for implementing practical projects during laboratory time.
- TVs: Used for group discussion or presentation.
- Projectors and screens: Used for instructor or student presentations.
- Audio system: Used for instructor or student presentations.

Software

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The laboratory computers run Windows, Ubuntu, and Mac OS operating systems. They are further equipped with basic compilers such as for the C and Java programming languages. However, teachers may ask technical support to install additional software for the support of their courses, if necessary.

A12.3.2 Activities and courses

A12.3.2.1 Courses that have been organized in the AI and Cyber security Active Learning lab

1. **Introduction to programming (using Python).**

   Engineering curriculum where it belongs: AI and Data Science.

   Course objectives: This course introduces students to the basics of programming including: i) basic concepts of programming such as variable, expressions, statements, control flow, and function; ii) basic data types and structures such as strings, lists, files, and classes; iii) basic concepts of exceptions, testing, and debugging. All algorithms and programming principles in the course are illustrated in Python. This course helps students feel justifiably confident of their ability to write small programs that allow them to accomplish useful goals.

   Number of students engaged: 50.

   Equipment, software, and educational material used:

   Equipment: Computers, TVs, projectors, audio systems.

   Software: Windows/Ubuntu, Python.

   Educational material:

   - Books:
     1. Peter Wentworth, Jeffrey Elkner, Allen B. Downey and Chris Meyers (2012). How to Think Like a Computer Scientist. Green Tea Press.
     2. John V. Guttag (2013). Introduction to Computation and Programming Using Python. MIT Press.
   - Slides: provided by the lecturer.

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Problem-based learning activities integrated in the course:

Course work includes exercises and assignments. Simple assignments are implemented individually by each student. Practical work takes place in the laboratory. The instructor introduces to the class a list of assignments, from which the students select one on which they work on in groups. Students design an algorithmic solution, and develop a program under the guidance of the teaching assistant. At the end of the course, the groups present their results to the class.

2. **Data Structures and Algorithms.**

Engineering curriculum where it belongs: Computer science.

Course objectives:

The course provides fundamental knowledge on the principles, computational features, and complexity of basic algorithms and data structures as the basis for developing information processing systems. Students learn how to build information processing systems through the development of simple application programs. The data structure section of the course focuses on arrays, lists, stacks, queues, some tree structures, and graphs. The algorithm section focuses on recursive algorithms, sorting algorithms, search algorithms, and graph algorithms.

Number of students engaged: 40.

Equipment, software, and educational material used:

Equipment: Computers, TVs, projectors, audio systems.

Software: Windows/Ubuntu, C/C++/Java.

Educational material:

- Book:
  1. Data Structures and Algorithms in C++. 2nd Edition. Prentice Hall, 2000.

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2. Nguyễn Đức Nghĩa. Cấu trúc dữ liệu và thuật toán. NXB Đại học Bách khoa Hà nội, 2013. 368 trang.

- Slides: provided by the lecturer.

Problem-based learning activities integrated in the course:

Students implement and use basic data structures such as stacks, queues, priority queues, lists, trees, and hash tables. Students must be able to design and implement programs that use data structures to develop information processing systems. Students understand and implement basic searching and sorting algorithms such as quick sort, heap sort, merge sort, and hash tables. Students master basic algorithm building techniques such as recursion and division. Students analyze complexity in asymptotic notation language for basic algorithms and data structures. Problem solving is a key part of the course.

The instructor delivers lectures on theoretical aspects. Students follow the lectures and participate in practical laboratory work. Laboratory exercises are implemented in the C programming language. Teaching assistants guide students during laboratory practice following the theoretical teaching schedule of lecturers.

Students are assigned a project to work in groups with an implementation time of about 2-3 weeks. Each project includes a number of in-depth math problems in class. This may involve a few difficult problems that require significant effort to solve. The implementation of these exercises is the best preparation of students for the exams.

The key to success is practice. The lecturer reviews data structures and algorithms implemented in the C programming language. Students learn how to apply theoretical solutions to real problems. In a first step, students are exposed to structures through theoretical lectures, followed by practical experiments and tutorials. For example, a lecturer teaches sorting algorithms and then the teaching assistant guides students

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through the practical implementation of algorithms in programs. Finally, students write a report in which they compare the efficiency of sorting algorithms on real datasets.

3. **Technical Writing and Presentations.**

Engineering curriculum where it belongs: All training programs of SoICT.

Course objectives:

The course aims to provide students with the understanding of principles and the development of practical skills on writing scientific and technical documents and delivering effective presentations. Students are introduced to the entire writing process including planning, drafting, evaluation, and editing. Students further analyze the objectives of the text, the organization of information, and the use of graphical support tools. Upon completion of the course, students are able to effectively write technical reports, theses, abstracts, proposals, CVs, and more in a correct and professional way. In addition, effective presentation techniques such as using voice, changes of tone, and body language are also introduced in this course. Students work in groups to formulate ideas and prepare the necessary material for writing and presenting, thereby building teamwork skills and positive collaboration attitudes.

Number of students to be engaged: 60.

Equipment, software, and educational material used:

Equipment: Computers, TVs, projectors, audio systems.

Software: Windows/Ubuntu.

Educational material:

- Books:
  1. Justin Zobel (2014), Writing for Computer Science, Springer.
  2. Lucinda Becker and Joan Van Emden (2016), Presentation skills for students, Palgrave.
- Slides: provided by lecturer

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Problem-based learning activities that will be integrated in the course:

The content of the course consists of 2 parts, namely presentation and writing. Each part lasts 7 weeks. In each part, students choose a topic from a list of topics provided by the teacher, for example: Computer Graphics, Data Base & DBMS, Security, Computer Ethics, AI, IOT, the Fourth Industrial Innovation, Data Science, and Digital Transformation. Students research, explore content, and prepare slides. After this initial phase, the class is divided into small groups of 5 – 7 students. Each student presents his results to his group and receives comments and feedback from all group members.

During the course, students are assisted by teachers and teaching assistants.

A12.3.2.2 List of courses that will use the AI and Cyber security Active Learning laboratory in the future

1. **Parallel and Distributed Programming**

   This course introduces parallel and distributed programming and their applications towards solving high-performance problems on parallel or distributed computing platforms. The course consists of following topics: parallel and distributed computational architectures such as multi-threaded architecture, multi-core computational architecture, and general purpose GPUs; how to design parallel algorithms for high-performance problems; parallel programming models such as OpenMP, MPI, CUDA; developing parallel programs for several typical problems such as matrix computations, graphs, sorting, partial differential equations, and more. Upon completion of the course, students are able to develop algorithms themselves and write parallel programs using different parallel programming models with applications in several practical high-performance problems.

2. **Technical Writing and Presentations**

   Please see description above.

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3. **Scientific Computing**

The course helps students grasp the basic concepts of scientific computing and to understand common problems in science and engineering. It focuses on methods and algorithms for solving complex problems in science and engineering. The course also helps students become familiar with the use of programming languages for developing software towards solving complex problems in science and engineering.

The course includes topics such as calculating and programming using MATLAB, problem errors and conditions, algebraic and calculus numerical methods, solving systems of linear equations, solving nonlinear equations, derivatives and integrals approximation, numerical methods for differential equations, curve fitting, numerical methods for optimization, non-linear programming, linear programming, and MATLABORATORY application in scientific computing.

4. **Discrete Mathematics**

The course is an introduction to discrete mathematics concepts of objects and their relationships. It introduces students to basic concepts of mathematical structures that are fundamentally discrete, rather than continuous. Concepts and notations from discrete mathematics are extremely useful in studying and describing objects and formulating problems in branches of computer science, such as computer algorithms, programming languages, cryptography, automated theorem proving, software development, and many other IT principles. The objects studied in discrete mathematics are various, such as logic, sets, functions, number theory, induction, combinations and permutations, graphs, recurrence relations, theoretical principles of cryptography, and trees. The course is mostly theoretical and takes place in an amphitheater. However, it is one of the key courses that highly important in building problem-solving capability, critical and analytical thinking. The curriculum is designed to build fundamental knowledge that is of use in other courses in the curriculum.

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5. **Object-Oriented Programming**

The course focuses on Object-Oriented Programming (OOP), a programming paradigm based on the concept of objects. OOP is a core development approach that is widely accepted around the world. Many of the most widely used programming languages such as C++, Java, Python, and more, are multi-paradigm and support object-oriented programming to a greater or lesser degree. The course aims to introduce students to the idea of programming with OOP, basic concept of objects and classes, the fundamental features of OOP, such as encapsulation, composition, inheritance, and delegation, and how to use OOP in software development. OOP offers benefits in re-usability, data redundancy, security, extensibility, easy troubleshooting and maintaining, and more. Concepts and schemes of OOP can be applied to improve programming and designing skills, which is highly important in almost every field of IT in general, especially software engineering. The course furthermore focuses on transversal skills including analytical thinking, critical thinking, entrepreneurial thinking, problem solving, planning and designing, ability to work in a team, and more.

6. **Network Management**

Network management remains the least understood aspect of networking. Managers of today's enterprise and carrier networks face great challenges as they need to manage a variety of devices, protocols, and mechanisms to meet a diverse set of goals in performance, security, availability, and cost. The course provides students with a comprehensive view of the network management problem, including its concepts, scope, challenges, techniques, and related tools. Concepts are demonstrated in concrete applications and scenarios such as MPLS, VPN, VLAN, and more. The course furthermore focuses on how practical network management can contribute, in combination with pedagogical models, towards the development of basic, transversal skills including

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analytical thinking, critical thinking, entrepreneurial thinking, problem solving, ability to work in a team, and more.

7. **Database Management Systems**

The course introduces the management of database systems. It emphasizes the understanding of the fundamentals of relational systems including data models, database architectures, and database manipulations. The course also provides an understanding of new developments and trends such as internet database environment and data warehousing. The course deploys a problem-based approach to learning.

8. **Data Structures and Algorithms**

See description above.

9. **Fundamentals of Optimization**

Optimization problems are evident in many aspects of daily-life: resource planning, machine design, automation, business administration, finance, transportation, manufacturing, urban architecture, and more. This course provides students theoretical foundations of linear programming, integer programming, a number of exact algorithms, and heuristic methods. The students build skills that help them understand and model different optimization problems under mathematical formulations. During the course, the students are exposed to optimization software and programming libraries used to model and solve practical optimization problems.

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A12.4 Resources

A12.4.1 Equipment

The following equipment is available in the AI and Cyber Security Active Learning Laboratory. The equipment has been purchased through the ALIEN project.

Equipment	Detail Description	Quantity	Purpose
iOS Programming Computer Set	Laptop Apple Macbook Pro MPXQ2 128Gb (2018) Core i5 / Ram 8GB/ 128 SSD/ 13,3"/ Mac OSX with UGREEN 9-1 HUB	4	For use by student groups during class sessions
Android and Windows Programming Computer Set	Laptop Dell Inspiron 3476 (2018) CPUIntel® Core™ i7 8550U (1.80GHz Upto 4.00GHz, 4 cores 8 threads, 8MB Cache)	2	For use by student groups during class sessions
SmartTV	Smart TV 4K 65 inch, 4K Ultra HD	2	For group discussions and presentations. For simulations
Audio system	Sony BDVN9200W/BMSP1	1	For group discussions and presentations; for simulations
Projector/Screen	Panasonic PT-LB383 Projector	1	For presentations to the entire class; instructors may use the equipment

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			for introducing theoretical subjects or problems; student groups may use the equipment for presenting project results
Wifi Router	4G TP-Link M7350	1	For connecting the laboratory to the internet

Table 4. Laboratory equipment at Hanoi University of Science and Technology.

In addition, the AI and Cyber Security Active Learning Laboratory is equipped with a number of computers sponsored by the Cyber Security project of Hanoi University of Science and Technology in cooperation with Korea. Through the above equipment the laboratory can accommodate groups of approximately 40 students.

A12.4.2 Staffing

The management of devices in the laboratory and the registration process for using the laboratory takes place through the SoICT website, so there is no need for an administrator.

The laboratory is supported by a technician who is a permanent employee of SoICT. The technician will assist the lecturers in installing computers, setting up the working environment, and repairing and maintaining the equipments and software.

The lecturers using the laboratory are permanent employees of SoICT. The number of lecturers depends on the number of courses held in the laboratory in each semester. In addition, courses are supported by teaching assistants. Usually each course is supported by 1 or 2 teaching

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assistants. The teaching assistants are Master's or PhD students at SoICT. Each teaching assistant receives an allowance through the regular budget of SoICT.

A12.4.3 Financial support

After the completion of the ALIEN project the AI and Cyber Security Active Learning Laboratory will be managed and operated by SoICT. The cost of operating the laboratory includes salary for the employees who operate the lab, operating costs, in particular electricity fees, and maintenance fees for the repair and replacement of aging equipment in the laboratory.

SoICT is a unit of Hanoi University of Science and Technology. Each year, SoICT is allocated a budget of approximately 3m USD, which includes staff salaries, facilities costs, and other expenses. The employees who operate the laboratory are all staff members of SoICT, so they receive their salary from the central budget. Costs for operation, maintenance, repair, and replacement of equipment in the laboratory will be covered by the facilities budget of SoICT. In addition, SoICT often receives funding from external companies and organizations for equipment packages. These funds can use it to upgrade, replace, or supplement laboratory equipment.

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