D3.5 Report on piloting in courses

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Executive summary

ICT-INOV aims to promote innovation skills in higher education through a methodological learning framework that combines design thinking and gamification elements to build the capacity of students and instructors in ICT higher education to apply knowledge to solve the pressing challenges of the modern world. Design thinking encourages students to think outside the box about how technology can foster quality of life and address sustainability goals. Gamification promotes heightened student engagement in learning, specifically in innovation-building activities.

The ICT-INOV learning intervention has been implemented vertically in a manner that addresses all aspects of fostering innovation in higher education, namely the establishment of physical innovation labs, the design and implementation of a digital learning platform that promotes gamified design thinking, educational activities that students deploy on-line collaborating in groups, instructor training, and community building for building organizational capacity to promote innovation for the benefits of wider communities.

This document summarises ICT-INOV piloting activities taken at all partner sites. Piloting occurred at 12 educational organizations in 8 countries: Malaysia, Nepal, Pakistan, Vietnam, Italy, Estonia, Portugal and Greece. Piloting took place in the context of formal curricula courses. It engaged 4,200 students in 70 courses, going well beyond the proposal target of 1,200 and ensuring a wide impact on project activities. Students used the ICT-INOV digital learning intervention in team collaboration across broad subjects. They further used the ICT-INOV digital learning labs and digital learning platform, which hosts over 4,200 student and 360 educator accounts, demonstrating its wide deployment.

The report discusses how the proposed ICT-INOV has been deployed to develop innovation skills and capacity among students and instructors in ICT higher education. For each consortium

partner, the report discusses the courses in which the ICT-INOV gamified design thinking intervention was deployed, how the ICT-INOV labs were used, and the activities that were designed for engaging students and enriching learning experiences in innovation-building contexts.

Finally, the report presents the results of questionnaire-based research in which students responded to questions related to the contribution of the proposed digital learning intervention for innovation, which are highly positive, highlighting the added-value offered by project ICT-INOV.

1. University of Thessaly

1.1 Course ECE329: Technology in Education

1.1.1 Description of the course

The course focuses on the use of technology as an educational instrument in settings of lifelong learning that are tailored to the requirements of certain groups such as school pupils, higher education students, adult learners, vocational learners, and professionals. The course examines both classic and developing modes of instruction, such as collaborative learning, explorative learning, active learning, mobile learning, problem-based learning, project-based learning, active learning, and game-based learning. The course addresses how technology, particularly information technology, might be used in conjunction with innovative pedagogies to improve learning processes and experiences in formal, informal, and non-formal settings. Additionally, the course focuses on how technology, in conjunction with pedagogical methods, may aid in the development of fundamental soft skills desirable in industry, such as analytical thinking, critical thinking, entrepreneurial thinking, problem-solving, collaboration capacity, ability to work independently and in groups, communication ability (both oral and written), and more.

As a result of the ICT-INOV project, the course has been updated to include design thinking principles. Students deploy design thinking to introduce innovation solutions that integrate emerging pedagogies and technology, addressing target users' needs more effectively.

1.1.2 Description of the participants

The course is an elective in the 3rd year of studies at the Department of Electrical and Computer Engineering of the University of Thessaly.

The ICT-INOV methodology was deployed in the 2021 – 2022 academic year. A total of 125 undergraduate students in the Department of Electrical and Computer Engineering of the

University of Thessaly were engaged in the course. The students are in their 3rd, 4th, or 5th year of studies. ICT-INOV will be further deployed in the following academic years, reaching additional groups of students.

1.1.3 Description of gamified design thinking activities

A learning activity based on design thinking was specifically designed for the course. The objective of the learning activity was to challenge students to design a digital learning service or product that enriches educational experiences for a target group of their choice. For example, to support the development of mathematical skills, promote mobile learning, foster programming skills, and develop critical thinking or others. The activity is directly in line with course objectives, which are to integrate emerging pedagogies with state-of-the-art ICT for better addressing specific educational goals in broad learning contexts.

Students worked in groups of up to 6 individuals. The ICT-INOV educational platform allows instructors to structure learning activities based on well-accepted design thinking steps. The activity was structured as follows:

Step 1: Team building.

Students were encouraged to select a team name and logo for team-building purposes. This activity provides teams with a sense of identify and affiliation. It also helps them express their interest and goals. In addition, students were asked to fill-in a Team Basic Canvas, which is available through Creative Commons licenses. The canvas encourages each team to discuss team objectives, roles and skills, values, rules of collaboration, and purpose.

Step 2: Understanding the problem.

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Team members were encouraged to research how ICT can enrich educational experiences, which is the general theme of the proposed activity. They were asked to research and post ideas related to technology and people, technology and places, and technology and feelings.

Step 3: Understanding users.

Students were provided with tools for discovering and documenting actual, as opposed to perceived, user needs. This included recommendations on structuring interviews and documenting results. It further included designing a «user persona», namely describing a characteristic user by considering what the user thinks and feels, sees and hears in her environment, says and does, fears, and must gain.

Step 4: Point of view.

Students were challenged to redefine their original problem, considering the results of their research in the previous steps, which helped them understand the problem from the user's point of view.

Step 5: Brainstorming and design.

Students were challenged to research the internet and describe the problem using images, texts, and videos. They were encouraged to post as many ideas as possible for the solution. Students collaborated with their team members to design and post their proposed solutions on the ICT-INOV platform.

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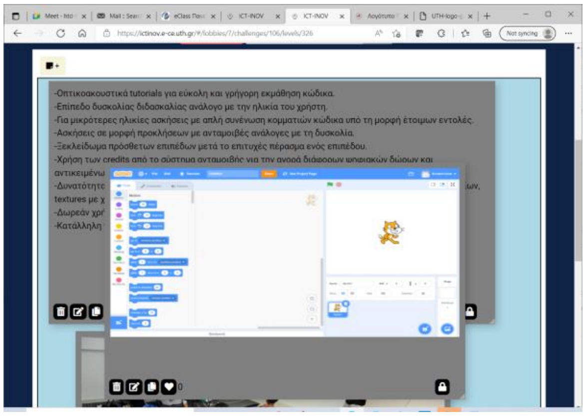
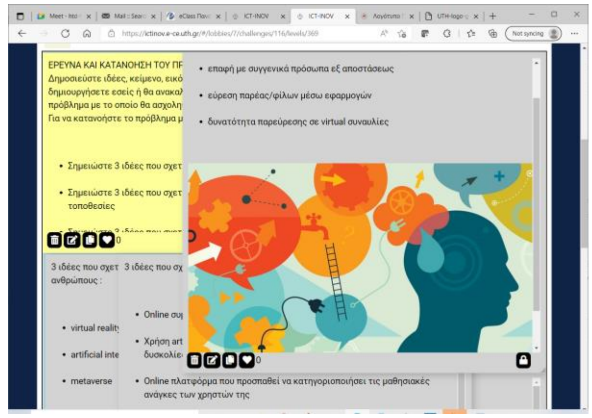
Figure 1. Student teams present innovative solutions in the Technology in Education course in the fall of 2021.

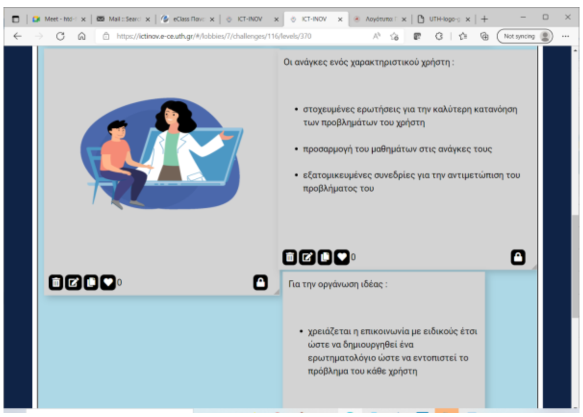
Students deployed the ICT-INOV educational platform to post their projects before they presented their solutions to the entire class. Some of the ideas that the team chose to elaborate on include:

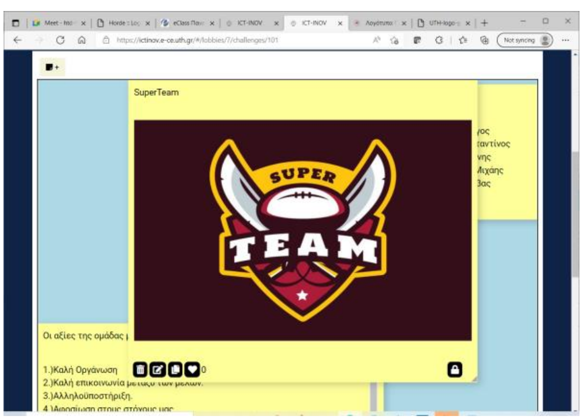
- **Little programmers**. Everyone has the right to education, and learning is valuable to all. The solution exposes young learners to algorithmic thinking and programming through visual tutorials, adaptable difficulty levels, challenges, unlocking additional levels, content personalisation, and open access.
- **Supporting students with attention deficit**. Design an on-line platform through which users will fill-in a questionnaire on their needs and stay in touch with experts who support them in the learning process through personalized training sessions.
- **Supporting individuals who face learning difficulties**. Design a software application that helps users research information and build knowledge through an engaging, safe, fun, and easy-to-use environment that publishes quality educational content through a friendly interface and alternative presentation modes based on text, images, and video.

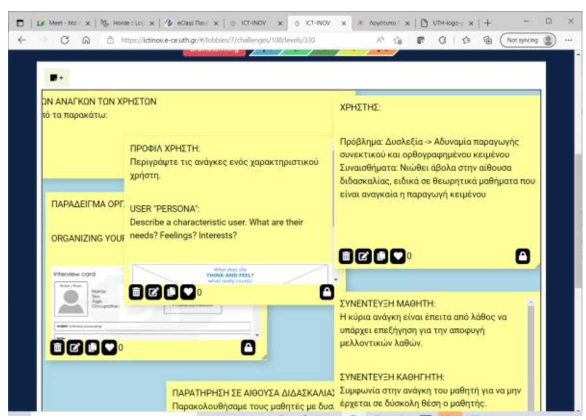
- **Designing an application that helps students identify valid information as opposed to fake news**. The application will help students to organize their knowledge, save time, and maximize the impact of their efforts.
- **Supporting all individuals to learn sign language**. The application will help hearing-impaired individuals better communicate with the world around them. The application will present an avatar that will demonstrate signs.
- **Supporting students with dyslexia**. The application will correct spelling errors, generate text through word prediction, and process text for suggesting enhancements. Another idea is to design computer labs with easy-to-use keyboards and screens; this solution may be expensive but offers advantages to individuals with dyslexia.
- **Technology for older people**. Design an application that allows elderly individuals who may feel isolated to stay connected and active and develop knowledge on subjects of interest.
- **A network of students for entrepreneurship**. Through the network, students will exchange ideas, receive credible information, and expand their knowledge.
- **Building foreign language skills**. Design an open educational application that provides access to oral, text-to-speech, and videotaped exercises while encouraging students to work on projects in groups. Furthermore, supports individuals with learning difficulties. Promote a game-based learning approach with short activities that individuals with busy schedules can use.











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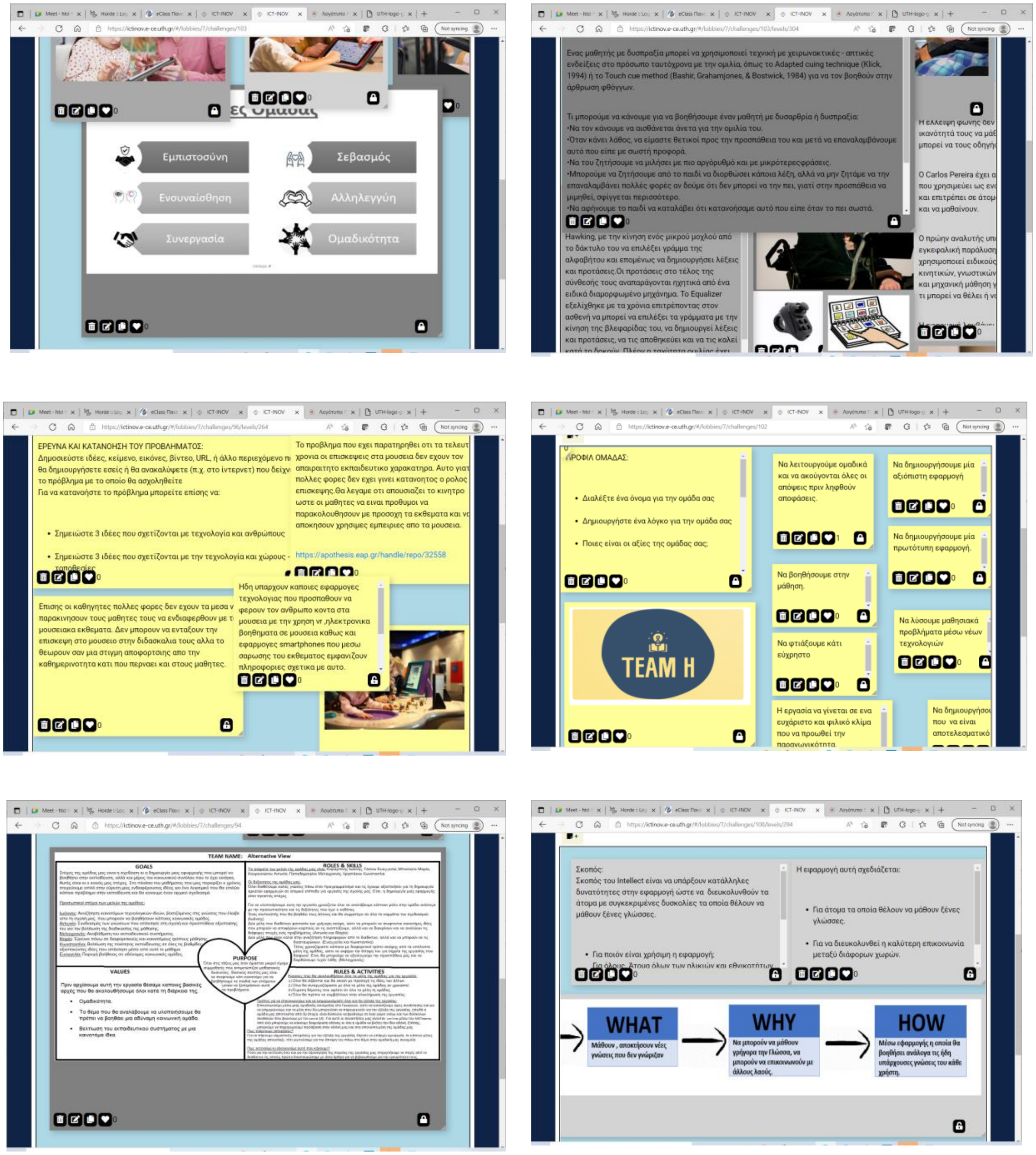

Figure 2. Screenshots of student projects in the Technology in Education course in the fall of 2021.

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1.2 Courses ECE470: Software Engineering and MDE607: Advanced Software Engineering

1.1.1 Description of the course

The courses focus on software engineering principles, namely good practices for designing, implementing, and validating software products. It addresses all aspects of software design, including requirements extraction and analysis, requirements definition, functional and non-functional requirements, software architectures, software design methodologies, and project management, including time management, modelling, reliability engineering, safety engineering, security engineering, and emerging agile design processes. During the course, students are challenged to work in teams to design and implement full software services by following sound software engineering principles.

The courses are jointly offered in the undergraduate and graduate programs of the Department of Electrical and Computer Engineering of the University of Thessaly. This means that both undergraduate and graduate students are present in the classroom at the same time.

As a result of the ICT-INOV, the course has been updated to include design thinking principles. Students are exposed to design thinking concepts and deploy design thinking to implement their projects.

1.2.1 Description of the participants

The courses are electives in the Bachelor's and Master's in Computer Science programs of the Department of Electrical and Computer Engineering of the University of Thessaly. The program targets students who wish to continue their studies, possibly entering a doctoral track. The course is also open to undergraduate students under specific conditions. Typically, 4th or 5th year undergraduate students, close to completing their studies, may attend the course along with graduate students. ICT-INOV was used in academic years 2021 – 2022 and 2022 – 2023.

In the 2021 – 2022 academic year, the courses were attended by 77 undergraduate and 8 graduate students from the Department of Electrical and Computer Engineering of the University of Thessaly.

In the 2022 – 2023 academic year, the courses were attended by a similar number of individuals.

1.2.3 Description of gamified design thinking activities

A learning activity based on design thinking was specifically designed for the course. The objective of the learning activity was to challenge students to design and implement a software service that addresses the needs of a specific group. For example, a learning game, a service for financial transactions, a community for reuse of unused items, a social network, software services for enriching the lives of individuals with disabilities, and more. The activity is directly in line with course objectives, which aim to encourage teamwork in the context of software development practices.

Students worked in groups of up to 6 individuals. The activity was structured as follows:

Step 1: Problem discovery.

Students were encouraged to research the problem by exploiting the internet. They were asked to post ideas related to technology and people, technology and places, and technology and feelings. Through this process, students broadened their perspective on technology as a means for enriching their quality of life. The exercise helped students build insight on various topics and select a specific challenge to solve.

Step 2: Empathy.

Students were encouraged to “put themselves in the user's shoes”. They were encouraged to structure and conduct interviews with characteristic users and to document their findings in interview cards. Based on the collected information, students were asked to create a user persona, namely a description of a typical target user. In the deployed, students were asked to describe what the user thinks, feels, hears, sees, says, and does.

Step 3: Problem definition.

Students were asked to define the problem they wished to work on through a sentence of the form “who, what, how”. This exercise encouraged students to define the challenge in focus in one line, identifying what they planned to create to address which needs and through what means.

Step 4: Ideation.

Students were encouraged to publish as many ideas as possible to synthesize a solution to the problem of their choice. The objective at this process stage was to “go wide”, noting as many ideas as possible.

Step 5: Solution synthesis, prototyping, and evaluation.

At this stage, students were directed to document their design towards a solution as specifically as possible to facilitate software development. In addition, students implemented their solutions in the programming languages of their choice. They presented their results for the benefit of the entire class.

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Figure 3. Students presenting their solutions in the Software Engineering course in fall 2021.

Throughout the process, students used the ICT-INOV platform to publish their ideas at each stage of the design thinking process.

Some of the projects that students worked on in the 2021 – 2022 academic year include:

- **Piano practising**. A software tool was prepared to help young students practice piano.
- **COVID-free device**. A software tool was developed that helps scan vaccination certificates and match them to personal ID cards. The application helps individuals gain fast access to shops, restaurants, and other closed spaces by making the certification checking process quicker.
- **Buddy finder**. A social network was developed that helps individuals with special needs be matched to individuals willing to support them and accompany them in excursions and everyday activities.
- **Fake news**. An application was developed to analyze the probability that an article is fake news.

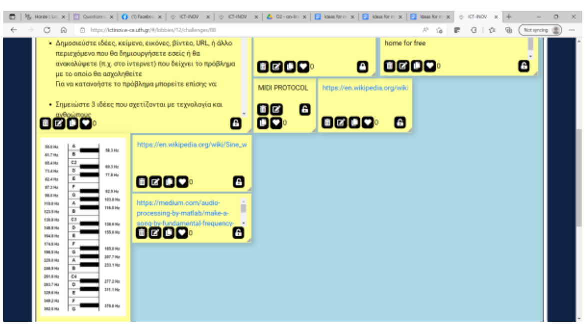
- **High blood sugar detection device**. A software tool was developed to identify individuals at risk of high blood sugar-related diseases by considering medical data. The tool deploys machine learning techniques.
- **Make my way**. A software application was developed that aims to help individuals with moving disabilities navigate around town by recommending optimal routes based on real-time data on obstacles.
- **Shopping assistant**. A software tool was developed that keeps track of a household's shopping inventory and makes recommendations or provides reminders on purchasing items that are low in stock.
- **Movie recommender**. A software tool was developed to recommend movies for viewing to individuals based on their preferences.

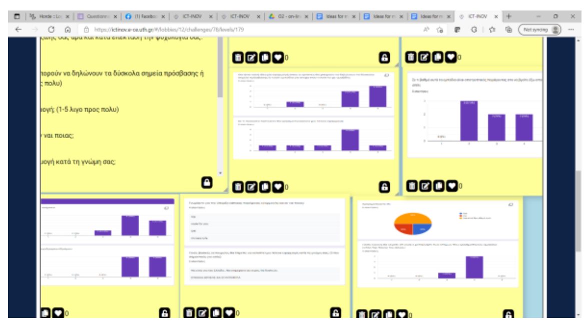
Some of the projects that students worked on in the 2022 – 2023 academic year include:

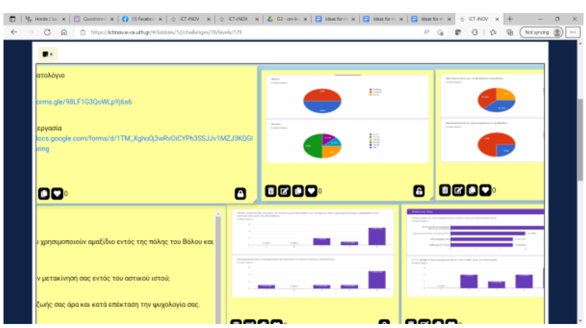
- **Fitness game**. An Android® application was developed to encourage users to stay fit.
- **Zoo DB**. A serious game was developed for managing a zoon
- **Diabetes management**. An application that uses machine learning was developed to provide recommendations for living well with diabetes.
- **Gifting application**. An application was developed to help groups of individuals share the costs and discover interesting ideas for buying a joint gift for a friend.

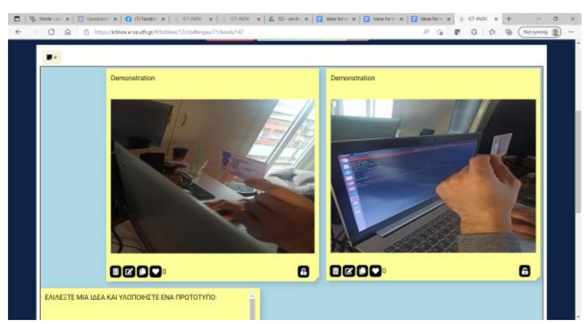
- **Teaching sign language**. An application was developed to teach individuals how to use sign language.
- **Bus routing application**. An application was developed to enhance users' bus travelling experiences.
- **First aid application**. An application was developed to support individuals in providing first aid.
- **Share your bike**. A bike-sharing application was developed.
- **eGrades**. An application was developed to support learning administration, including the management of student grades.

The following are some screenshots of student project work on the ICT-INOV platform.









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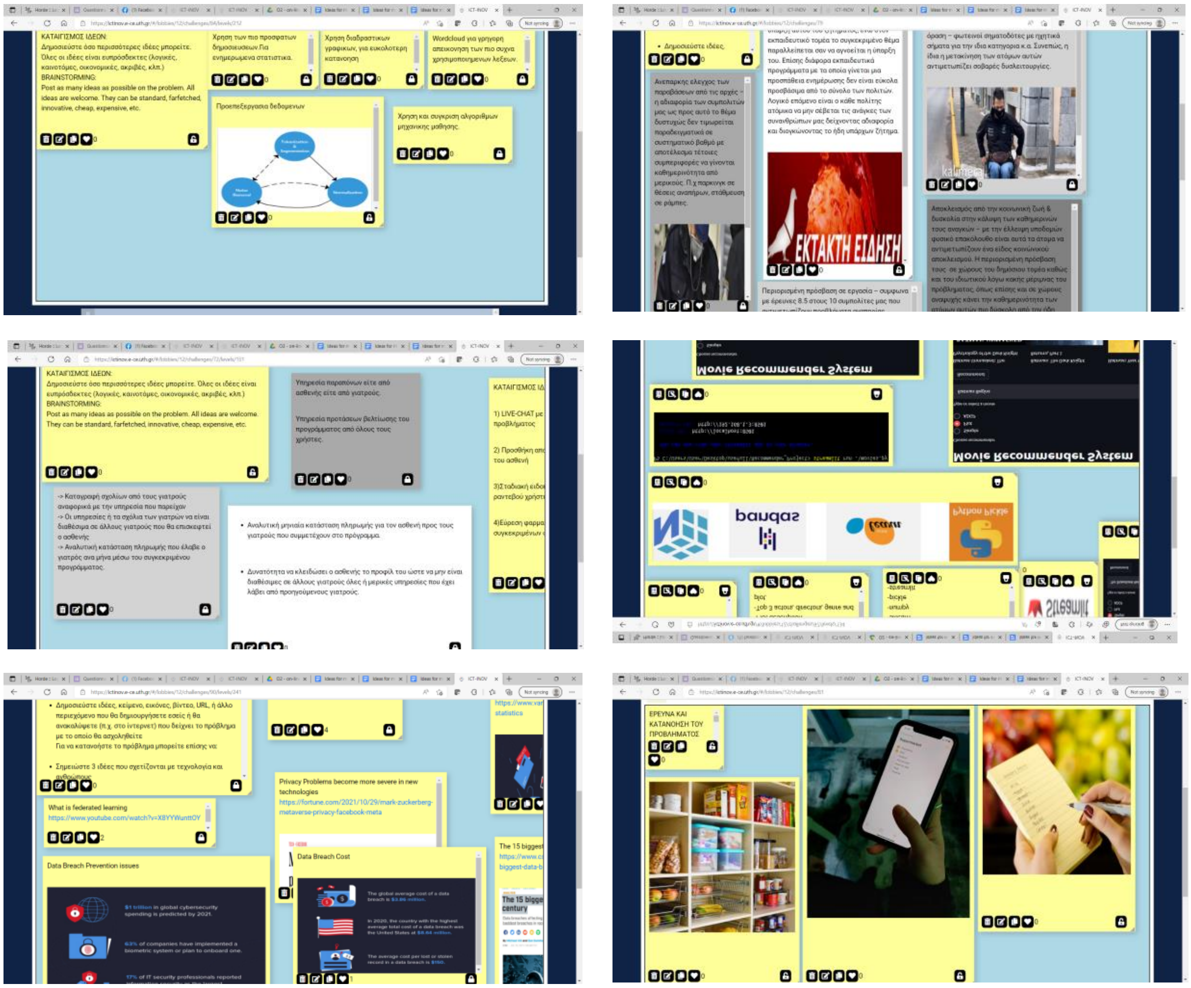

Figure 4. Screenshots of student projects in the ICT-INOV platform in the Advanced Software Engineering course, fall 2021.

1.3 Course ECE516: Game Design and Implementation

1.3.1 Description of the course

The course focuses on principles of game design and implementation. It addresses all aspects of game design, starting from the definition of a game concept, which focuses on a 3-minute pitch of a game to be implemented throughout the semester, including the game idea, target audience, game world, compelling features, camera models, single or multiplayer design, game genre, characteristic gameplay, story, game world, and marketing plan. Subsequently, the course follows through all steps of the game design process, including user analysis, game world design, story design, character design, puzzle design, gameplay, game balancing, level design, creative and expressive play, on-line games, serious games, and other aspects. The course addresses both theory and practice. Students design and implement an in the UNITY® game development environment an actual game based on the lecture presentations. They present the game concept, game design, and final implementation in the class for the benefit of all participants. Upon completion of the course, students will have a good understanding of game design principles and will be able to apply them in practice to develop actual games.

1.3.2 Description of the participants

This is an elective course in the undergraduate program of the Electrical and Computer Engineering Department of the University of Thessaly. Typically, the course is attended by 4th or 5th-year undergraduate students close to completing their studies.

In the 2021 – 2022 academic year, the course was attended by 124 students.

In the 2022 – 2023 academic year, the course was attended by 76 students.

1.3.3 Description of gamified design thinking activities

A learning activity based on design thinking was specifically designed for the course. The objective of the learning activity was to challenge students to design and implement a digital game with a learning focus. Students could design a game that addresses the needs of a target group of their choice, such as primary or secondary school learners, higher education students, professionals, disadvantaged individuals, or others. Students further had freedom in selecting the game focus. Example topics included math, critical thinking, history, geography, team skills, or any theme related to formal educational curricula, soft skills, or informal learning.

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ICT-INOV supported gamified design thinking was deployed both in the 2021 – 2022 and the 2022 – 2023 academic years. In both cases, students worked in groups of up to 6 individuals. In both academic years, the activity was structured as follows:

Step 1: Game concept.

Students were encouraged to design a game concept addressing the following aspects: game objectives, user experience, and learning focus of the game.

Step 2: User analysis.

Students were challenged to describe a characteristic user or player by considering aspects such as what is the target audience, what characteristics differentiate the target audience from other groups, and what challenges the audience likes. They were further encouraged to describe a typical player by describing the "user's journey", namely the experiences of the user throughout her life that make her the person that she is today, for example, experiences in school, university, workplace, family, and more.

Step 3: Game mechanics.

Students were instructed to describe the core game mechanics, including physics rules, progression mechanics, game economy for trading resources, social dimension, tactical elements, game objects and attributes, relationships between game objects, sources and drains of resources, and more.

Step 4: Game world design.

Students were asked to design the game world, including the physical dimension, time elements such as day and night or seasons, values, emotional dimension, ethical dimension, style, mood, aesthetics, and more.

Step 5: Story design.

Students were challenged to introduce a story into the game by applying Vogler's model. This model presents a structure to story design, starting from the ordinary world and moving to a call to adventure, refusal of the challenge by the hero, meeting a mentor, accepting the challenge, trials, enemies, allies, reaching the largest conflict of the story, reward, and the road back.

Step 6: Character design.

Students were challenged to describe the main characters of the game. They were further asked to describe if the characters would be art- or story-based, the looks of the characters, and the behaviour. They were encouraged to introduce an avatar into the game and consider how the avatar would grow through the challenges and story.

Step 7: Game balancing and final overall design.

Students were challenged to consider elements for balancing their game, namely, making the game fair by ensuring that the challenges have an appropriate difficulty level that corresponds to the skill of the user.

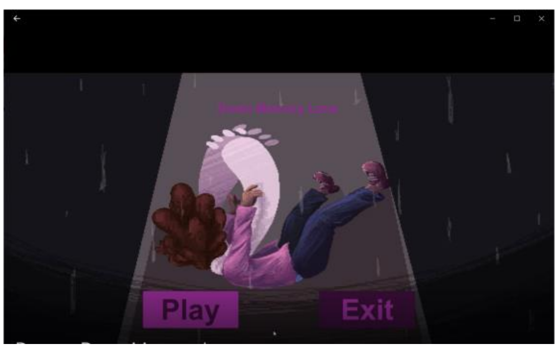
Throughout the process, students used the ICT-INOV platform to publish their ideas and collaborate through every step of the game design process. The platform encouraged students to build on each other's ideas and allowed them to collaborate from home in between class sessions.

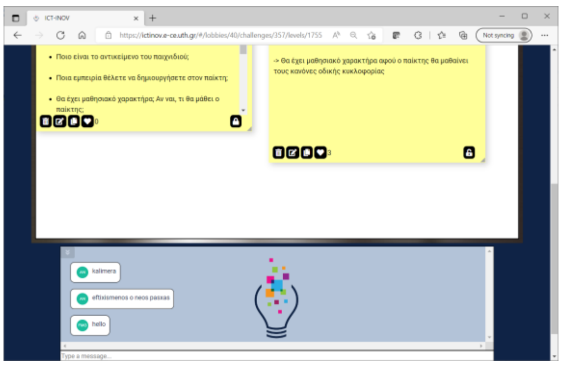
Some examples of projects that students developed in the 2021 – 2022 academic year include:

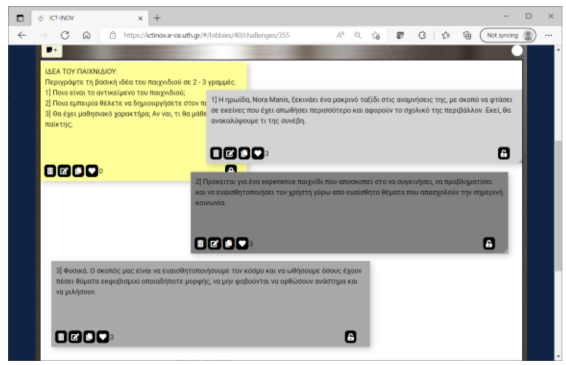
- **A game on raising awareness of COVID-19**. An arcade game in which users collect items related to the fighting of COVID-19, such as vaccines and medication.
- **A game on raising awareness on mental health**. The game follows a character who ponders her past experiences to discover her strength and build confidence.
- **A game of history**. The game encourages the player to discover different history periods, such as ancient Egypt, ancient Greece, and the Roman empire.
- **Math games**. Diverse games on playfully building early math knowledge.

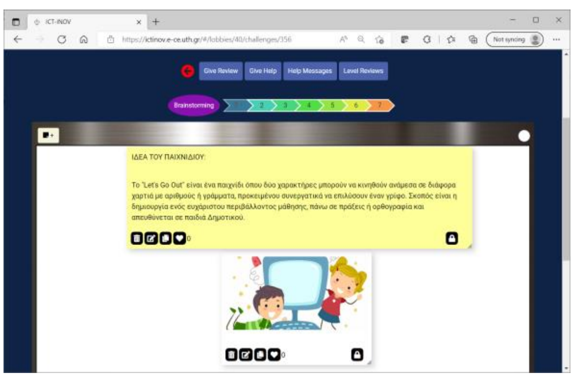
- **A game on raising awareness for air pollution**. The game encourages players to limit the emissions of toxic gases.
- **Arcade games that combine entertainment with knowledge building**. The games combine popular mechanics, such as avoiding obstacles and collecting items, with questions for building knowledge on mathematics and other primary and secondary education curricula subjects.
- **A game on geography**. A world trivia game challenges players to answer questions related to different continents, gaining badges and travelling the globe.

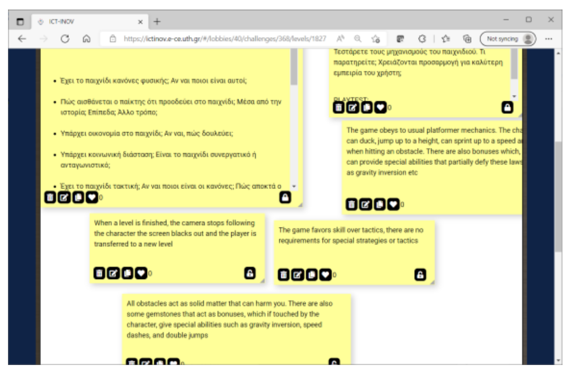












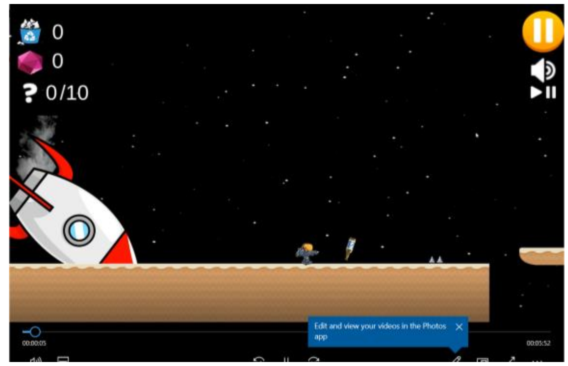


Figure 5. Student projects, presentations, and use of the ICT-INOV platform in the Games Design and Implementation course, spring 2022.

Some of the projects developed in the 2022 – 2023 academic year include:

- **A game on geography**. A multiple-choice exercise on information related to countries around the globe.
- **A strategy game**. A game on strategic preparation of player defences for fighting enemies with different capabilities.
- **A puzzle game or escape room for knowledge**. A game through which players are encouraged to build critical and analytical thinking by discovering information and establishing associations between facts.
- **Action – adventure games**. In arcade games, players are encouraged to overcome obstacles and avoid enemies while responding to trivia questions.
- **A driving rules game**. An educational game on building awareness and knowledge on safe driving behaviour.
- **Trivia snakes and ladders**. This is a variation to the popular children’s game in which players are challenged to respond correctly to educational questions before receiving rewards, such as climbing a ladder that brings them closer to victory.

- **Language games**. Games on recognizing words and letters suitable for young learners who may also face learning difficulties.
- **Math games**. Multiplication games for young learners and game elements such as navigating a labyrinth.

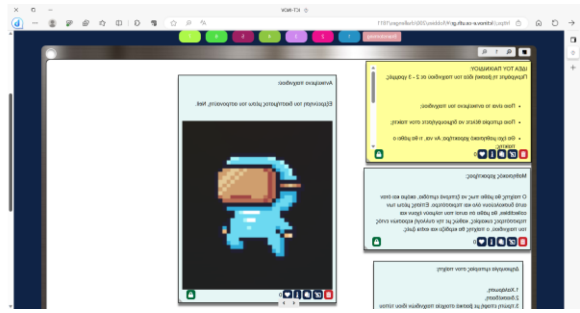
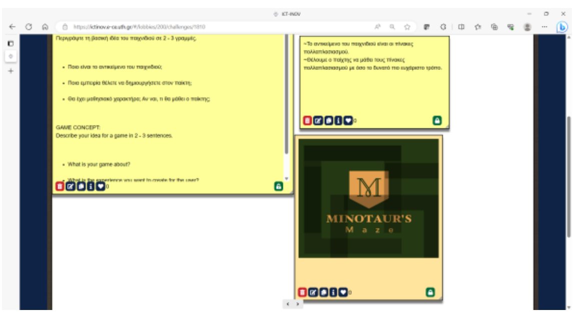




Figure 6. Student projects, presentations, and use of the ICT-INOV platform in the Games Design and Implementation course, spring 2023.

1.4 Course ECE516: Serious Games

1.4.1 Description of the course

The course focuses on the design and implementation of games and serious games. Given its focus on serious games, namely games implemented for learning purposes, the course further integrates aspects of pedagogical design, such as active, experiential, collaborative, and game-based learning. The course offers a theoretical and a practical component. In the theoretical component, students focus on all aspects of game design, starting from the understanding of the principle of serious games, game terms, and game genres and continuing to game design activities such as world design, character design, story design, game balancing, characteristics of on-line games, puzzle design, level design, tactical game design, and more. In addition, the theoretical aspect of the course covers areas such as the use of serious games in diverse contexts, including education, marketing, health, and awareness raising on social issues such as engaging in civic life, preserving the environment, and more. In the practical component of the course, students develop a game in teams. They can develop a digital prototype of their game using popular platforms, such as UNITY® and Scratch® or a board game designed with paper.

Co-funded by the Erasmus+ Programme of the European Union

1.4.2 Description of the participants

The course is an elective in the Master's program on Applied Informatics. The program targets professionals who want to obtain a Computer Science degree. It has a duration of 2 years. In the 2021 – 2022 academic year, it was attended by 15 students out of the 17 enrolled in the Master's program, demonstrating that the course is very well received.

1.4.3 Description of gamified design thinking activities

A learning activity based on design thinking was specifically designed for the course. The objective of the learning activity was to challenge students to design a game and implement a digital or physical prototype. Students had the option to design a game that addresses the needs of a target group of their choice, such as primary or secondary school learners, higher education students, professionals, disadvantaged individuals, or others. In addition, students had the choice of designing a game of any genre, such as an arcade game, an adventure game, or an escape room. The course took place mostly virtually. The ICT-INOV platform proved to be a great team collaboration tool when individuals were not in the same room.

Students worked in 6 groups of up to 3 individuals. The activity was structured as follows:

Step 1: Game concept.

Students were encouraged to design a game concept addressing the following aspects: game objectives, user experience, learning focus of the game, basic aspects of game world design, elements of story design, user interaction models, and marketing plans.

Step 2: User analysis.

Students were challenged to describe a characteristic user or player by considering aspects such as what is the target audience, what is the age of the audience, what characteristics differentiate the target audience from other groups, and what challenges the audience likes. They were further encouraged to describe a typical player by describing the “user’s journey”, namely the experiences of the user throughout her life that make her the person that she is today, for example, experiences in school, university, workplace, family, and more. Also, students were exposed to other tools for user analysis, such as the empathy map.

Step 3: Game mechanics.

Students were instructed to describe the core game mechanics, including physics rules, progression mechanics, game economy for trading resources, social dimension, tactical elements, game objects and attributes, relationships between game objects, sources and drains of resources, and more.

Step 4: Game world design.

Students were asked to design the game world, including the physical dimension, time elements such as day and night or seasons, people, values, social organization, emotional dimension, ethical dimension, style, mood, aesthetics, style, mood, dimensions, whether it is located inside a building or outdoors.

Step 5: Story design.

Students were challenged to introduce a story into the game by applying the Hero’s Journey model, in which the story follows the hero in the ordinary world, his exposure to the challenge, refusal of the hero to face the challenge, meets a mentor, accepting the challenge, trials, enemies, allies, reaching the largest conflict of the story, reward, and the road back.

Step 6: Character design.

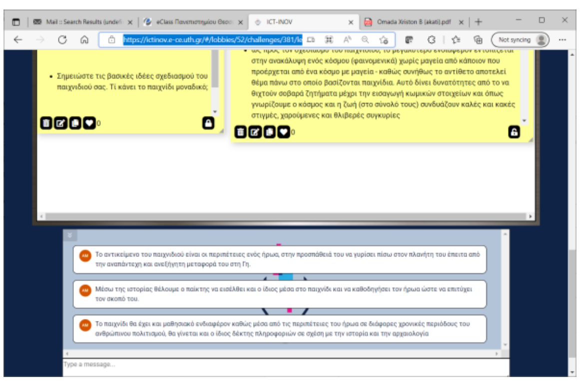
Students were challenged to describe the main characters of the game. They were further asked to describe if the characters would be art- or story-based, the looks of the characters, and the behaviour. They were encouraged to introduce an avatar into the game and consider how the avatar would grow through the challenges and story.

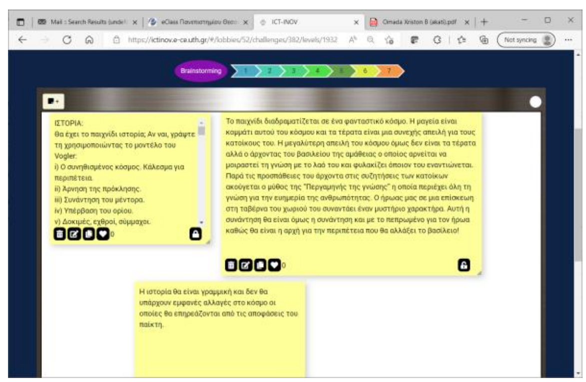
Step 7: Outline of final game design.

Students were encouraged to present a summary of all design elements of their game, which is a synthesis of the ideas analysed in previous steps.

Following are examples of projects implemented by students:

- **An educational escape room**. A game that challenges the player to solve puzzles to leave a closed space.
- **A world trivia game.** A knowledge game that challenges players to answer questions related to geography.
- **A driving rules game**. A game that helps players understand street signs.
- **A space game**. The game has 2 gameplay modes. In the first, the player answers questions, building general knowledge. In the second, the player drives a spaceship following the rules of arcade games.
- **A history game**. An arcade game that exposes the player to history questions.





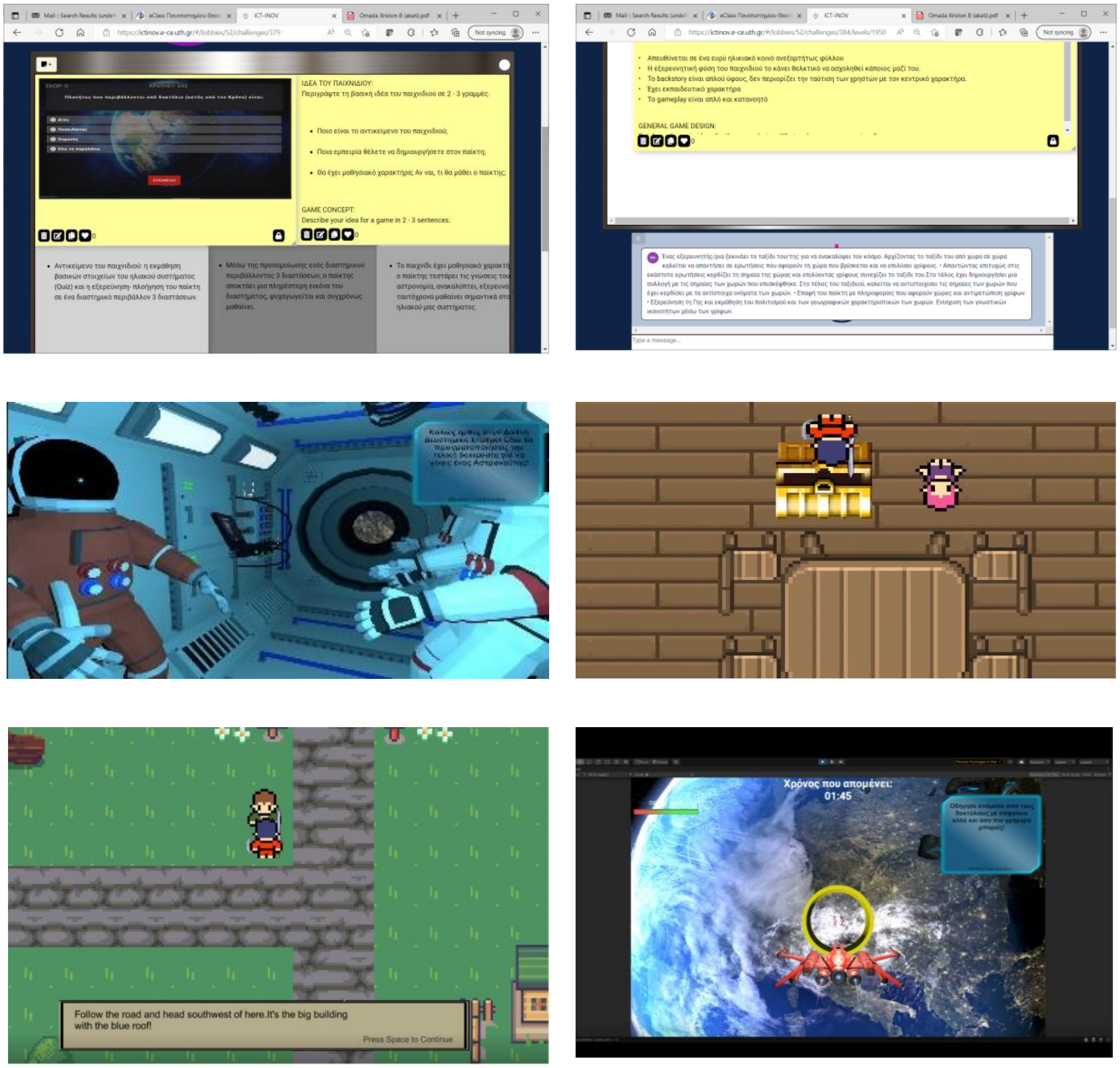


Figure 7. Screenshots of student projects and team collaboration in the ICT-INOV platform in the Serious Games course, spring 2022.

1.5 Course ECE113: Discrete Mathematics

1.5.1 Description of the course

The course focuses on discrete mathematics with applications in Computer Science and Engineering. While the subject of discrete mathematics is very wide and applicable in a broad range of engineering, science, and other principles, this course focuses mainly on elements that are applicable in subjects of Computer Science and Engineering curricula. The course addresses logical expressions, algorithm growth, induction, graphs, trees, sets, functions, and numbering techniques. These have applications in areas such as programming, algorithms, networks, performance, and other areas. The course is heavily problem-based, challenging students to introduce solutions and to build their critical thinking abilities.

1.5.2 Description of the participants

This is a mandatory 1st year course in the Department of Electrical and Computer Engineering of the University of Thessaly. It is attended by 180 individuals each academic year.

1.5.3 Description of gamified design thinking activities

A learning activity that promotes collaboration in problem-solving contexts was designed for the course and used in the 2021 – 2022 academic year. Students worked in 30 teams of up to 6 individuals. The activity included 3 steps, each challenging teams to address relatively long challenges that are more appropriate as projects rather than exam questions. The activity included the following steps:

Step 1: Introduction of a solution to the Tower of Hanoi problem.

This classic Computer Science problem asks students to move disks of increasing diameters from one pole to another using a 3rd pole for support. The problem has one rule, that no larger disk may be placed over a smaller disk. Students need to calculate the number of moves necessary for moving a specific number of disks. Students were asked to perform the activity as a group, building creative thinking, problem-solving, and critical thinking skills inherent in design thinking.

Step 2: Counting available internet addresses.

This is a numbering problem directly related to the real world. Students are asked to count all available IP addresses under the IPv4 protocol. The exercise helps students reflect on the actual implementation of networks. Students were asked to perform the activity in groups in order to apply mathematical skills in practical activities inspired by real life, establishing associations between classic problem-solving and the world of work.

Step 3: Describing applications of graphs in engineering and everyday life.

This activity challenges students to consider different aspects of everyday life in which graphs are applicable for introducing solutions, such as communications, road networks, computer networks, biology, chemistry, friendship maps, influence maps, static analysis of software programs, and more. This activity challenged students to reflect on how mathematics is embedded in real life. It further encouraged them to be creative in identifying links between the theory and practice of networks.

Each team collaborated to introduce solutions to the challenges, using the ICT-INOV platform to foster communication. The projects demonstrate how the platform supported teamwork by publishing text, images, and even scanned handwritten solutions.

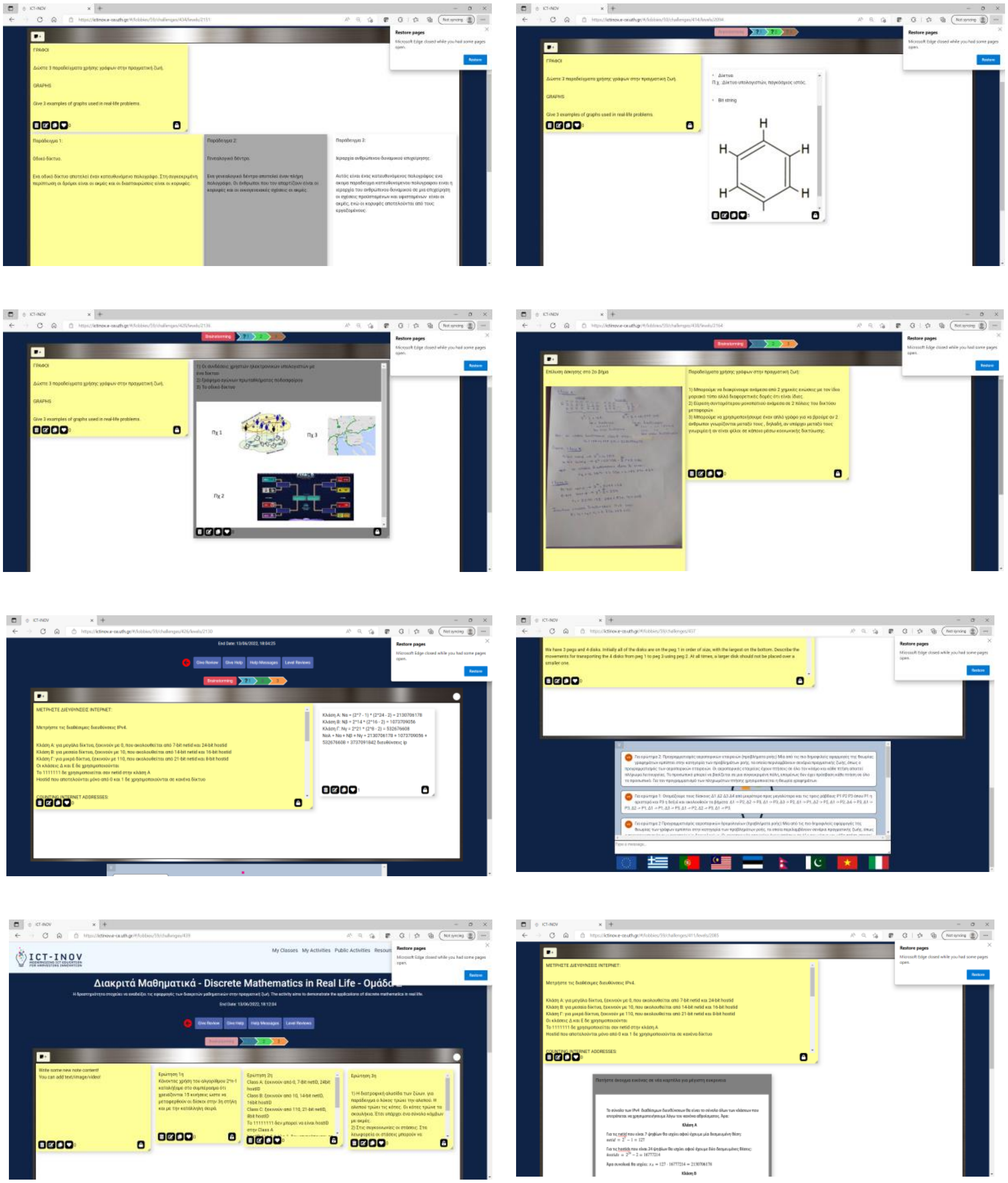


Figure 8. Student projects in the Discrete Mathematics course, spring 2022.

1.6 Course ECE454: Machine Learning

1.6.1 Description of the course

The course is an introduction to programming environments and algorithms for machine learning. Emphasis is placed on Excel, Python, R, Orange, Rapidminer, and Weka data mining environments for solving problems with data mining techniques. The course presents statistical machine-learning techniques, categorization and regression for business analytics, sentiment analysis, and opinion mining. More specifically, the courses focus on technical learning for analyzing large amounts of data from business applications and social networks. It addresses different types of machine learning algorithms, such as supervised learning, in which datasets are labelled. Problem-solving is based on regression and classification techniques and unsupervised learning, in which datasets are not labelled. Problem-solving is based on dimensionality reduction and clustering, as well as reinforcement learning, in which a model learns from every action. Through specific case studies, the course applies machine learning in diverse fields, such as finance and business, government, health, bioinformatics, IoT, and more.

1.6.2 Description of the participants

This is an optional course in my 4th year of study in the Department of Electrical and Computer Engineering at the University of Thessaly. In the fall 2022 – 2023 semester, the course was attended by 40 students.

1.6.3 Description of gamified design thinking activities

Students were challenged to implement a machine learning project and, specifically, to develop a software recommendation system. The project activities covered the entire semester. The ICT-INOV learning intervention was used to promote team collaboration towards designing and implementing innovative solutions. The activities occur in the Department of Electrical and Computer Engineering computer lab.

The project was broken down into the following steps.

Step 1. Problem discovery.

In problem discovery, students were challenged to research the problem area in relation to building a recommendation system for a specific purpose of their choice. They were asked to describe the problem in focus through images, videos, and articles. They were further challenged to analyze user needs and describe a characteristic user through an empathy map that demonstrates how a user thinks and feels, what the user sees and hears, what problem the user faces, and what potential gains from a good solution are.

Step 2. Problem re-definition.

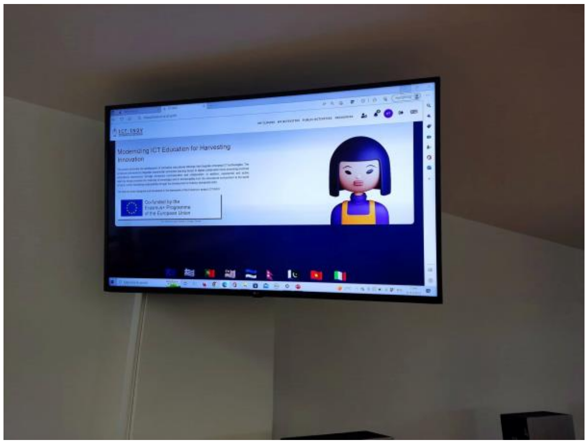
Students were challenged to redefine the problem in focus through a point of view statement by considering the information they discovered in the problem research phase and by enriching it with their newly developed understanding of the problem.

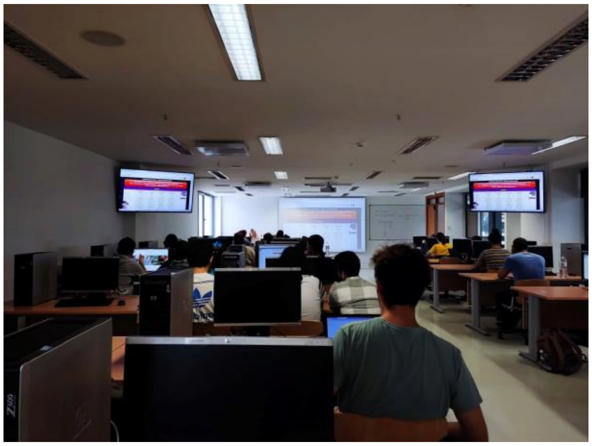
Step 3. Ideation.

Students were challenged to introduce as many ideas as possible towards a solution. They were asked to consider solutions that require a significant budget for implementation, a small budget, and technology. From this pool of ideas, students were asked to select one for prototyping. Students evaluated ideas by categorizing them into 3 groups: easy-to-implement and normal ideas, easy-to-implement but innovative ideas, and difficult-to-implement ideas for which technology is not mature yet. They were asked to select an idea that was easy to implement and innovative.

Step 4. Prototyping.

Students developed a prototype through software coding in the Python programming language. The prototype was a recommendation system that applied machine learning principles, linking theory to practical applications.





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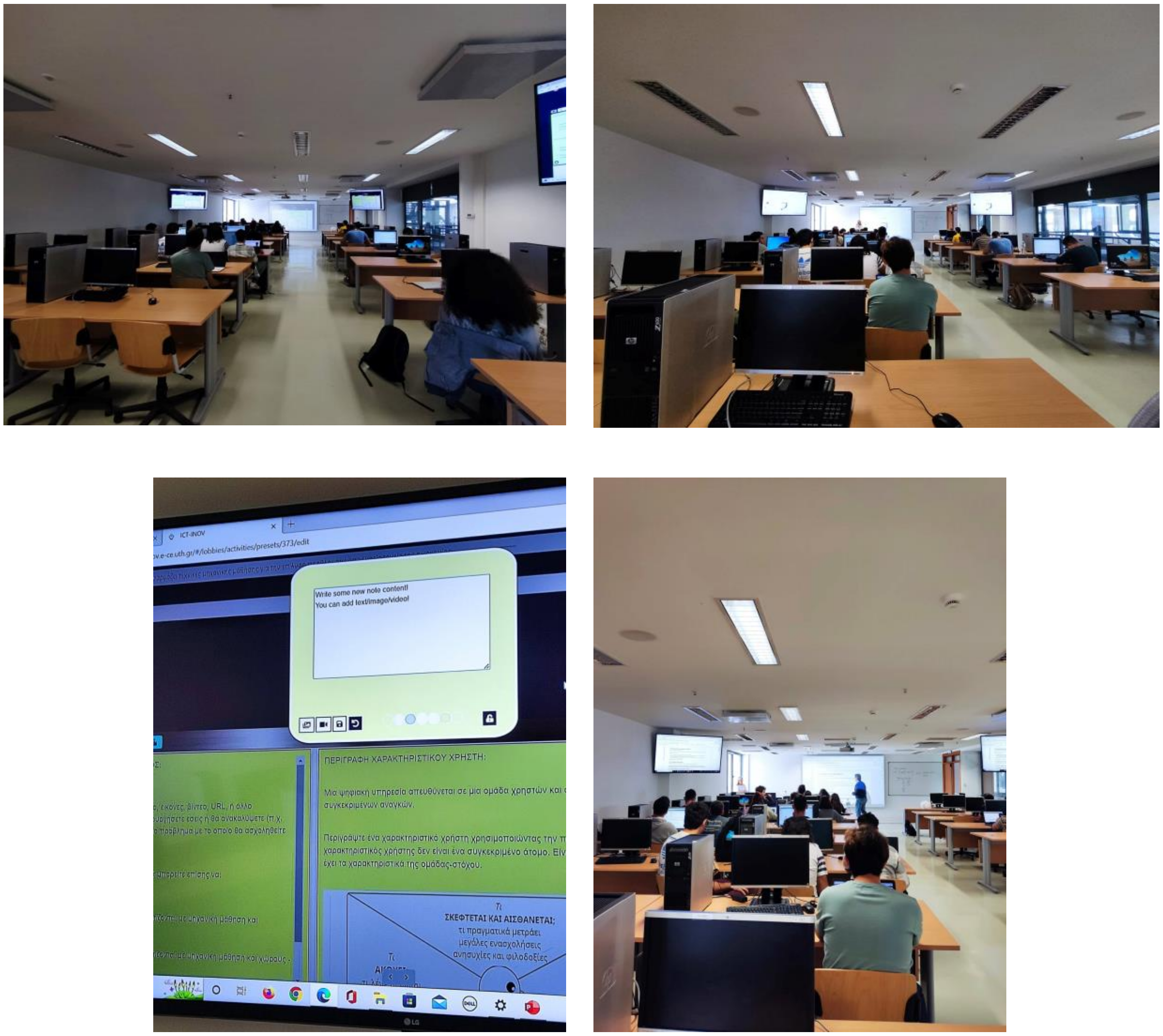


Figure 9. Students are exposed to the ICT-INOV digital learning platform in the context of the Machine Learning course, fall 2022.

1.7 Course ECE111: Physics 1

1.7.1 Description of the course

This is an introductory course aimed at introducing students to the concepts of mechanics and thermodynamics. The course covers straight and curvilinear motion topics, Newton's laws and applications, forces, kinetic energy, dynamic energy, energy conservation, inertia, rotational motion dynamics, gravity, fluid mechanics, and thermodynamics. The course covers both theory and practice. Upon completion of the course, students can understand basic physics concepts and principles and laws related to material mechanics, fluid mechanics, and thermodynamics, apply these concepts to solve real-world problems, and have enriched their critical thinking and collaboration skills.

1.7.2 Description of the participants

This is an obligatory course in the 1st year of studies in the Department of Electrical and Computer Engineering of the University of Thessaly. In the fall 2022 – 2023 semester, 180 students attended the course.

1.7.3 Description of gamified design thinking activities

The course includes a theoretical and a practical component. In the course's theoretical component, students are exposed to physics principles through lectures. In the practical component, they are exposed to practical exercises. In this context, a project deploying the ICT-INOV gamified design thinking approach was developed. Students worked on the project throughout the semester in groups of 6 individuals.

The project's purpose was to encourage students to establish mental associations between physics principles and clean energy production through renewable resources. The activity demonstrated the links between physics and real life. In addition, the activity promoted the development of critical thinking, analytical thinking, solution synthesis, solution evaluation, and team collaboration skills that are highly desirable in design thinking and innovation-fostering environments.

The students worked on the following steps.

Step 1. Problem research and analysis of the current situation.

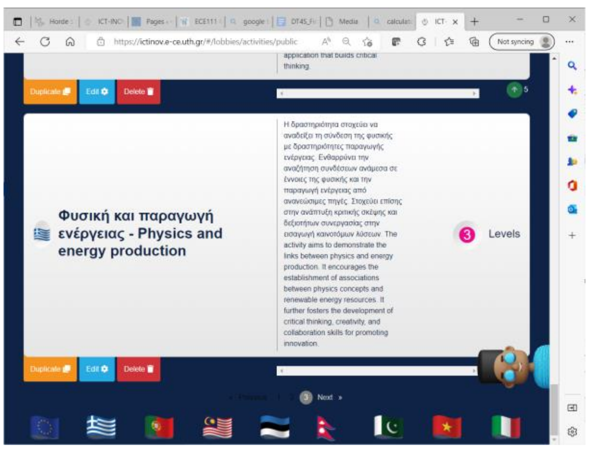
Students were challenged to research current energy production practices and document areas for improvement, such as cost, pollution, and safety.

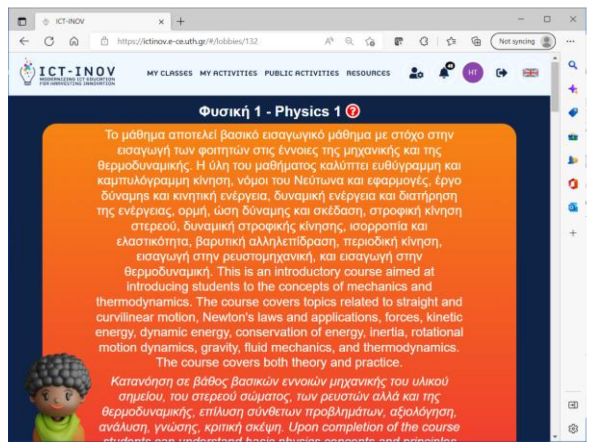
Step 2. Ideation.

Students were challenged to research and document emerging and alternative energy production solutions based on renewable and other resources and know-how that can enrich existing practices.

Step 3. Solution synthesis and prototyping.

Considering sustainable energy resources, students were challenged to design and prototype an environmentally friendly solution to the clean energy production challenge.





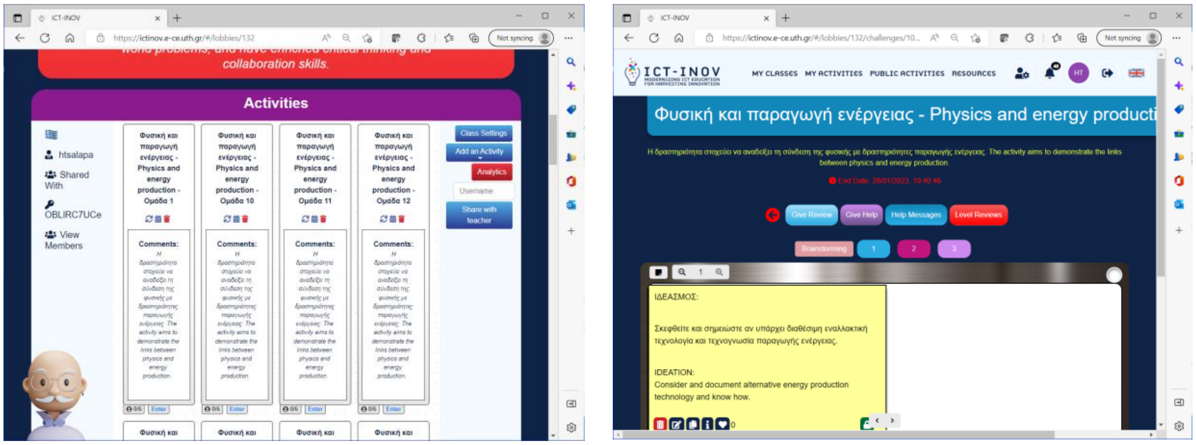


Figure 10. Activities designed for the Physics 1 course, fall 2022.

1.8 Course MDE627: Design Thinking in Computer Engineering

1.8.1 Description of the course

This is an introductory course on design thinking principles offered at the graduate level in the Master's in Computer Engineering program. The course is a direct result of the ICT-INOV project. It was designed and integrated into the Department of Electrical and Computer Engineering curriculum of the University of Thessaly by taking ICT-INOV activities and applying them in practice towards a design course. The course was introduced for the first time in the formal curriculum of the Department of Electrical and Computer Engineering in the 2022 – 2023 academic year. The course complements the department curricula nicely, as in the last departmental external evaluation, there was a recommendation for introducing a design course. The course aims to build students' understanding of the importance of innovation and design. It further aims to build student competencies and skills to turn ideas into action by integrating foundational knowledge developed in other curricula courses with design thinking principles, resulting in ideas, projects, and solutions that deploy digital technologies in the context of entrepreneurship for addressing customer needs, or social entrepreneurship, for addressing social challenges of the 21st century.

1.8.2 Description of the participants

The course is an elective in the Master's Program on Information Science of the Department of Electrical and Computer Engineering of the University of Thessaly. In the spring 2023 semester, 10 graduate students attended the course.

1.8.3 Description of gamified design thinking activities

The course is organized in the form of an active, hands-on workshop. In the initial classes, students are exposed to the importance of design in addressing modern challenges and design thinking principles in introducing human-centred solutions to difficult problems. Subsequently, students are presented with a semester project, the focus for the academic year 2022 – 2023 was "Digital Technologies for Sustainability". Students worked in teams of 2 – 3 individuals for the remainder of the semester. They engaged in exercises related to design thinking for researching the problem, redefining it in a manner that allows the introduction of diverse solutions, and generating, evaluating, and prototyping ideas. At the end of each design thinking step, students presented their findings and received feedback from the educator and their peers. At the end of the semester, students presented their solutions.

The students worked on the following steps.

Step 1. Team building.

Students were asked to select a team name and to design a team logo, which helped create the team identity.

Step 2. Problem discovery.

Students were guided through a series of exercises, including problem research and discovery. They were asked to describe the problem with images, videos, scientific articles, media articles, and other resources that they researched on the internet. They were further asked to post ideas that describe the problem and to identify associations between the problem and people, the problem and places, and the problem and feelings.

Step 3. Problem re-definition.

Students were challenged to redefine the problem in a manner that allows the introduction of a rich pool of ideas before reaching a solution. They were encouraged to describe the problem with a verb, which reflects an action or challenge, rather than a noun, which reflects a solution.

Step 4. Interviews.

Students were challenged to organize interviews. They were asked to consider the arc of the interview, the space, the time, and the duration. They were challenged to interview at least 2 individuals. Students were then challenged to create interview questions. This process included questions for establishing trust between the interviewer and interviewee, questions for creating “colour”, which encourages the interviewee to provide more detail, questions that promote progress to additional subjects, and reflection questions.

Step 5. User persona.

Students were challenged to create a user persona. The persona does not describe an actual person. Rather, it describes an imaginary person with a typical user's characteristics. They were provided with diverse tools for creating a user persona, including an empathy map, user’s journey, and mind map.

Step 6. Ideation.

Students were challenged to introduce as many diverse ideas as possible towards a solution. They were guided in this process through exercises. Initially, they were asked to introduce ideas without specific guidance, which were followed by ideas the implementation of which requires a large budget, ideas the implementation of which requires a small budget, ideas that start from each letter of the alphabet, which help students use a different part of their brain in ideation, and ideas the implementation of which requires technology. They were further challenged to build on team members' ideas in a circular fashion, with each individual suggesting ideas that other team members enriched.

Step 7. Evaluation of ideas.

Students were challenged to categorize their ideas into “normal” ideas that are easily implementable, breakthrough ideas that are implementable with current technology, and ideas for future implementation, which requires technology that is not yet mature. Subsequently, they were asked to select one of the breakthrough but implementable ideas for prototyping.

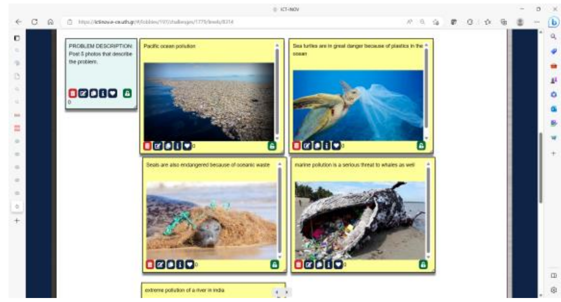
Step 8. Prototyping.

Students were asked to create a prototype of their idea and to present it in class. They were free to create paper prototypes, digital prototypes, or posters that described their solution.

Students worked on the following projects:

- **Removing plastic from oceans**. Students designed a solution for identifying ocean pollution using a drone flying over water and AI to identify polluting factors, such as plastic.
- **Reducing water waste and pollution in agriculture**. Students designed a solution that focuses on reducing water and fertilizers used in agriculture through sensors that identify irrigation and fertilization needs.
- **A public transport system that helps reduce car usage in cities**. Students designed a “last mile” pod-based transport system, with electric vehicles that can circulate on existing roads, taking individuals to their door. This system aims to encourage the use of public

transport by eliminating one of the factors that lead individuals to use their cars, namely the fact that public transport does not take them to their destination.

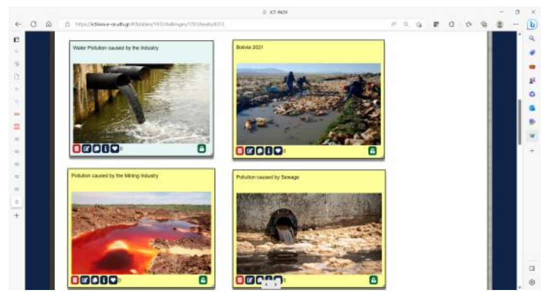


Figure 11. Projects screenshots and photos from the Design Thinking in Computer Engineering course, spring 2023.

1.9 Course ECE553: Design Thinking

1.9.1 Description of the course

This is an introductory course on design thinking principles offered at the undergraduate level. The course is a direct result of project ICT-INOV. It was introduced into the formal curriculum of the Electrical and Computer Engineering Department of the University of Thessaly for the first time in the 2023 – 2024 academic year. Similarly to Course MDE627: Design Thinking in Computer Engineering, the course aims to introduce undergraduate students to principles of design thinking for harnessing their power for innovation. The course introduces design thinking theory and practical applications of design thinking steps to challenge students to solve real-world problems related to entrepreneurship or social entrepreneurship.

1.9.2 Description of the participants

The course is an elective in the 4th year of undergraduate studies at the Department of Electrical and Computer Engineering of the University of Thessaly. In the fall 2023 semester, the course was attended by 260 undergraduate students.

1.9.3 Description of gamified design thinking activities

The course is organized in the form of an active, hands-on workshop. Activities started by stressing the importance of innovative thinking in addressing 21st-century challenges. Students were subsequently introduced to design thinking steps to address a challenge under the general topic of sustainability. The course had the format of a workshop. Students used the ICT-INOV digital learning platform throughout the semester to collaborate through design thinking towards introducing innovative solutions. Work was organized in the following steps.

Step 1. Team building.

Students were asked to select a team name and to design a team logo, which helped create the team identity. In addition, they worked on a team-building exercise where they had to identify fellow students who had achieved specific tasks or had specific interests, such as mastering 2 foreign languages, travelled abroad, visiting some of the Greek islands, eating pizza prosciutto, designing a game, are eager programmers, and more.

Step 2. Problem discovery.

Students were guided through a series of exercises, including problem research and discovery. They were asked to describe the problem with images, videos, scientific articles, media articles, and other resources that they researched on the internet.

They were further asked to post ideas describing the problem and identify associations between the problem and people, the problem and places, and the problem and feelings.

Step 3. Problem re-definition.

Students were challenged to redefine the problem in a manner that allows the introduction of a rich pool of ideas before reaching a solution. They were encouraged to describe the problem with a verb, which reflects an action or challenge, rather than a noun, which reflects a solution.

Step 4. Interviews.

Students were challenged to organize interviews. They were asked to consider the arc of the interview, the space, the time, and the duration. They were challenged to interview at least 2 individuals. Students were then challenged to create interview questions. This process included questions for establishing trust between the interviewer and interviewee, questions for creating "colour", which encourages the interviewee to provide more detail, questions encouraging progress to additional subjects, and reflection questions.

Step 5. User persona.

Students were challenged to develop a user persona. The persona does not represent a real person. Rather, it represents a hypothetical person who shares the traits of a typical user. They were given various tools for constructing a user persona, such as an empathy map, user journey, mind map, lists, and more.

Step 6. Ideation.

Students were challenged to introduce as many diverse ideas as possible towards a solution. They were guided in this process through exercises. They were asked to introduce ideas without specific guidance, which were followed by ideas the implementation of which requires a large budget, ideas the implementation of which requires a small budget, ideas that start from each letter of the alphabet, which help students use a different part of their brain in ideation, and ideas the implementation of which requires technology.

Students further performed the 6 – 3 – 5 exercise, in which each member of a 6-person team was asked to write 3 ideas within 5 minutes before circulating the paper to another member who performed the same exercise until the cycle was completed.

Other exercises performed by the students include negative brainstorming, or what would make the situation worse; figurative brainstorming, or how a specific person solves the problem; and bi-associations, or combining 2 ideas to create a new one.

Step 7. Evaluation of ideas.

Students were asked to divide their ideas into three categories: "normal" ideas that are easily implemented, breakthrough ideas that can be implemented with present technology, and ideas for future applications that require not yet developed technology. They were then asked to choose one of the most innovative but feasible ideas for prototyping.

Step 8. Prototyping.

Students were asked to create a prototype of their idea and to present it in class. They were allowed to use diverse tools for prototyping, such as a digital application, a physical prototype with easy materials, a storyboard, or a solution poster.

Some of the projects that students worked on include:

- **Addressing fast fashion**. Students introduced ideas for addressing the challenge of fast fashion, a significant environmental pollution source.
- **Removing plastics from the sea**. Students introduced ideas for removing plastics from the oceans.
- **Addressing light pollution**. Students focused on how light pollution can be reduced so that it affects both people and the ecosystems around cities and towns less.
- **Forest fire management**. Students design solutions for preventing and acting against forest fires through smart monitoring systems.
- **Saving the bees**. Students introduced solutions for saving the bees and their ecosystems.
- **Addressing food waste**. Students focused on how to address food waste at home and in restaurants.

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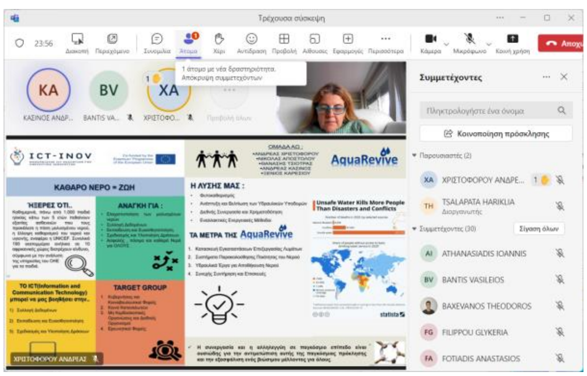
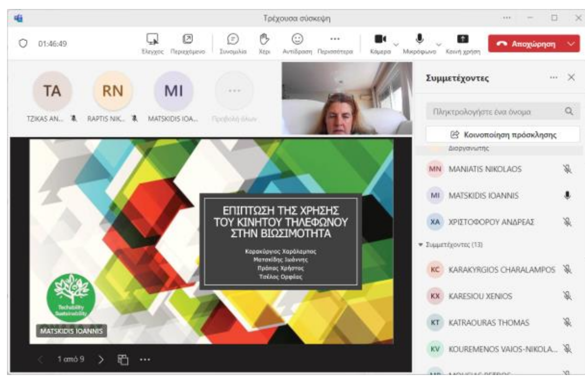
- **Reducing waste from cement products**. Students suggested solutions for recycling construction building materials.
- **Building smart roads**. Students introduced ideas for reducing waste from road creation and maintenance.







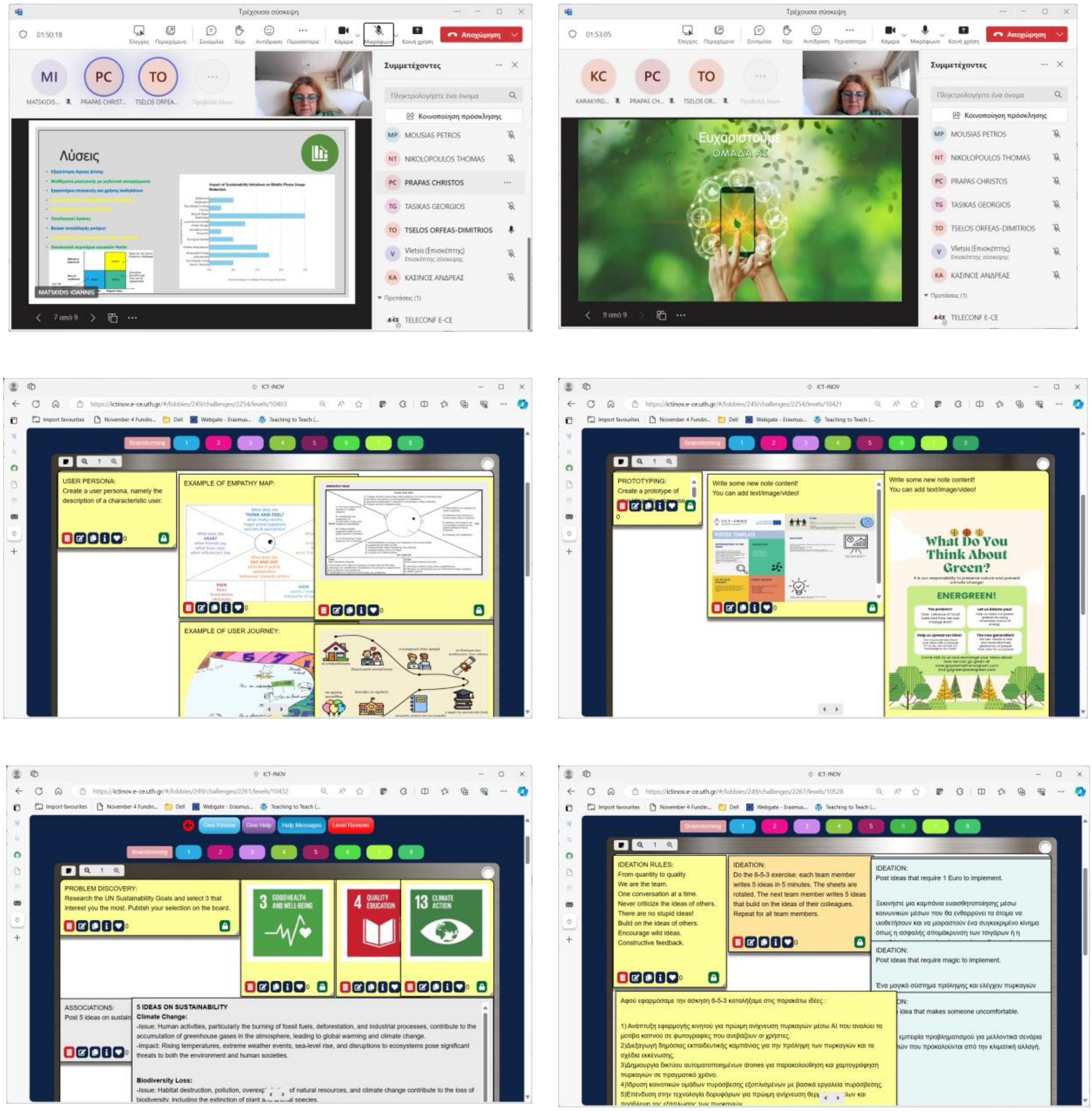


Figure 12. Students collaborate in projects, present their solutions, and use the ICT-INOV digital learning platform in the Design Thinking course, fall 2023.

1.10International University of Greece course: Business Administration

1.10.1 Description of the course

The course offers basic knowledge of the management and organization of businesses and their operations. It focuses on many areas, including finance, marketing, accounting, human resources, etc. It gives students the knowledge and skills needed to succeed in various business-related careers.

1.10.2 Description of the participants

The course is mandatory in the 1st year of studies at the Logistics and Informatics Department of the International University of Greece, which is located in Thessaloniki. A design thinking workshop based on the principles introduced by ICT-INOV was delivered in the context of the course in the fall of 2023 after a formal invitation by the International University of Greece. The workshop was attended by approximately 40 students and educators from the International University of Greece.

1.10.3 Description of gamified design thinking activities

Students worked towards introducing solutions to challenges related to the UN Sustainability Goals. They worked in groups of 2 to 3 individuals. An activity was created for the workshop on the ICT-INOV digital learning platform. The workshop took place in hybrid mode, with approximately 25 individuals physically present in the classroom while 16 were online. The lack of computers led to offline activities, following ICT-INOV principles.

Activities were organized in the following steps.

Step 1. Creativity and team building.

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Students were encouraged to draw an object of use to someone using predefined shapes. The purpose of the exercise was to boost the confidence of students in their creative nature.

Subsequently, students were asked to decide on a team name and create a team logo as a team-building exercise.

Step 2. Discovery.

Students performed discovery exercises on the broad subject of sustainability. They noted ideas related to sustainability. They established associations between the concept of sustainability and places, people, actions, and feelings. Finally, they selected a specific sustainability topic and described it through images, videos, scientific articles, and press articles they researched online. Students presented their work to the class.

Step 3. Problem re-definition.

Students defined the problem they decided to work on in the form “how might we … design something that … allows users to …”.

Step 4. Ideation.

Students performed ideation exercises to generate as many ideas as possible to solve the problem in focus. Exercises included noting ideas and building on the ideas of other team members.

Step 5. Idea selection.

Students categorized the ideas generated in the ideation phase into 3 groups: simple ideas, innovative but feasible ideas, and ideas for which technology is not yet mature enough to implement. They were asked to select an idea from the innovative but feasible pool and present it to the class.

Step 6. Prototyping.

Students became familiar with prototyping principles for generating user feedback on a proposed solution, including physical prototypes for tangible solutions as well as storyboards and user journey descriptions of intangible solutions.

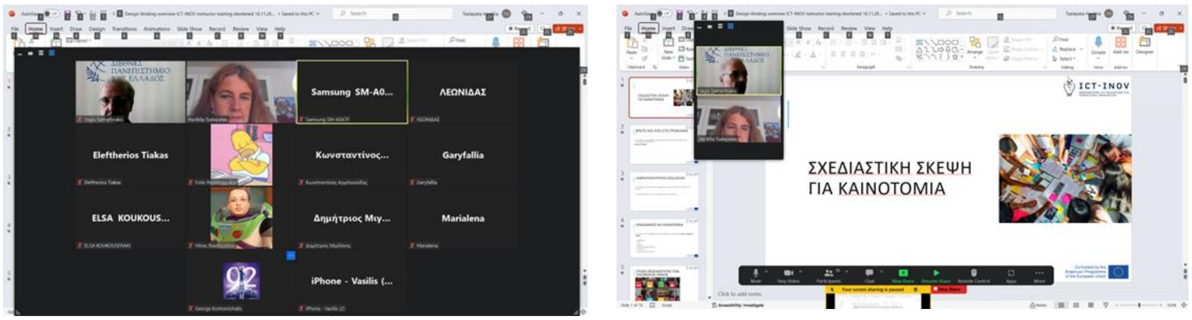

Figure 13. Screenshots from the workshop on sustainability in the Business Administration course of the International University of Greece, fall 2023.

1.11 International University of Greece course: Logistics

1.11.1 Description of the course

The course offers basic knowledge of accounting and logistics. It also addresses how ICT solutions can support financial management practices.

1.11.2 Description of the participants

The course is an elective in the Financials Management, Accounting, and Information Systems graduate program of the Department of Logistics and Information Systems of the International University of Greece, which is located in Thessaloniki. A design thinking workshop based on the principles introduced by ICT-INOV was delivered in the context of the course in the spring of 2024 after a formal invitation from the International University of Greece. The workshop was attended by approximately 30 students enrolled at the International University of Greece.

1.11.3 Description of gamified design thinking activities

Students worked towards introducing solutions to challenges related to the UN Sustainability Goals. They worked in groups of 5 individuals. An activity was created for the workshop on the ICT-INOV digital learning platform. The course took place virtually. Students used the ICT-INOV digital learning platform to collaborate in teams from a distance.

Activities were organized in the following steps.

Step 1. Creativity and team building.

Students were encouraged to draw an object of use to someone using predefined shapes. The purpose of the exercise was to boost the confidence of students in their creative nature.

Subsequently, students were asked to decide on a team name and create a team logo as a team-building exercise.

Step 2. Discovery.

Students performed discovery exercises on the broad subject of sustainability. They noted ideas related to sustainability. They established associations between the concept of sustainability and places, people, actions, and feelings. Finally, they selected a specific sustainability topic and described it through images, videos, scientific articles, and press articles they researched online. Students presented their work to the class.

Step 3. Problem re-definition.

Students defined the problem they decided to work on in the form "how might we … design something that … allows users to …".

Step 4. Ideation.

Students performed ideation exercises in order to generate as many ideas as possible to solve the problem in focus. Exercises included identifying high-level ideas, high and low-cost ideas, ideas that require technology for implementation, and ideas that start from different letters of the alphabet. This exercise promotes the use of different parts of the brain.

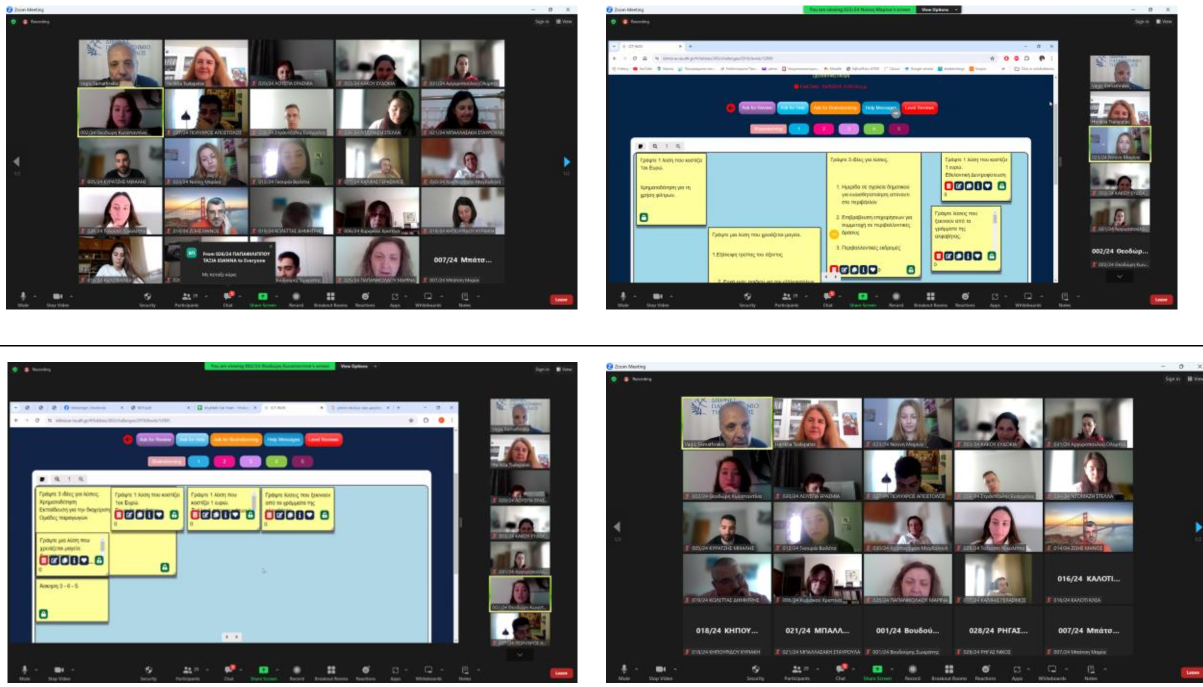

Figure 14. Screenshots from the workshop on sustainability in the Business Administration course of the International University of Greece, spring 2024.

2. Porto Polytechnic

2.1 Course: Algorithms and Programming

2.1.1 Description of the course

The course focuses on the learning of algorithms and programming concepts. The course is part of the Civil Engineering program and aims to provide students with a basic understanding of programming using Visual Basic® for Application with a focus on applications in Civil Engineering.

Students start by learning to use spreadsheets as they help solve engineering-related problems. For example, civil engineers can use these kinds of tools to estimate costs or do structural calculations. The tools allow the easy creation of charts, graphs and reports. Macros and VBA programming capabilities of the ME® application can help simplify or automate these tasks. Applications such as AutoCad® use Visual Basic® as one of their intrinsic module development languages, and learning VBA can facilitate the transition to Visual Basic®.

As a result of the ICT-INOV project, the course has been updated to include design thinking principles. Students deploy design thinking to introduce and discuss potential problems in the area that might be solved using programming.

2.1.2 Description of the participants

The course is part of the 1st year of studies at the Department of Civil Engineering of the Porto Polytechnic. The ICT-INOV methodology is being deployed in the 1st semester of the 2022 – 2023 academic year (Sep 2022 – Jan 2023). A total of 64 students were involved in the process. ICT-INOV will be further deployed in the following academic years, reaching additional groups of students.

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2.1.3 Gamified design thinking activities

A learning activity based on design thinking was specifically designed for the course. The objective of the learning activity was to challenge students to reflect on current issues of Civil Engineering and how they could be solved through programming. The activity aligns with course objectives: integrate emerging pedagogies with state-of-the-art ICT to better address specific educational goals in broad learning contexts.

In the first part of the activity, students discussed potential problems as a class. Different problems were analyzed, and a single problem was selected. Issues relating to the problem's solution were also discussed in the group. Students then worked in groups of up to 2 individuals to propose a programmatic solution. The ICT-INOV educational platform allows instructors to structure learning activities based on well-accepted design thinking steps. The activity was structured as follows.

Step 1. Problem identification.

Students were instructed to research potential problems, understand if they could be solved with programmatic solutions and assess if the students could create those solutions. In addition, students researched existing related solutions.

Step 2. Selecting and understanding the problem.

Students selected a challenge to focus on based on the previous identification. They discussed specific issues of the problem.

Step 3. Forming groups.

Students were divided into teams of 2 and encouraged to select a team name and logo for team-building purposes. This activity provided teams with a sense of identity and affiliation. It also helped them express their interest and goals.

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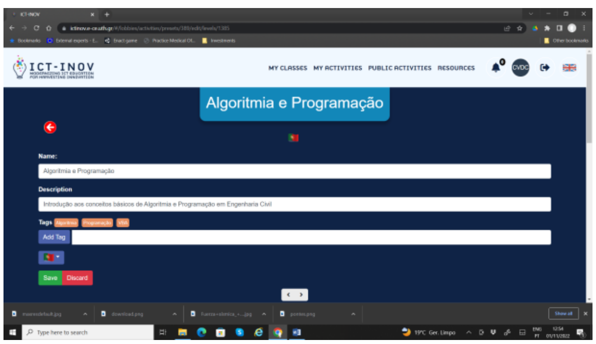
Step 4. Point of view.

Students were challenged to redefine their original problem, considering the results of their research in the previous steps, which helped them develop an understanding of the problem from the user's point of view.

Step 5. Prototyping and testing.

Students were challenged to solve the problem and deploy the solutions on the ICT-INOV educational platform to post their projects before presenting their solutions to the entire class.

The following are screenshots of student projects in the ICT-INOV gamified learning platform.



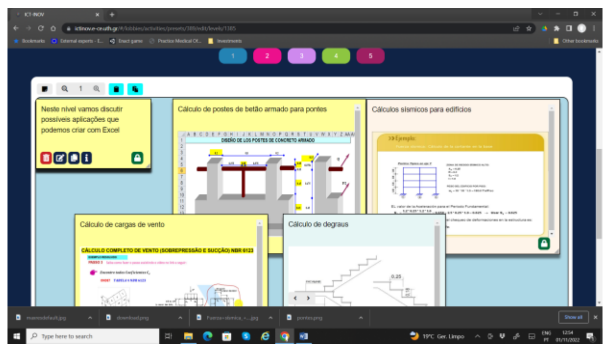


Figure 15. Screenshots of student projects in the Algorithms and Programming course, fall 2022.

2.2 Course: Advanced Graphics Applications

2.3.1 Description of the course

The course is part of the Master's in Computer Engineering program, a branch of Graphical Systems. It focuses on understanding the most common applications and business models of multimedia technologies, effectively applying a project methodology in multimedia design and development of a new product, and understanding how to produce a business plan for a new product or service for a set of investors. This course integrates these concepts in developing

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advanced and innovative applications. Upon completion of the course, students are able to argue the most common applications and the business models of multimedia technologies and business models, analyze the problem to be solved, adopt engineering sciences and best practices, evaluate different approaches for solving the problem by adopting appropriate engineering sciences and best practices, design a solution to the problem by adopting appropriate engineering sciences and best practices, lead the developing process of a product and/or system supported by multidisciplinary teams, analyze the results, adopting appropriate engineering sciences and best practices and evaluate the designed/implemented solution by applying appropriate engine.

The course is based on a fundamental problem-based learning approach. The ICT-INOV platform supports that methodology.

2.2.2 Description of the participants

The course is part of my 2nd year of studies for a Master's in Computer Engineering at Porto Polytechnic, a branch of Graphical Systems. The ICT-INOV methodology is being deployed in the 2022 – 2023 academic year. A total of 14 students are involved in the process. ICT-INOV will be further deployed in the following academic years, reaching additional groups of students.

2.2.3 Description of gamified design thinking activities

The learning activity based on design thinking allows students to reflect on problems that might be solved through multimedia applications. In the current year, students have had to discuss and find problems related to creating games for handicapped players, specifically games that foster the game dynamic of collection.

The activity is directly in line with course objectives, which are to integrate emerging pedagogies with state-of-the-art ICT for better addressing specific educational goals in broad learning contexts.

In the first part of the activity, students discussed potential problems as a class. Different problems were analyzed, and a single problem was selected. Issues related to the solution of the problem were also discussed in the entire class. Students were then divided into 2 groups, and each group proposed a programmatic solution. The ICT-INOV educational platform provides instructors with flexibility in structuring learning activities. The activity was structured as follows.

Step 1. Problem identification.

Students were challenged to identify potential problems, understand if these problems could be solved with programmatic solutions and assess if the students could create those solutions.

Step 2. Selecting and understanding the problem.

Students selected a challenge to focus on based on the previous identification. They discussed specific issues of the problem.

Step 3. Forming groups.

Students were divided into two teams. The peers assigned individual roles in the team.

Step 4. Point of view.

Students were challenged to redefine their original problem, considering the results of their research in the previous steps, which helped them develop an understanding of the problem from the user's point of view.

Step 5. Prototyping and testing.

Students were challenged to solve the problem and deploy the solutions on the ICT-INOV educational platform to post their projects before presenting their solutions to the entire class.

The following are screenshots of student projects in the ICT-IVOV gamified digital learning platform.

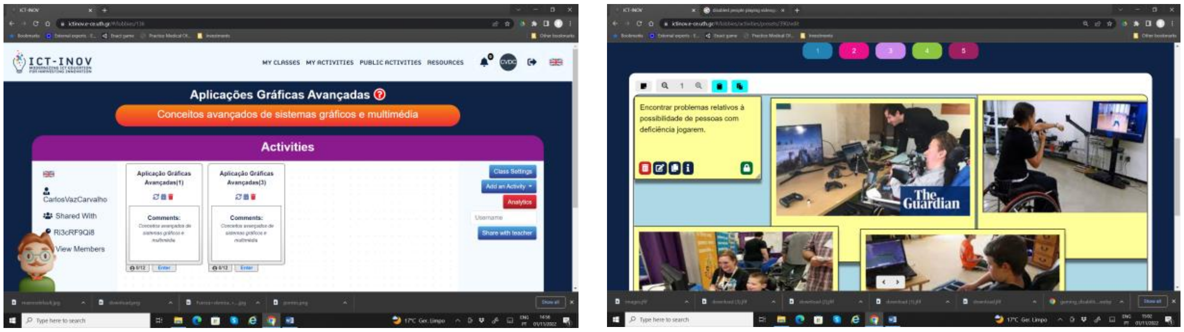

Figure 16. Screenshots of student projects in the Advanced Graphics Applications course, fall 2022.

3. Tallinn University

3.1 LIFE course

3.1.1 Description of the course

The purpose of the LIFE course is to support the development of transversal competencies necessary for resolving interdisciplinary problems. The course is attended by students enrolled in a wide variety of programs at Tallinn University. Learning activities are implemented in teams of 6 individuals. To promote interdisciplinary collaboration, each team must include students from at least 3 different study areas. Up to 3 teams of 6 students can join each project.

Within the LIFE course, projects are carried out in cooperation among students and supervisors. They include the following components: defining a common topic or problem, setting goals, creating an action plan, and carrying out the plan.

Workshops and seminars support participation in the LIFE course. More detailed information about the course is available at http://elu.tlu.ee.

Upon completing the course, students can make connections and analyze the goals of the project and possible solutions from their own as well as a field perspective, can use newly acquired professional and cross-disciplinary knowledge by identifying its deployment potential, can develop collaboration competencies, including the division of roles, taking responsibility, and contributing to group work, has acquired time management skills, can analyze the performance and effectiveness of their proposed solution by critically assessing their own activities and suggesting improvement measures, can analyze their own as well as team members' role and responsibilities when implementing the activities and goals of the project, and can present results of their to stakeholders and/or public by using different media channels.

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3.1.2 Description of the participants

A total of 14 students at Tallinn University attended the course in the 2021 – 2022 academic year. The students were enrolled in a variety of Tallinn University curricula, such as IT management, andragogic, law, environmental management, educational science, special pedagogics, and business management.

3.1.3 Description of gamified design thinking activities

A learning activity based on gamified design thinking was specifically designed for the course. The objective of the learning activity was to challenge students to design and deliver an educational video about climate change for a target group of their choice. Students worked in groups of up to 5 individuals. The ICT-INOV educational platform provided instructors with flexibility on structuring learning activities based on well-accepted design thinking steps. The activity was structured as follows:

Step 1: Team building.

The team building step took place offline, without using the ICT-INOV digital learning platform, as people were excited to be physically in the same room after a long period. Team building consisted of playing games to break the ice and allowing students to get to know each other.

Step 2: Problem discovery.

Team members were encouraged to research how climate change takes effect in Estonia and the main problems society faces. They were encouraged to share their findings with their teams through the ICT-INOV digital learning platform.

Step 3: Problem definition.

Students were encouraged to discuss with their peers and accurately state the main problem on which they would focus. They decided on the topic that they would address in the video.

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Step 4: Brainstorming and ideation.

Students were challenged to research the internet and describe the problem using images, text, and videos. They were encouraged to post as many ideas as possible for a solution. Students collaborated with their team members to design and post their proposed solutions on the ICT-INOV digital learning platform.

Step 5: Prototyping.

Students had a month-long training with Climatubers Erasmus+ project members on video development. They uploaded their ideas, scripts, and storyboards for the video onto the ICT-INOV digital learning platform.

Step 6: Presentation.

Students deployed the ICT-INOV educational platform to post their projects before they presented their solutions to the public.

The following projects were developed through the course:

- **Video 1.** Group 1 decided to do an animated film about digital trash and its impact on well-being. The video is available at the address https://www.youtube.com/watch?v=-NMnsKefk5g&list=PLTUT0jPPotgHCsLNVQq_89OXY6yfSfJd0&index=2.
- **Video 2.** Group 2 decided to make a TikTok-style video about the fashion industry and clothes manufacturing. The video is available at the address https://www.youtube.com/watch?v=giVN-WnUniQ&list=PLTUT0jPPotgHCsLNVQq_89OXY6yfSfJd0&index=3.
- **Video 3.** Group 3 developed a video in which kindergarten students present their thoughts on climate change. The video is accessible at the address https://www.youtube.com/watch?v=6sdbtIEOChU&list=PLTUT0jPPotgHCsLNVQq_89OXY6yfSfJd0.

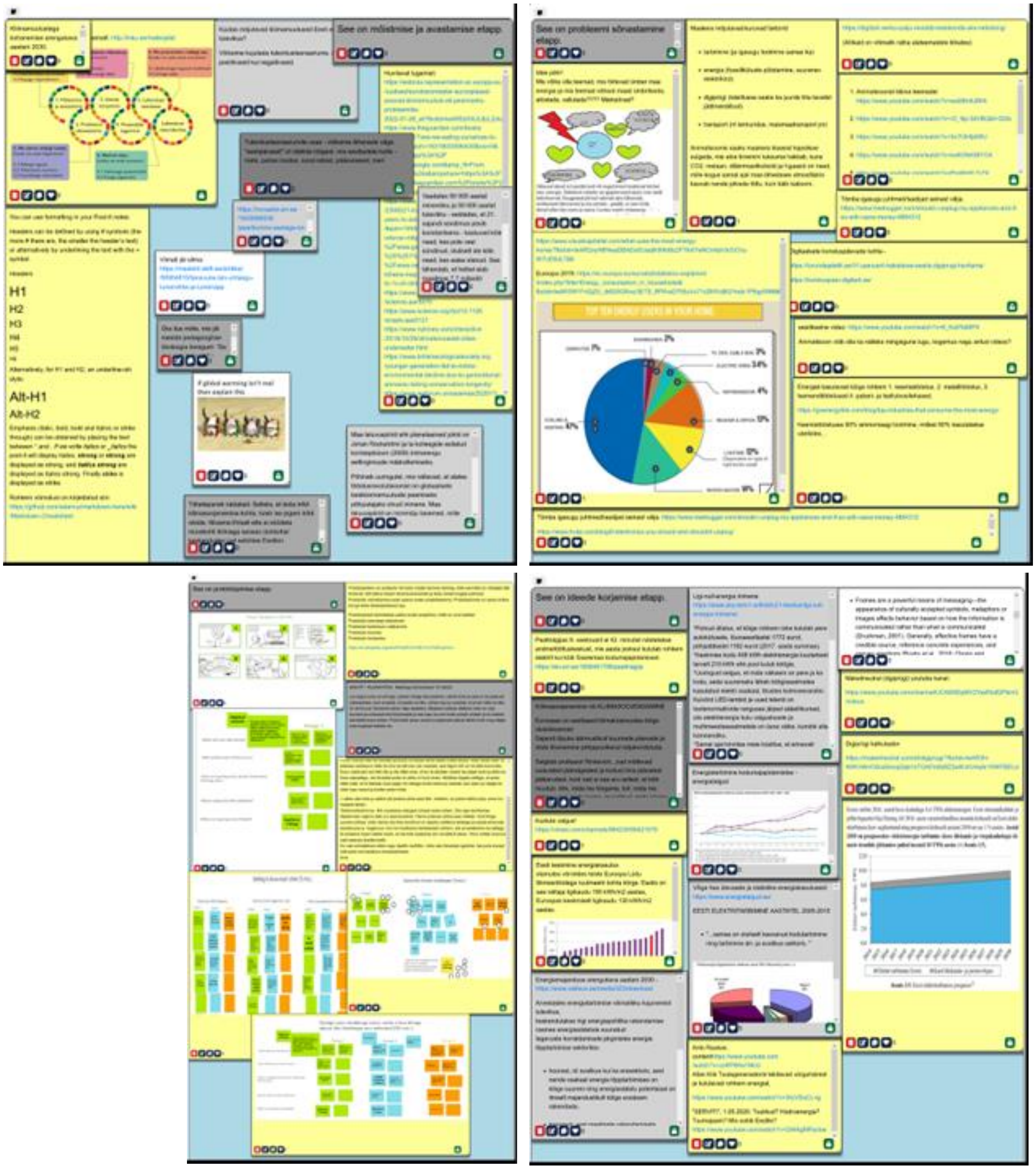

Figure 17. Screenshots of student projects in the LIFE course, spring 2022.

3.2 Project day at Tallinna Saksa Gümnaasium

3.2.1 Description of the course

The purpose of project day in the German Gymnasium in Tallinn was to introduce Tallinn University and its activities and programs. The project week is run for high-school graduates to prepare them for university entrance. The aim is to support the development of students' various competencies towards resolving interdisciplinary problems in tertiary education.

During the project week, projects are implemented in collaboration among university educators and students.

3.2.2 Description of the participants

The ICT-INOV methodology was deployed on April 18, 2022, for a day-long workshop course. A total of 35 students from Kadrioru Saksa Gümnaasium were engaged in the course. Participants were high school graduates from 2 separate classes.

3.2.3 Description of gamified design thinking activities

A learning activity based on gamified design thinking was specifically designed for the course. The objective of the learning activity was to challenge students to become aware of sustainability problems in their everyday lives and to propose solutions.

Students worked in groups of up to 7 individuals. The ICT-INOV digital learning platform provided instructors with flexibility in structuring learning activities based on well-accepted design thinking steps. The activity was structured as follows:

Step 1: Problem discovery.

Students were instructed to identify sustainability issues in their everyday lives over the timespan of a week as homework before the project day.

Step 2: Design thinking methodology and sustainability.

Triinu Jesmin and Jaanus Terasmaa started the day with presentations about sustainability and the introduction to design thinking methodology.

Step 3: Problem definition.

Students were encouraged to post the main sustainability challenges they identified over the week leading up to the workshop on the ICT-INOV digital learning platform. They subsequently had a discussion with their peers, during which they selected a joint problem to be addressed by the entire team. They accurately defined the problem and posted it on the platform.

Step 4. Research.

Students were encouraged to research online information that helps describe the problem in focus through text, images, and videos. They described a characteristic individual facing the problem, its causes, what has been done about it, and why suggested solutions have failed so far.

Step 5: Brainstorming and ideation.

Students were further encouraged to post as many ideas as possible towards a solution. Students collaborated with their team members to design and post their proposed solutions on the ICT-INOV digital learning platform. They used the results of the research step as inspiration towards innovation.

Step 6: Prototyping.

Students created either paper or digital prototypes of their proposed solutions and posted them on the ICT-INOV digital learning platform.

Step 7: Presentation.

Students deployed the ICT-INOV digital learning platform to post their presentations before they presented their solutions to the class and mentors.

The projects that students worked on were the following:

- **Red asphalt bicycle roads**. Improving bicycling experience in Tallinn by introducing safe and environmentally friendly red asphalt roads.
- **Intuitive and nice-looking recycle bins**. Introducing recycling bins with attractive and intuitive designs to encourage further recycling.
- **Reducing light pollution**. Saving energy and promoting safety for all living beings.
- **Pedestrian areas**. Designing a new Tallinn city centre in which central streets are closed for motor vehicles. At the same time, it creates enticing pedestrian areas.
- **Greener Tallinn**. Making the city centre more environmentally friendly by building green/living bus stops.

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Figure 18. Screenshots of student work at project day in Kadrioru Saksa Gümnaasium, spring 2022.

3.3 Environmental Innovation and Communication micro degree course

3.3.1 Description of the course

The micro-degree program aims to equip participants with academic knowledge and skills that enable organizations to understand better their activities' connection with the UN sustainable development goals. The program covers several areas, including mapping out the areas of influence of organizational activities, analyzing and implementing sustainable solutions, and supporting the development of related knowledge about environmental changes and sustainability.

The program Environmental Innovation and Communication focuses on using collaborative e-platforms during practical independent work, enabling participants to understand the role of environmental communication in creating environmentally friendly behaviour. Participants will gain an overview of the most common theoretical starting points of environmental communication and the possibilities of their implementation, as well as develop their communication problem-solving ability during practical independent work.

3.3.2 Description of the participants

Participants in the spring 2023 session were managers and professionals from the private and public sectors with at least a bachelor's degree or equivalent educational level. The course was suitable for individuals currently working or working in the near future in areas related to the green revolution, sustainable and sustainable development, implementation of environmental and innovation policy measures, and related communication. More specifically, the participants were department, process, service and product managers, quality specialists, production engineers and managers, project, administration, development and executive managers of private and public sector organisations.

3.3.3 Description of gamified design thinking activities

A design thinking learning activity was custom-made for the course, aiming to encourage participants to identify sustainability problems in their daily lives or work life and to find potential solutions. The activity involved participants working in groups of up to 7 individuals. To facilitate the learning process, the ICT-INOV educational platform offered instructors the flexibility to structure activities using the steps of design thinking.

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Step 1: Empathy.

At the beginning of the day, Jaanus Terasmaa delivered a presentation on sustainability and introduced the design thinking methodology to participants. The class was then divided into 4 smaller groups. They began the activity by sharing their ideas and thoughts on potential areas of common interest with the goal of identifying problems that could be solved using the design thinking approach. During the activity, the participants focused mainly on gathering information to become familiar with the sustainability field and better understand its problems. This step was important to ensure that the solutions proposed by the groups in the future were relevant and practical.

Step 2: Problem definition.

Once the participants had gained insight into the sustainability issues facing our planet and people, they moved on to defining the specific problem they would work on. They reviewed the information gathered in the empathy phase of the activity and focused on identifying the core problems to address. This step was critical in enabling the groups to develop effective and actionable solutions.

Step 3: Ideation.

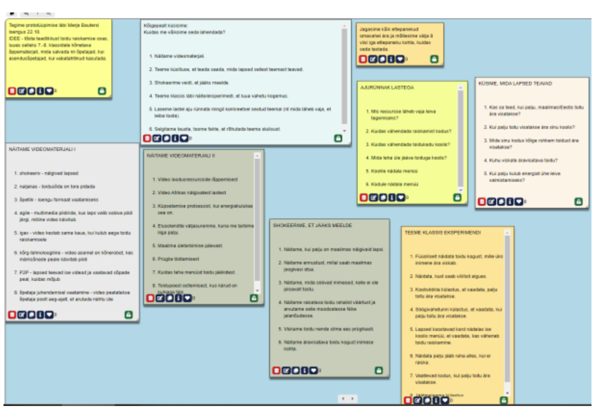
Participants were encouraged to post their main ideas to the ICT-INOV digital learning platform and discuss with their teammates. After the discussion, they selected a common problem for the whole team to address. Then, they articulated the problem that they would work on. Participants reviewed the previously identified challenges and engaged in a brainstorming session to generate potential solutions. It was important for participants to focus on generating a large quantity of ideas rather than being concerned about the quality of each idea. Whether working in teams or individually, participants were encouraged to be open-minded non-judgmental, and to let their imaginations run wild. They were also reminded that even unconventional or fantastical solutions could be valuable, as they may later be refined into more practical and feasible solutions.

Step 4. Prototyping.

Participants worked to transform their ideas into paper prototypes, with the goal of receiving feedback on their solutions through interviews and other means. The focus was on creating a draft version of the intended solution, which could be refined and improved over time. Sustainable design was emphasized, with the understanding that there are many ways to incorporate sustainability principles into the design of a solution.

Step 5: Testing and presenting.

During the testing phase, participants had the opportunity to receive feedback on their prototype from users, to learn if their proposed solution would have a positive impact and to identify areas for improvement. The feedback received during testing was valuable in helping participants refine their solution and ensure that it was effective and sustainable. At the end of this phase, participants used the ICT-INOV educational platform to post their projects before presenting their solutions to the others.



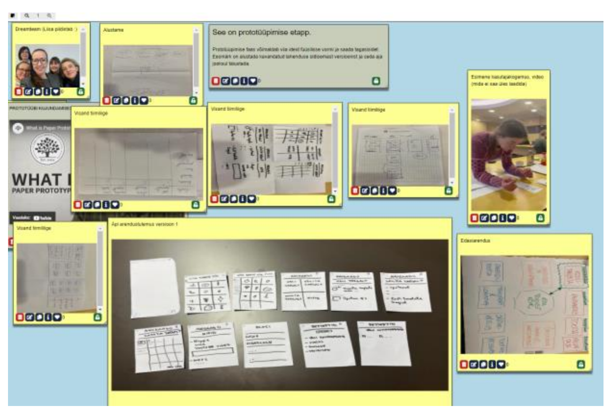


Figure 19. Screenshots of student projects in the Environmental Innovation and Communication course, spring 2023.

3.4 Design Thinking course at Rakvere Riigigümnaasium

3.4.1 Description of the course

The Design Thinking course aims to give the students an overview of the methodology and hands-on experience in developing a solution using the design thinking methodology. Also, to contribute to developing generic competencies and enriching competencies necessary for resolving interdisciplinary problems.

3.4.2 Description of the participants

The course was attended by 56 students in spring 2023. The students were from Rakvere Riigigümnaasium. They were enrolled in 2 different directions, namely Innovation and Product Design and Information Technology. The elective course took place every Friday from January to March 2023.

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3.4.3 Description of gamified design thinking activities

A learning activity based on design thinking was specifically designed for the course. The objective of the learning activity was to challenge students to work on an environmental issue and design a solution.

Students worked in groups of up to 8 individuals. The course content was structured as follows:

Step 1: Team building.

Activities started with a lecture on the most urgent environmental issues, such as climate change, overconsumption, biodiversity loss, etc. Subsequently, students were challenged to observe environmental issues around them in their everyday lives over a week. At the next class session, they proposed the most urgent issue based on their experiences and perceptions and were grouped into teams of 8 students by topic. The topics were as follows: overconsumption and fast fashion, food waste, transportation, winter maintenance on the streets, sorting of biowaste, waste from discarded cigarettes, overpopulation and knowledge of safe sex, and plastic waste sorting. After that, students played games with sustainability goals cards, through which they got to know each other a little better.

Step 2: Problem discovery.

Team members were challenged to research the issues around their selected topic online and online. They were encouraged to share their findings with their teams through the platform, and they filled out their Team Canvas.

Step 3: Problem definition.

Students were encouraged to discuss with their peers and articulate the problem they would focus on. They had to answer the following questions on the ICT-INOV digital learning platform: Whose problem is it? Who or what has caused the problem? What has been done previously to solve the problem? Why has it not worked?

Step 4: Brainstorming and ideation.

Students brainstormed on potential solutions using exercises such as the 30 circles and What if…? Challenges. They further used the 6-3-5 brainwriting methodology to produce a large number of possible solutions. Students posted their papers to the ICT-INOV digital learning platform.

Step 5: Prototyping.

Students were allocated 3 weeks to work on their prototypes. They were asked to interview their end users and stakeholders on two occasions.

Step 6: Presentation.

The final presentation day was open to students at the school and other stakeholders. Students held their presentations on their work in all design thinking steps as well as the final proposal for the solution. Some of the solutions proposed by the groups were as follows:

- Making second-hand shops more visible to address overconsumption and fast fashion overspending.
- A competition between students to weigh the food that gets wasted at a school cafeteria. The team with the least amount wins. This can be done locally, nationally or internationally.
- Smart systems for buses that make them aware of where they are currently needed.
- An app for individuals to report issues with road maintenance: snow blocking the road, slippery, etc.
- Well-designed bins for raising awareness of the importance of biowaste.
- Designated areas in the city for smokers.
- Condom machines schools that provide free condoms to students after providing information about safe sex.
- Special containers for plastic bottles and refunding on an individual's bus card.

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Figure 20. Student work in the Design Thinking course at a, spring 2023.

3.5 Second ELU (LIFE) course YID6001.YM

3.5.1 Description of the course

Please see section 3.1.1 above.

3.5.2 Description of the participants

The second LIFE course using the ICT-INOV innovation-building methodology took place in the spring semester of the 2022 – 2023 academic year. A total of 11 students were engaged in the course. The students were enrolled in a variety of Tallinn University curriculums, such as IT management, law and educational sciences. The course took place weekly on Wednesdays, with each session lasting 2 hours.

3.5.3 Description of gamified design thinking activities

A learning activity based on design thinking was reused for the previous LIFE course. The objective of the learning activity was to challenge students to design and deliver a solution that would enable the exchange of second-hand goods between TLÜ students.

Students first worked in a single group, and after the first month, they divided into groups of up to 5 individuals. The activity was structured as follows:

Step 1: Team building.

Team building activities took place during the 1st class session. Students played ice-breaking games. Subsequently, the educators introduced the course and the ICT-INOV digital learning platform.

Step 2: Problem discovery.

Students were encouraged to research the challenge in focus and existing solutions online and online. They shared their findings with their teams through the ICT-INOV digital learning platform. Each student published the results of their research work on the ICT-INOV digital learning platform.

Step 3: Problem definition.

Students were encouraged to discuss with their peers and articulate the problem in focus. They were encouraged to talk to end users, namely foreign students who came to study in Estonia only for a few years. They documented their findings on the ICT-INOV digital learning platform.

Step 4: Brainstorming and ideation.

Students engaged in brainstorming exercises using pen and paper, such as the 6-3-5 method. The students selected the best ideas that came out of that session.

Step 5: Prototyping.

Students created a low-fidelity prototype, meaning they started a Facebook® group and constructed rules for using the cabinet system. They also remodelled the cabinet itself to look nicer.

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Step 6: Presentation.

The final presentation took place on May 16, 2023. Students received feedback from peers and educators. All feedback was very positive. Students felt they did a good job and saved the world from overconsumption.

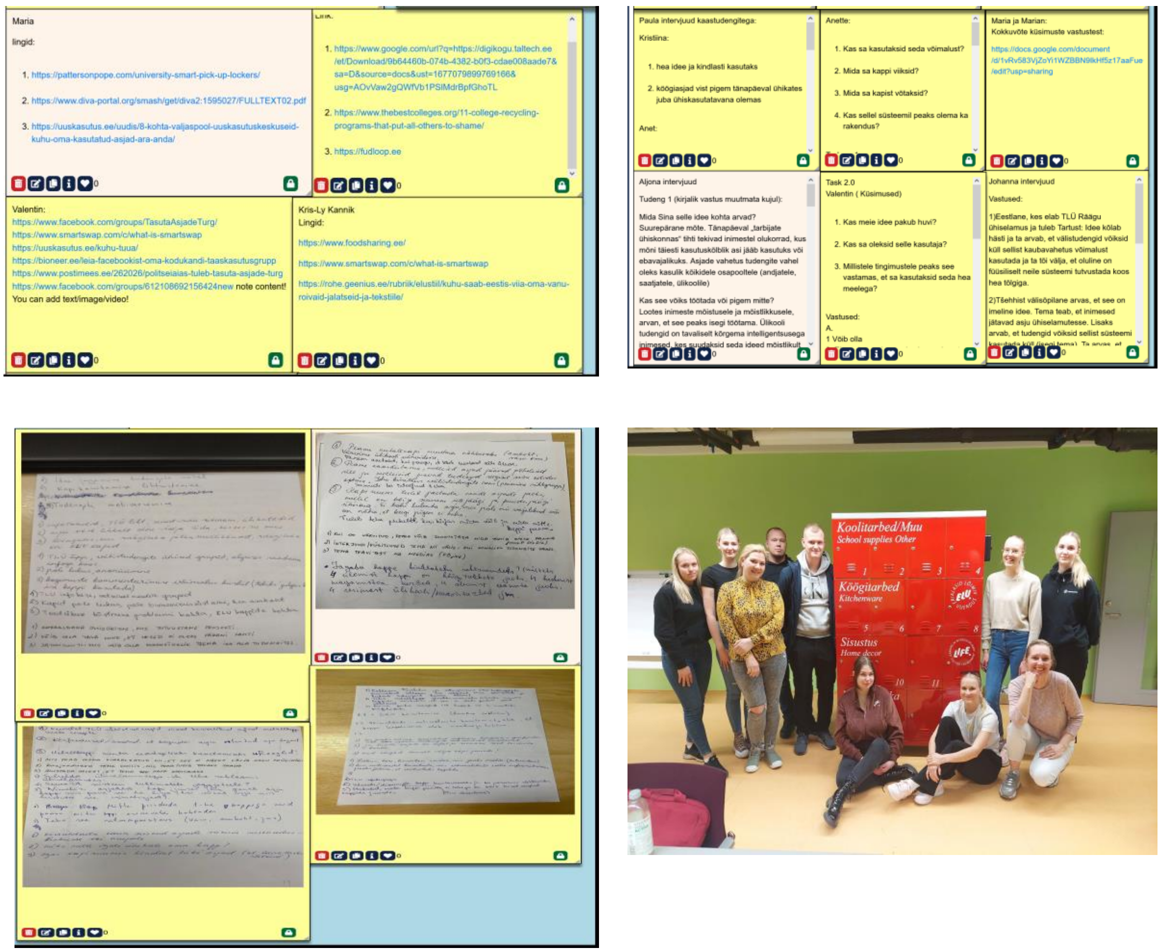

Figure 21. Screenshots of student projects in the LIFE course, spring 2023.

4. EU-Track

4.1 Course: EduRobot

4.1.1 Description of the course

The course focuses on a contextualized delivery of fundamental issues stemming from physics, mathematics, and coding. The course deploys problem- and project-based learning design. It aims to develop new skills, introduce opportunities for students to experiment, create and prototype models, provide feedback, and encourage reflection and redesign to achieve better results. Through well-planned educational robotics activities, students learn not only to build a robot to solve a problem but also to plan their actions, perform tests, work collaboratively with each other, and develop higher-order skills. The course covers electronics fundamentals with Arduino® coding, robotics construction through 3D design, developing an application idea and working through the set of critical points for the chosen application.

The continuous evolution of educational approaches and the ever-increasing complexity of real-world issues that today's students are expected to face in the future naturally leads to the need for educators to revise learning methods, especially in fields such as STEM and robotics. This revision incorporates highly acclaimed skills such as critical and analytical thinking, independent and collaborative working capacity, and more while preserving a real-world problem-solving perspective. In this context, the main distinctive feature of the course is integrating design thinking skills into the curriculum. Design thinking is combined with computational thinking to develop higher-order thinking skills, enabling students to analyze real-world problems and synthesize innovative solutions while bringing a new perspective and making a solid contribution to strengthening STEM education and increasing scientific literacy.

Rightfully defined as standing at the heart of maker education, design thinking elements are implicitly present in the EduRobot curriculum. Given its accent on creative and out-of-box thinking

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and problem-solving, the method's full-fledged and systematic adoption is a natural extension of existing learning practices.

4.1.2 Description of the participants

The course has been designed to address the needs of diverse user groups at the secondary and higher education levels. When the course is delivered to secondary education students, the focus is on background concepts, such as Arduino® platform basics as well as related hardware principles. When it is delivered to higher education students, the focus is on design thinking principles.

A total of 20 students aged 17 - 20 years were engaged in the course in the 2021 – 2022 academic year.

4.1.3 Description of gamified design thinking activities

Course activities aimed to expose students to design and engineering issues in a balanced manner. Students designed and constructed a robotic arm using 3D printing technology. Underlying concepts related to working with 3D objects and electronics were conveyed early in the course.

Once the course goal, namely the robotics arm construction and auxiliary electronics concepts, had been addressed through the number of mini-projects, students were guided in a systematic manner to act like real-life engineers considering the perspective of the product, namely the robotic arm, users, which was controlled by diverse mechanisms selected in accordance with the expected use.

The ICT-INOV educational platform was deployed throughout the course. Activities were organized in the following steps.

Step 1. Team building.

Students were divided into 4 teams consisting of 5 members. They were invited to select a team name, roles and skills, values, rules of collaboration, and goals in order to start their design thinking process. Students worked on this activity by using a team description canvas.

Step 2: Understanding the problem and the users.

Students were encouraged to research the topic in focus to better understand the general problem and its characteristics. They posted videos, articles, and images describing their findings.

After a deep analysis of the problem, each team described a characteristic user. They used an empathy map describing the user's thoughts, feelings, visions, environments, and fears.

Step 3: Problem definition.

Students were invited to provide specific definitions of the problems to be resolved at the end of the design thinking process. They defined the problem statement using a who-what-why clause that allowed them to integrate user needs into the description.

Step 4: Brainstorming and ideation.

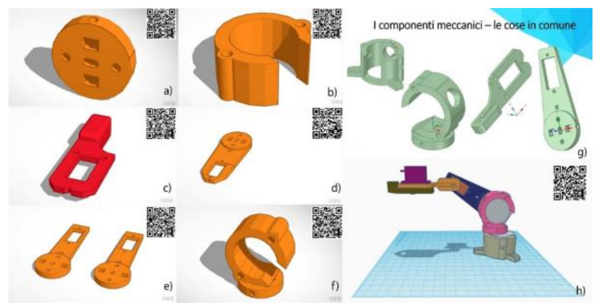
Students were encouraged to express their ideas, aiming to identify the final solution to the problem in focus through technology and, in particular, robotics and artificial intelligence as instruments to prevent damage caused by climate change. For example, one of the teams built a robotic arm for the automatic control of the ripening level of the fruit.

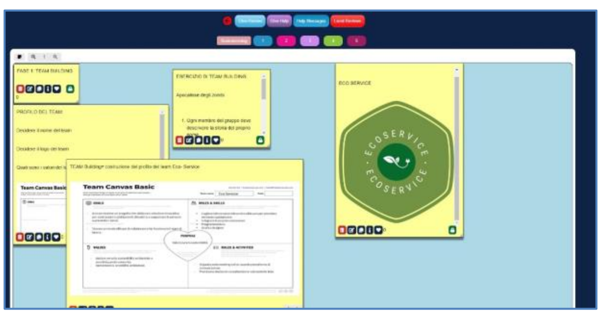
Step 5: Prototyping and design.

Students designed a prototype using the TinkerCad® environment. Subsequently, they implemented the prototype's mechanical elements by using a 3D printer and coded its behaviour through Arduino® IDE.

Some examples of projects developed by students include:

- **Artificial limb**. The robotic arm was equipped with tactile and temperature sensors to provide feedback to the user.
- **Distantly controlled manipulator for explosives disarming**. The robotic arm was equipped with a camera.
- **Automatic items sorter**. The robotic arm was equipped with an automatic image analyzer.
- **Distance surgery assistant**. The robotic arm was equipped with precise movement control and human tremor-compensating mechanisms.





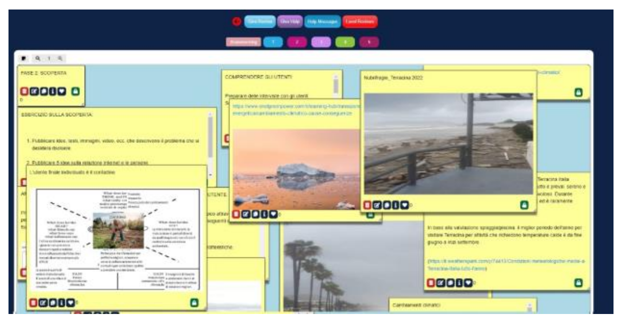


Figure 22. Images of student projects in the EduRobot course, fall 2021.

4.2 Course: Enhancing Student Learning through Research-Based Approach

4.2.1 Description of the course

The course aims to engage students in research-based learning approaches by improving student independence, confidence, and self-management in their tasks, mainly related to real-life problem-solving.

Participants are assisted in deepening their knowledge and skills to conduct research. Moreover, encouraging students to use technological tools promotes the internalization of concepts and develops the understanding of research methods, such as formulating a precise question or monitoring a research skill.

Research-based learning enhances student capacity to deal with uncertainty. It promotes independence, teamwork and organizational skills. It encourages students to be thoughtful, motivated, collaborative, and innovative, capable of engaging in their own inquiries and thriving in a world of constant change.

The course aims to deepen theoretical and practical knowledge. The course aims at building student skills in performing research, including formulating and defining a question, planning research activities and specifying methods and tools, undertaking investigations, analyzing and interpreting data, reporting and presenting results, implementing, guiding the inquiry process, understanding the analogies between creative processes in artwork production and research, discovering, reasoning and thinking, and understanding the difference between real and virtual experiments. Students work in groups on practical exercises.

Design thinking was integrated into this training due to its formal method of solution-focused thinking. It starts with a goal and explores multiple alternative solutions simultaneously, as in the research process. This method reveals its efficiency mainly in investigating ill-defined problems where many factors may be unknown. This can be useful, particularly in open research investigation and qualitative research.

4.2.2 Description of the participants

The course has been designed to be adopted by educational institutions of corresponding profiles at different levels: school and university.

The ICT-INOV methodology was deployed for this training in the 2021 – 2022 academic year. Students between 22 and 30 years old were engaged in the course managed by the research centre, EU-Track.

4.2.3 Description of gamified design thinking activities

Design thinking was integrated into the course to help students develop a deep contextual understanding of users via non-numerical means and direct observations that highlight attitudes, behaviour, and latent needs. Design thinking deployment aimed to achieve a more effective needs analysis. Activities were organized in the following steps.

Step 1: Team building.

Students were divided into 4 teams consisting of 5 members. They were invited to select a team name and identify the main features of the team, including their purposes. They used a team

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canvas template to carry out this task. The principal objective was to define the team roles and skills, values, rules of collaboration, and goals to start their design thinking process.4

Step 2: Understanding the problem and the users and empathy map.

Students collected data on how users think and feel. Unlike quantitative research, this qualitative approach helped students understand users' motivations, hopes, needs, pain points, and more. This rigorous user analysis work contributed to eliminating design errors in the implementation phase.

Moreover, they conducted interviews to analyze user needs. The interviews included a set of clear, predefined questions of the form "how much" or "how many" that could be answered with a "yes", "no", "never", "twice a week", or similar responses.

The achieved results of this process were rich, detailed insights into users' feelings and thinking. The gathered data was unstructured, in the form of notes, drawings, or pictures, which students organized in an empathy map. The method provided deep insights, and the students, who worked as designers, gained a better understanding of the research topic in focus. Even though students did not know exactly what to look for initially, they solved the context.

Step 3: Problem definition.

Students were invited to be specific in the definition of the problem to be resolved through design thinking. They defined the problem using a clause of the form "who", "what", and "why" which allowed a clear description of user needs.

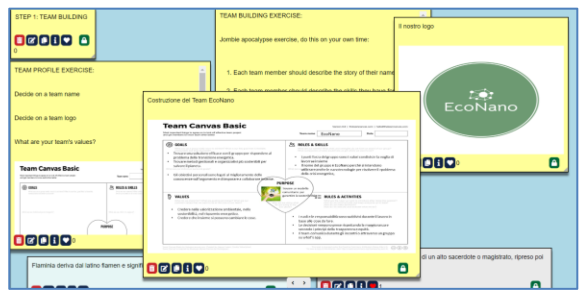
Through this method, students gained deep insights and better understanding of the researched topic and the context in which they operate through a holistic approach belonging to the ICT-INOV methodology implementation.

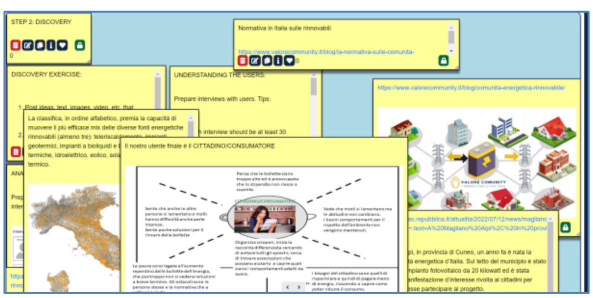
Step 4: Brainstorming and ideation.

Students generated a rich pool of ideas to identify the final solution to be proposed by combing technology and the different ways to construct an effective organizational social model based on sustainable development, focused in this case on renewable energy communities and energy transition.

Step 5: Prototyping and design.

Students built the proposed solution prototype using a poster template to present the action plan focused on different aspects of the renewable energy communities and energy transition.





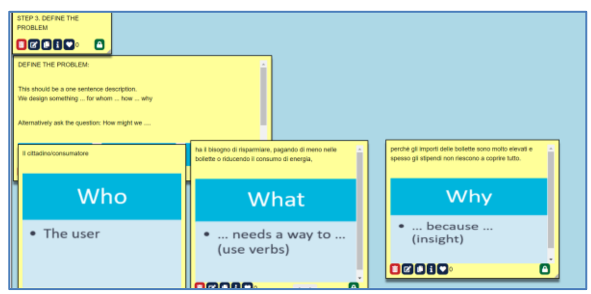


Figure 23. Student projects in the Research-Based Approach course, fall 2021.

4.3 Robotics

4.3.1 Course description

This hands-on and interdisciplinary training course aims to empower students to tackle the challenge of transforming their campus into an eco-friendly and sustainable environment. By combining various aspects of robotics, multimedia resources, musical instruments, and design thinking, students embark on an exciting journey to create an inspiring and environmentally conscious campus.

During the course, students delve into the world of educational robotics, learning to program robots and using Arduino®-based systems. They further leverage multimedia resources, such as video, audio, and augmented reality, to enhance their understanding and showcase their innovative solutions. The course is based on interactive and practical teaching approaches, which allow participants to acquire theoretical knowledge and put the skills learned into practice.

Through the design thinking approach, students develop a human-centred perspective and cultivate empathy as they identify and understand the needs of their school community. Using the ICT-INOV platform, they employ design thinking principles to craft eco-friendly solutions. Working in teams, students hone their collaboration skills, combining the strengths of diverse perspectives to devise comprehensive solutions. Critical thinking is encouraged as they address complex challenges and evaluate the effectiveness of their ideas.

The ICT-INOV methodology and tools are integrated into this training to engage students in robotics, mainly using the Arduino® platform. In this context, design thinking helps students identify the best solutions for the problem scenario suggested in the ICT-INOV digital learning platform.

4.3.2 Description of the participants

The course has been created for use in STEM learning activities in schools and universities. The ICT-INOV methodology was deployed in the academic year 2022 - 2023. Students aged 17 – 20 years have been engaged in the course managed by EUTrack. A total of 20 students participated in the course.

4.3.3 Description of gamified design thinking activities

Students explored the intersection of eco-sustainability and robotics. Through hands-on activities, they leveraged robotics as a powerful instrument to address environmental challenges and develop sustainable campus solutions. With a focus on creativity and problem-solving, students used robotics to experiment, prototype, and optimize eco-friendly designs, fostering a greener and more environmentally conscious campus. This exciting combination of eco-sustainability and robotics empowered students to create meaningful and impactful changes for a sustainable future. Activities were organized in the following steps.

Step 1: Team building.

Students were divided into 4 groups of 5 members each. They were asked to select a team name and logo, which helped generate a team identity. They decided on the rules of team collaboration and documented them into a team canvas, a useful tool for building the team, distributing the roles, knowing the members' skills, and setting a unique vision for the final objective.

Step 2: Understanding the problem and the users by creating an empathy map.

Students collected information about their thoughts and feelings through peer-to-peer and expert interviews. Social investigation techniques and tools were used at this stage to help students understand the problem to be solved in depth.

In addition, students researched articles on natural resource management. During this research, they identified the end-user profile and determined the possible challenges and opportunities through unstructured material in the form of notes, sketches, or photos. Finally, they constructed an empathy map regarding the user to be considered.

Step 3: Problem definition.

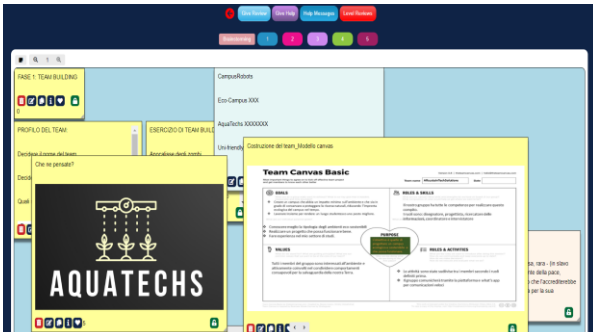
Students identified critical issues in natural resources management on a university campus and tried to define a specific problem to be solved based on their priorities and needs listed. They defined the problem using a clause of the form "who", "what", and "why" which allowed a clear description of user needs.

Step 4: Brainstorming and ideation.

Students worked in groups, coming up with original solutions to problems. They introduced innovative design concepts, eco-friendly technologies, and effective management techniques.

Step 5: Prototyping and design.

To finalize the design thinking process, students prepared their prototype by integrating Arduino® in their solution and drew a poster using the provided template to present their solution.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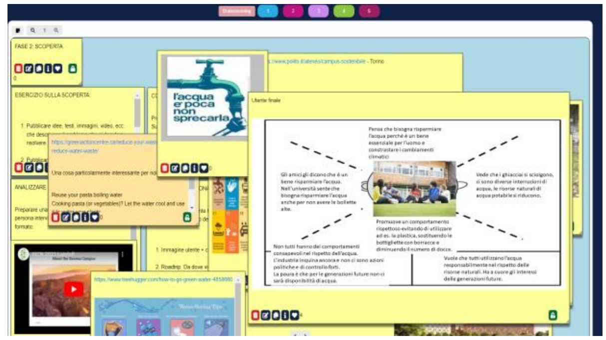
Team Canvas Basic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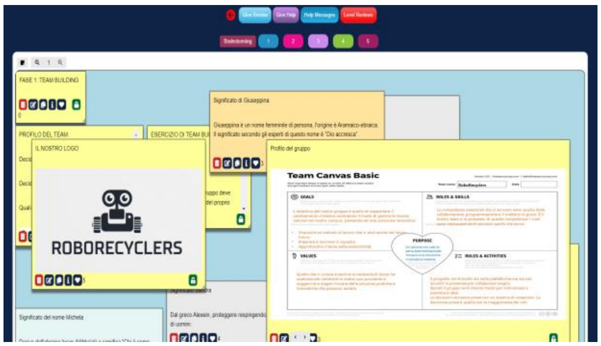
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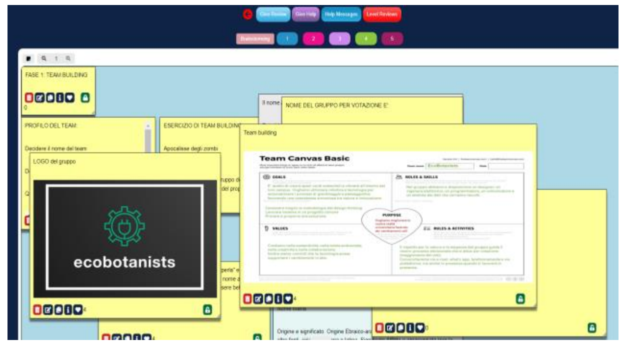
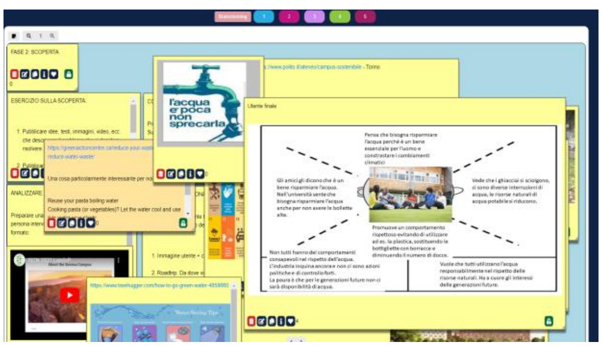
Team Canvas Basic


ecobotanists
Team Canvas Basic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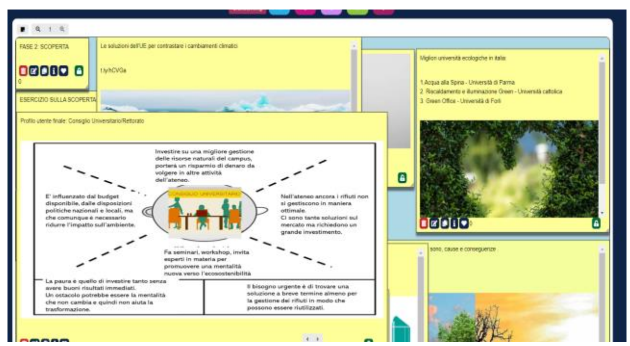

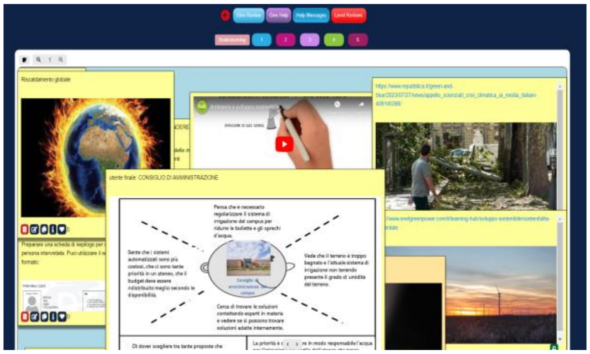

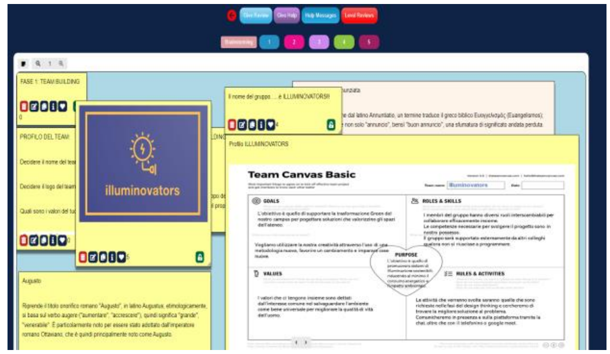

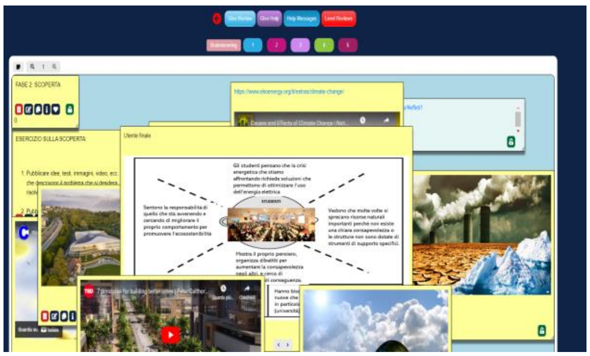

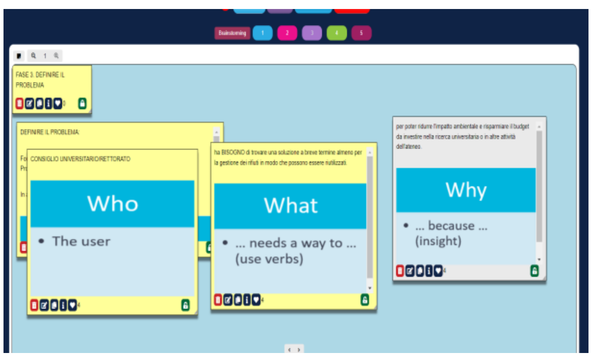

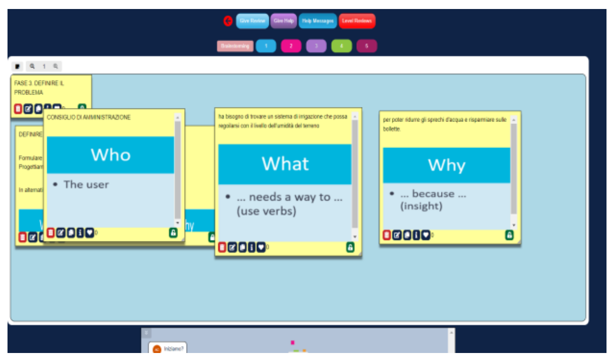

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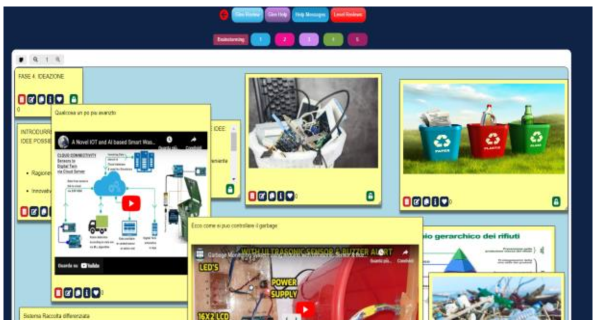

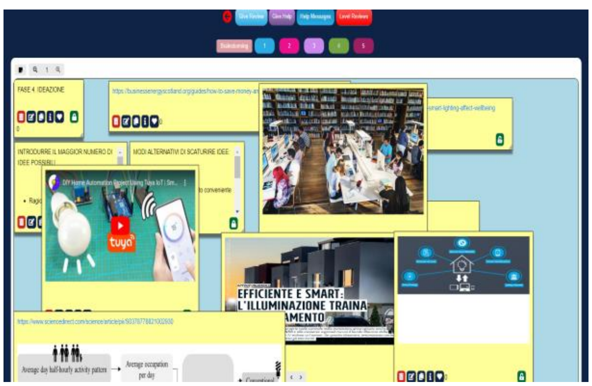

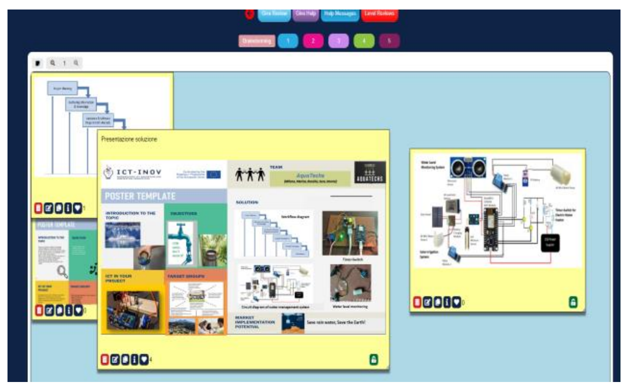

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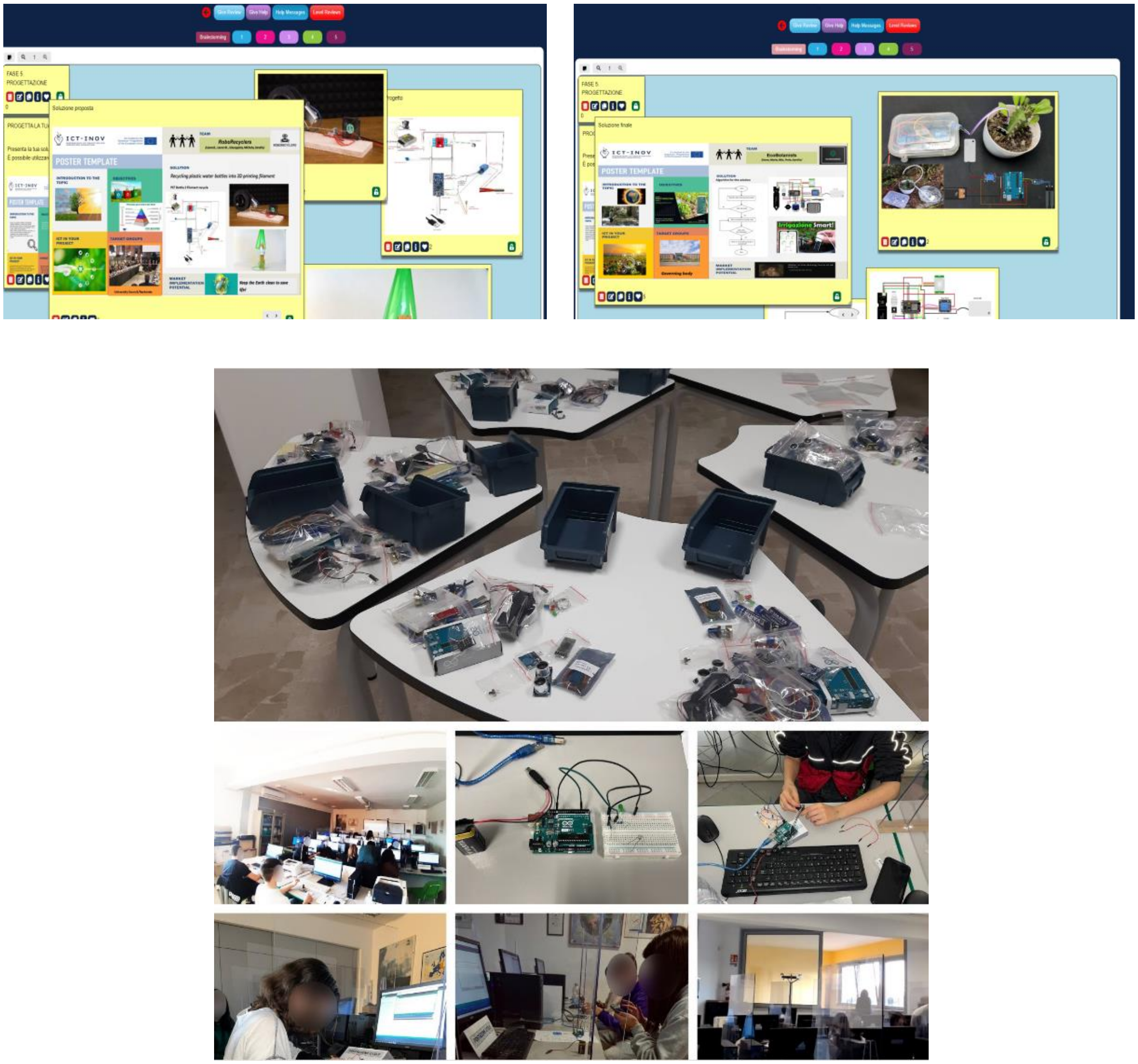

Figure 24. Screenshots of student work in the Robotics course, spring 2023.

4.4 Augmented Reality

4.4.1 Course description

The course constitutes an innovative training designed for educators who wish to enrich their students' learning experience through augmented reality.

Students have the opportunity to explore the potential of augmented reality. Through augmented reality, educators actively involve students in class work, making complex concepts more accessible and interesting. The course is based on interactive and practical teaching approaches, which allow participants to acquire theoretical knowledge and put the skills learned into practice.

Students gain a basic understanding of augmented reality apps, learn what it is and how it works, and how to create augmented reality content using easily accessible tools and platforms for presenting solutions. This approach helps stimulate student curiosity and interest, making learning an engaging and fun experience.

The integration of design thinking has enriched this training by making learning even more engaging and practical. It allowed students to take a holistic, needs-centered approach to augmented reality, ensuring that the proposed solutions are relevant, effective and engaging for the end audience.

4.4.2 Description of the participants

The course has been created to be used in schools and universities with relevant profiles at various levels. The ICT-INOV methodology was deployed in the 2022 – 2023 academic year. Students aged 17 – 20 were engaged in the course managed by EUTrack. A total of 20 students attended the course.

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4.4.3 Description of gamified design thinking activities

By using different techniques and direct observations that emphasize attitudes, behaviour, and latent demands, design thinking was incorporated into the curriculum to assist students in developing a thorough contextual understanding of users. The design thinking implementation aimed to produce a more accurate needs analysis. The following steps were used to organize the activities.

Step 1: Team building.

Students were split up into 4 teams of 5 members each. They were asked to select a team name and describe the group's key elements, such as their goals. To complete this work, they applied the team canvas template. The main purpose was to establish the team's beliefs, working principles, roles, and goals in order to kick off the design thinking process.

Step 2: Understanding the problem and the users by creating an empathy map.

Students gathered information on users' thoughts and feelings. In contrast to quantitative research, this qualitative technique helped students comprehend user goals, objectives, pain areas, and more. This meticulous user study effort helped to obviate design mistakes throughout the implementation stage.

Additionally, students interviewed users to analyze their demands. A series of specific, predetermined questions of the type "how much" or "how many" were asked throughout the interviews, and the answers ranged from "yes" to "no," "never," "twice a week," and other similar responses. The outcomes were deep insights into consumer emotions and thoughts. Students organized their unstructured material, which came in the form of notes, sketches, or photos, into an empathy map.

Students conducted research on the environmental and social challenges in urban environments and the demand for eco-sustainable housing for university communities. They interviewed other students to understand their housing needs, environmental behaviour, and design preferences. In addition, they analyzed previous projects of eco-sustainable buildings to extract ideas, solutions and best practices applicable to the possible solutions.

Step 3: Problem definition.

Students identified key challenges in university buildings, such as energy efficiency, waste management, use of sustainable materials, and integrating nature into the constructed environment. Students were asked to specifically identify the problem to be solved at the end of the design thinking process through precise definitions of "who", "what", and "why" that help clarify the needs of the selected end users.

Step 4: Brainstorming and ideation.

Students worked in groups to generate creative ideas and innovative solutions to address the identified challenges. They introduced innovative design ideas integrated with sustainable technologies and efficient management practices.

Step 5: Prototyping and design.

Students created prototypes of proposed solutions using poster templates to present an action plan that focused on developing a building project for an eco-sustainable apartment by integrating innovative ideas to reduce environmental impact and improve the occupants' quality of life. Their solutions and products were presented by using the augmented reality application Eyejack Creator®.

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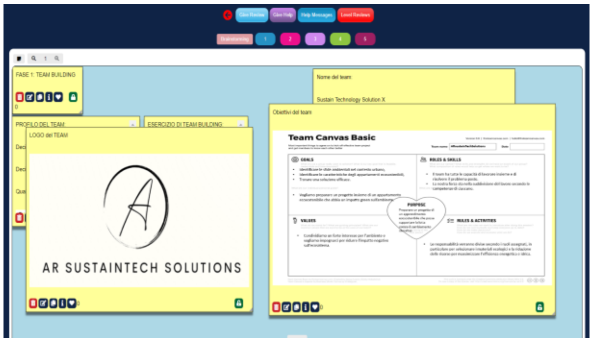

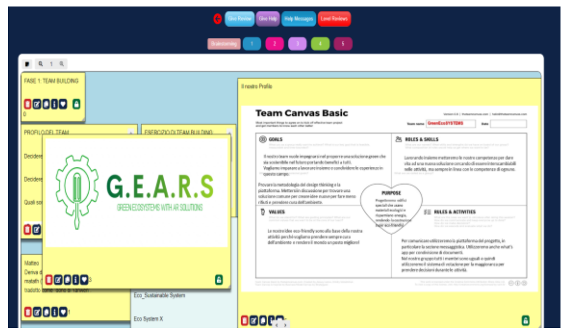

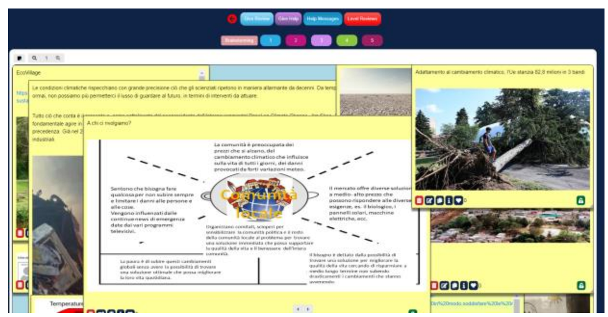

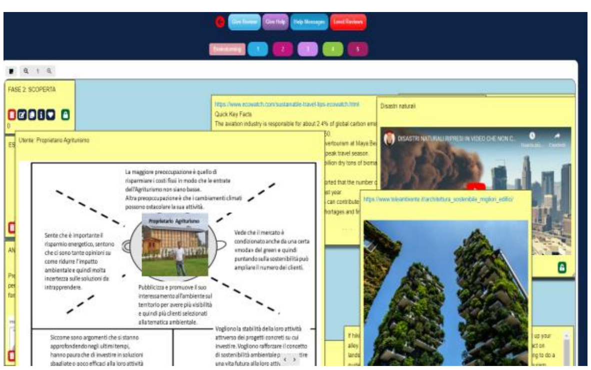

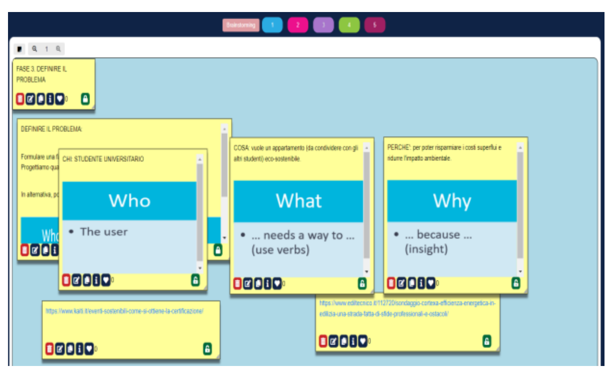

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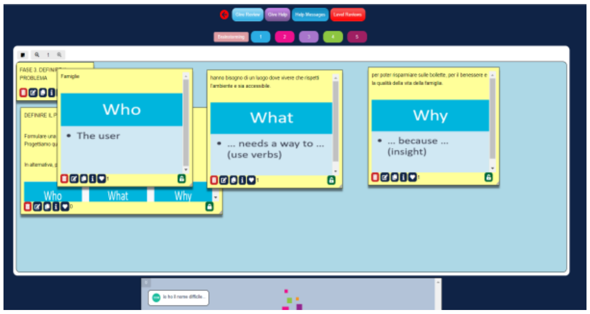
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What
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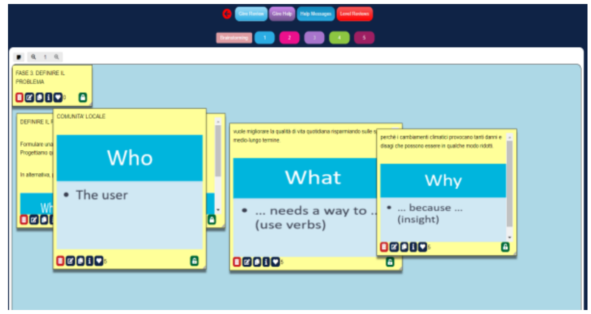
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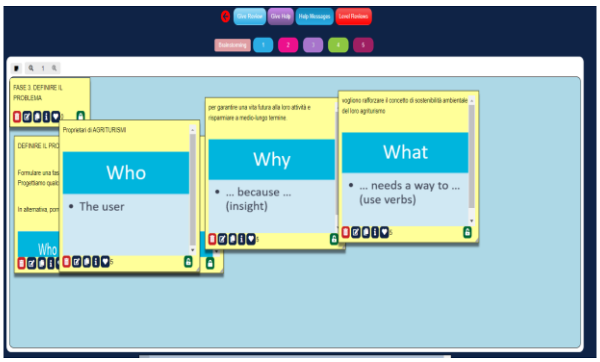
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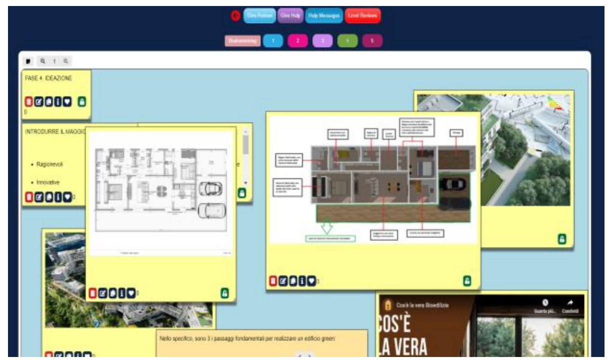

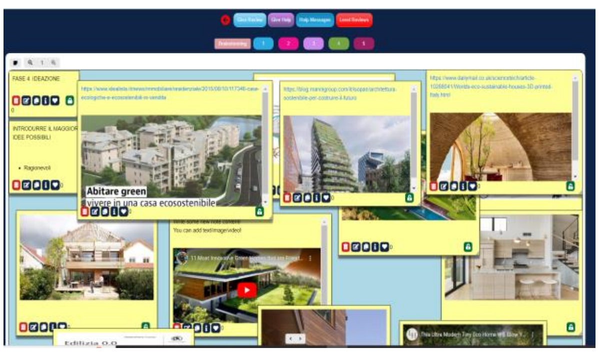
Abitare green
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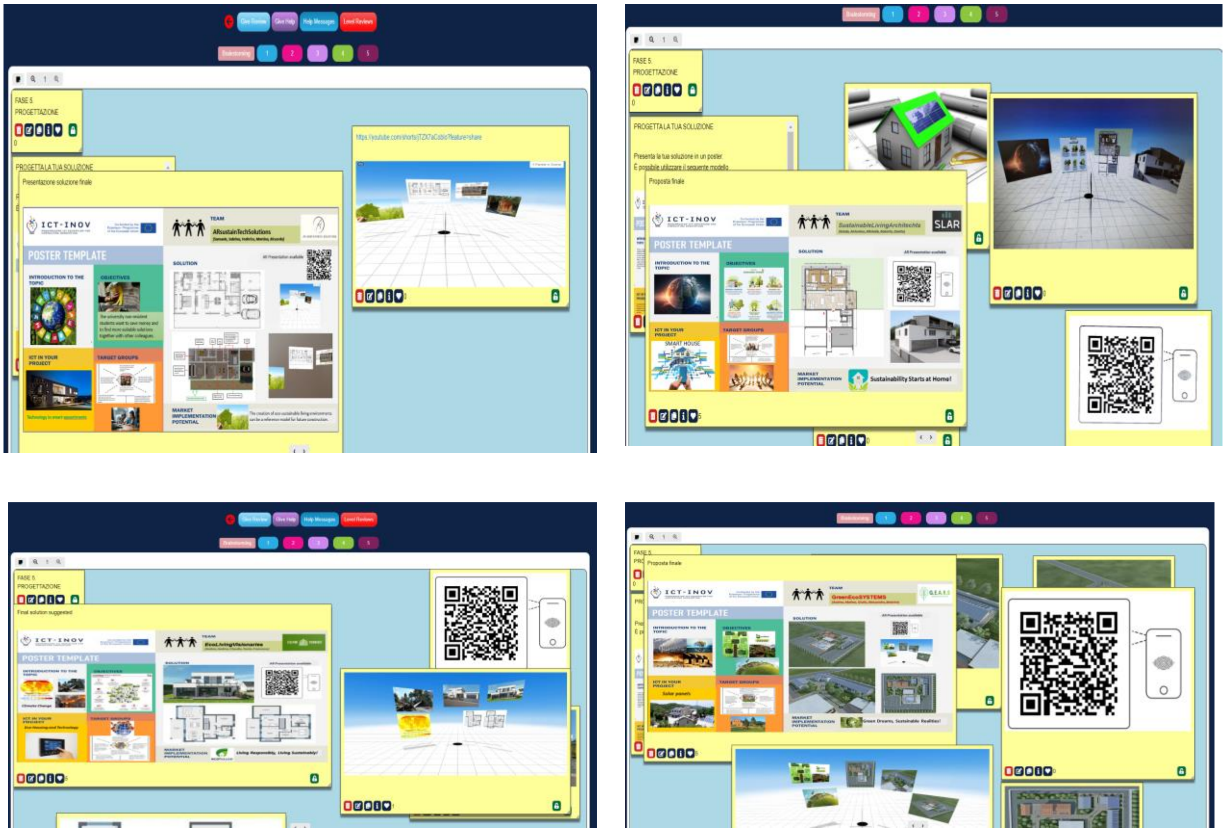

Figure 25. Screenshots of student projects in the Augmented Reality course, spring 2023.

4.5 Multimedia Learning Environment

4.5.1 Course description

The course aims to teach students to enhance their knowledge of using new technology by transforming their setting into a multimedia educational environment. The training aims to offer some easily applicable examples, such as virtual labs, virtual reality, serious games, digital storytelling, and robotics, to support and strengthen teaching and learning processes. Students are provided with adapted technological tools and methods to be used in and outside the classroom. The expected training activity has been structured to acquire know-how and develop

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the skills needed through theoretical deepening, simulation, and practical exercises. The course delivery is accompanied by the demonstration and an active participants' co-involvement in the use of numerous technological instruments relevant to the topic, such as Oculus® Quest VR Platform, Oculus® Mixed Reality Capture, Chroma® Key, Samsung® Gear VR, Octagon® studio AR sets, Clevertouch® interactive touchscreen, LEAP® motion controller, and combination of the above instruments with Arduino® robotic artefacts.

4.5.2 Description of the participants

The ICT-INOV methodology was deployed in the 2022 – 2023 academic year. Students aged between 22 - 30 were engaged in the course managed by EU-Track.

4.5.3 Description of gamified design thinking activities

Design thinking was integrated into the course to help students develop a deep contextual understanding of users via non-numerical means and direct observations that highlight attitudes, behaviour, and latent needs. Design thinking deployment aimed to achieve a more effective needs analysis. Activities were organized in the following steps.

Step 1: Team building.

Students were split up into 4 teams of 5 members each. They were asked to select a team name and describe the group's key elements, such as their goals. To complete this work, they applied the team canvas template. The main purpose was to establish the team's beliefs, working principles, roles, and goals in order to kick off the design thinking process.

Step 2: Understanding the problem and the users by creating an empathy map.

Students gathered information on the assigned problem. In particular, they started to think about possible users' motivations, hopes, needs, and pain. This process helped them to define the empathy map of the target group. The method provided deep insights. The students who worked as designers better understood the problem issues.

Step 3: Problem definition.

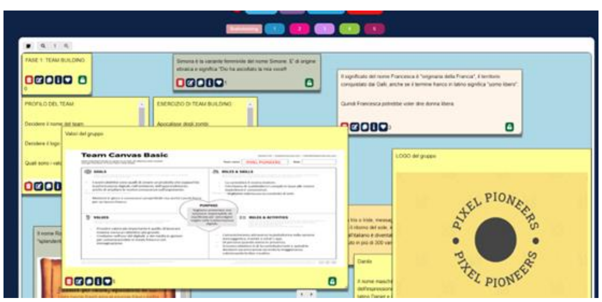
After conducting research on the problem in focus, students were asked to specifically identify the problem to be solved at the end of the design thinking process through precise definitions of "who", "what", and "why" that help clarify the needs of end users.

Step 4: Brainstorming and ideate.

Students suggested ideas, from the most realistic ones to be implemented to the most impossible to realize. This part of the design thinking method allowed students to generate freely and develop innovative ideas by combining the work conducted in teams.

Step 5: Prototyping and design.

Students built prototypes of their proposed solution in the form of a poster that they used to deliver a final presentation.



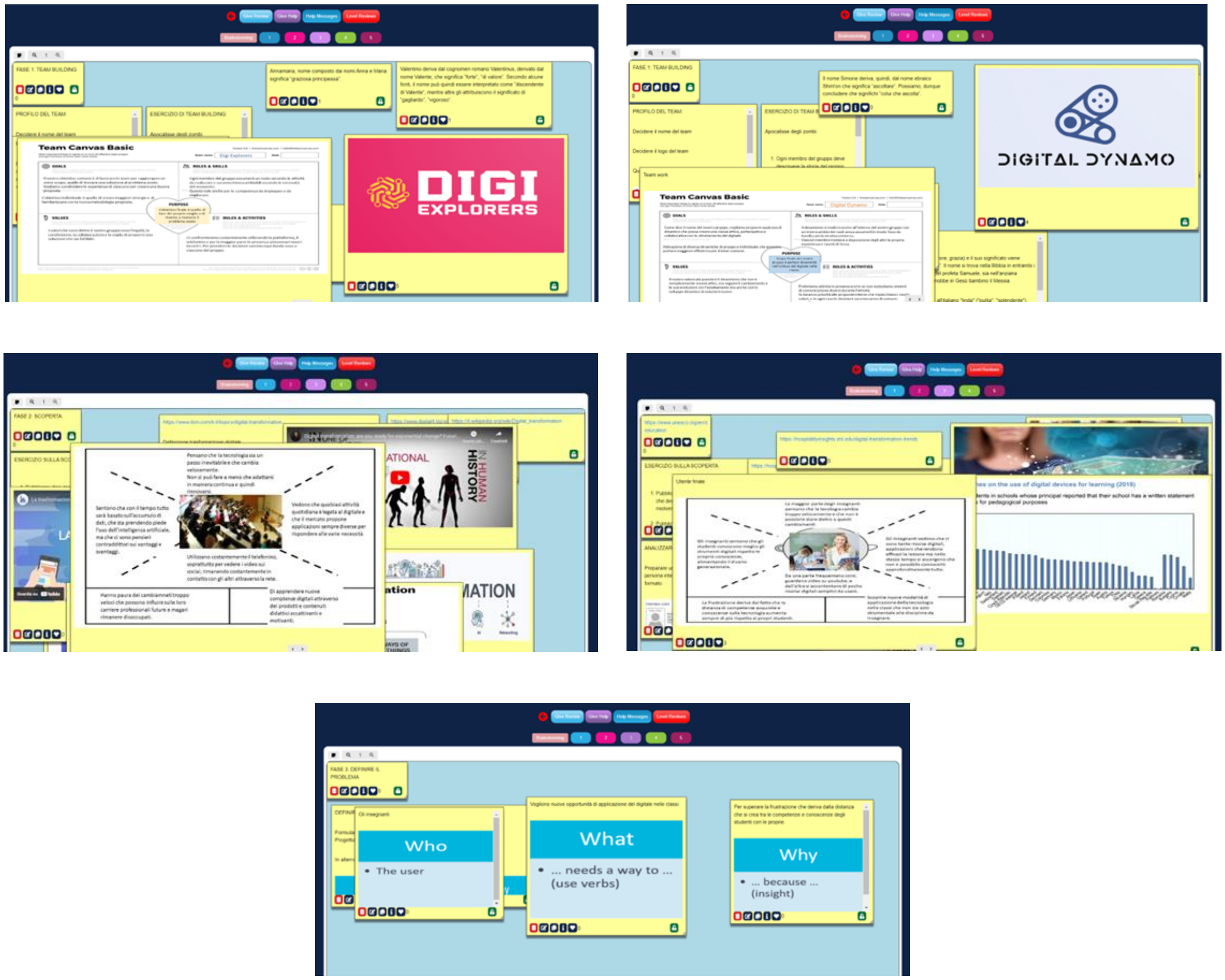


Figure 26. Screenshots of student projects in the Multimedia Learning Environment course, spring 2023.

5. University of Malaya

5.1 Course GFW 0002: Computational Thinking

5.1.1 Description of the course

The Computational Thinking course is offered by the Faculty of Computer Science and Information Technology course as a university course that can also be taken by students from other faculties. It is a course under the Student Holistic Empowerment (SHE) Program. The course offers 2 credit hours with no prerequisite requirements. In this course, students are exposed to the concepts of computational thinking in solving everyday problems. Students engage in unplugged activities in the classroom that aim to reinforce understanding and deployment of key concepts. In addition, students are taught Scratch programming, a hands-on activity that further facilitates understanding concepts. Students from different areas of study are asked to present problems related to their area. Using the skills and concepts learned, they are required to develop a well-thought method for solving the problem in focus. They are then required to design and develop a program that provides a digital solution to the problem. The Computational Thinking course requires no prior knowledge in programming or Computer Science. It aims to demonstrate that everyone uses computational thinking, whether they are aware of it or not, rather than guide them in using it in a structured manner. The course is conducted fully online.

5.1.2 Description of the participants

The course targets full-time undergraduates at the University of Malaya. In semester 1 of the 2021 - 2022 academic year 79 students attended the course.

618768-EPP-1-2020-1-EL-EPPKA2-CBHE-JP

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5.1.3 Description of gamified design thinking activities

Design thinking was deployed in the course as part of the class project. Activities focused on the methodology's ideation, prototyping, and evaluation phases.

The pedagogical approach applied in the course was project-based learning. Project-based class activity had multiple goals. It aimed at encouraging students to demonstrate problem-solving skills using computational thinking methods. It further aimed at supporting students in developing a simple program to solve a problem related to their study area. In addition, the class project aimed to build students' ability to plan and execute the project using design thinking. Finally, the class project encouraged students to design a game through storyboarding, to develop a game using the Scratch® platform, and to evaluate the game through a questionnaire.

Students worked in groups. They were asked to familiarize themselves with Scratch® and then use it to create their own game following pre-defined guidelines. Specifically, the game was required to include at least 10 elements demonstrated by the instructor in tutorial sessions and be tested by at least 5 individuals from other groups. Students were asked to use the ICT-INOV digital learning platform for brainstorming, communication, and solution synthesis.

Students worked with their team members to discuss and deliver the specified weekly output. At the end of the week, students went through an interview on the project implementation progress. Each week, the following deliverables were expected:

Step 1: Empathy.

Students applied principles of empathy towards understanding user needs for creating the game. Work included analysis of the target group, the type of game to be developed, and the input mechanisms. The results were delivered at the end of week 1 of the activity.

Step 2: Ideation.

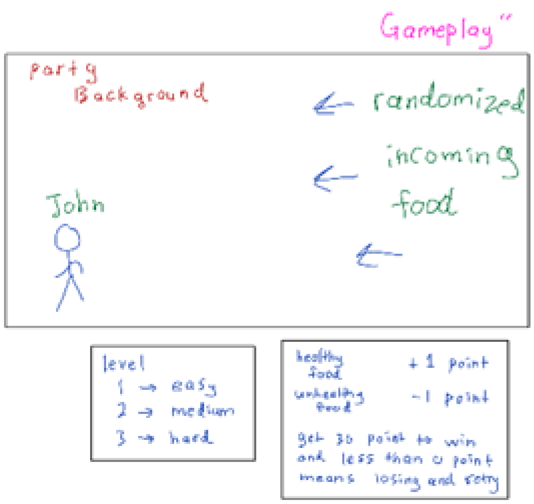
Students brainstormed towards introducing ideas for game creation. The ideation outcomes were documented through a storyboard on the initial game design. The results were delivered at the end of week 2 of the activity.

Step 3: Prototyping.

Students designed a game prototype using Scratch®. The results were delivered at the end of week 3 of the activity.

Step 4: Evaluation.

Students performed game evaluation and prepared a presentation of their game. The results of the activity were delivered at the end of week 4.



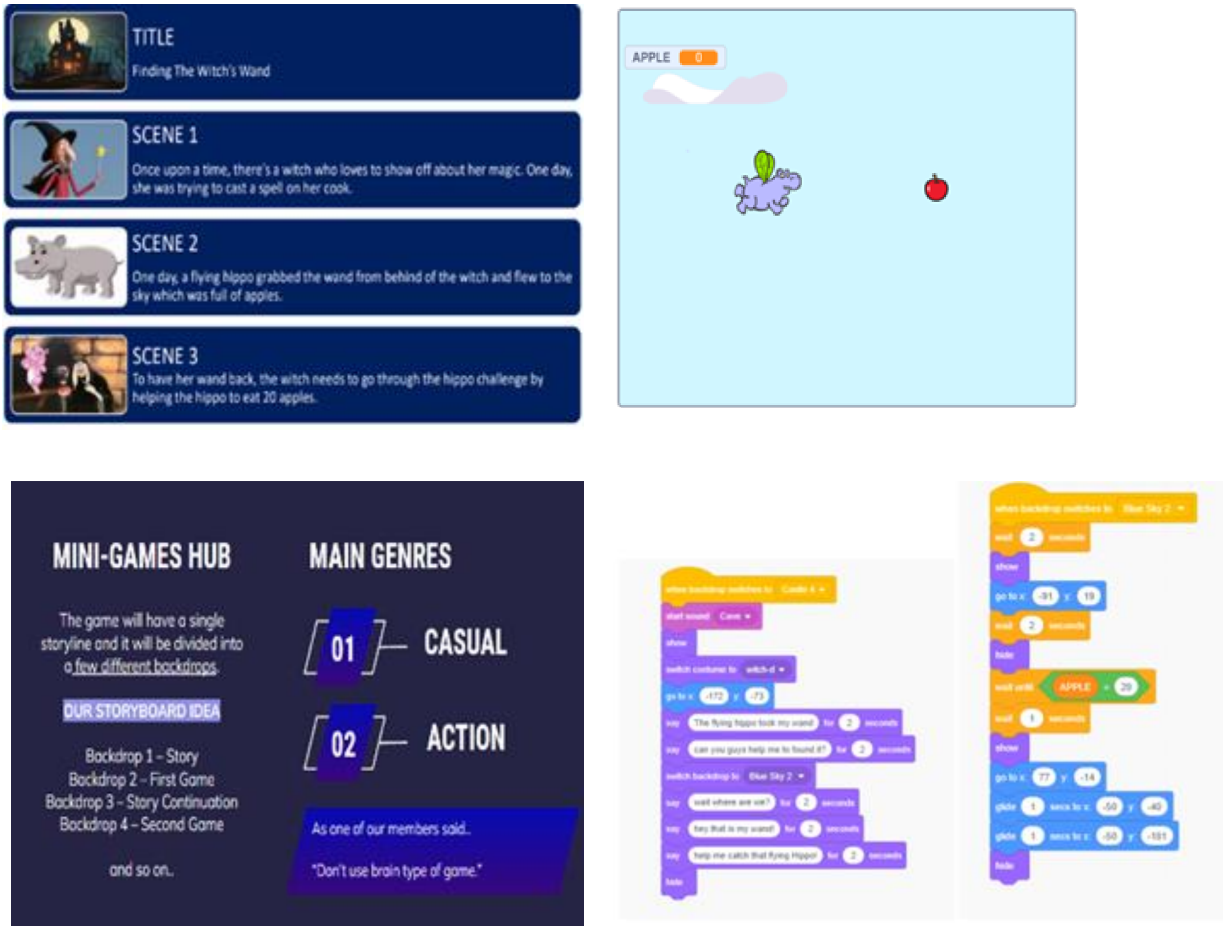


Figure 27. Screenshots of student projects in the Computational Thinking course, fall 2021.

5.2 Course WIF3005: Software Maintenance and Evolution

5.2.1 Description of the course

The course mainly covers software maintenance fundamentals, key issues in maintenance, maintenance processes, maintenance techniques, and the evolution of maintenance activities. The course takes place virtually.

5.2.2 Description of the participants

The course targets students enrolled in the Bachelor of Computer Science program. In semester 2 of the 2021 – 2022 academic year 20 students attended the course.

5.2.3 Description of gamified design thinking activities

Design thinking, and more specifically empathy, ideation, and prototyping practices were deployed as one of the methodologies in the course toolkit that helps expose students to the analysis of real-world issues faced by older individuals. In these activities, students analyzed real-world challenges and suggested relevant system features that can enrich the quality of everyday life of older people. Students applied design thinking in groups using the ICT-INOV digital learning platform to share ideas and brainstorm. Through group collaboration, students introduce solutions that address the health challenges of older people.

The pedagogical approach applied in the course was project-based learning. The activities aimed at building innovative skill sets towards the design of software system features by applying suitable techniques and tools for performing software development and by assessing strategies

Students identified problems and issues older people face, such as health issues, mobility difficulties, reduced hearing, or reduced vision. They engaged in empathy activities and brainstormed to identify common challenges and activities in which elderly individuals may need assistance. Based on this analysis, students suggested features that can offer relief and enrich the lives of older people.

Students worked in teams of 5 individuals. They were instructed to design a mobile app that helps address a specific challenge elderly individuals face. To achieve their objective, students engaged in the following design thinking steps:

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Step 1. Problem research.

Students selected a problem to focus on. They researched the topic chosen and described the problem through photos, drawings, notes, and article links posted on the ICT-INOV digital learning platform. In addition, students observed the behaviour of the targeted group, namely elderly individuals and recorded their findings. They conversed with at least 6 individuals facing the problem and recorded their thoughts and feelings. They identified and recorded patterns.

Students were instructed to be curious in this context and keep an open mind. For example, if elderly individuals already used an app, what would not work for them? If they did not use an app, what was the reason behind that?

Step 2. Problem statement definition.

Based on the problem research results, students were asked to define at least 3 different problem statements.

Step 3. Brainstorming.

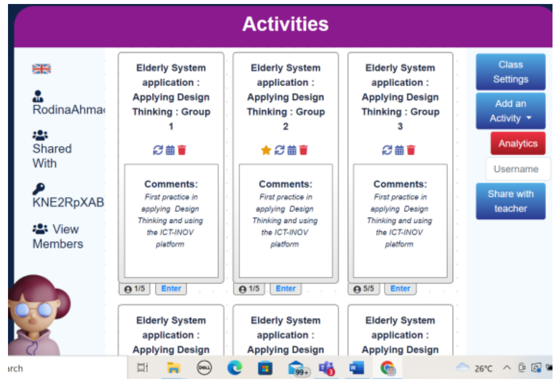
Students brainstormed in groups. They were instructed not to judge the ideas of others, to strive for a high volume of ideas, to encourage wild ideas, and to build upon the ideas of others. Students brainstormed on the main goals of the system under design, usually 3 – 4 goals, and the main stakeholders, usually 2 – 3 stakeholders.

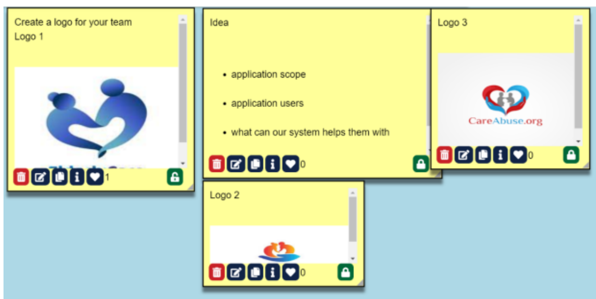
Step 4. User requirements definitions.

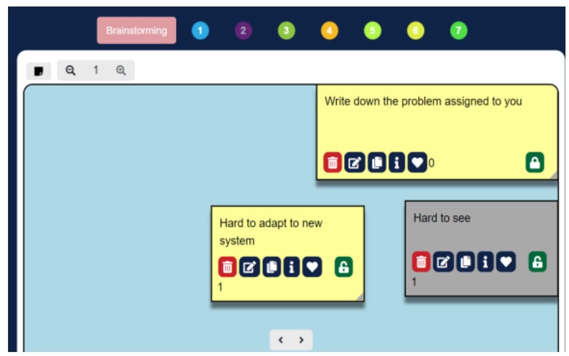
Students identified techniques for requirements elicitation through target user engagement. They defined user and system requirements for each feature, functional and non-functional, including quality requirements and constraints.

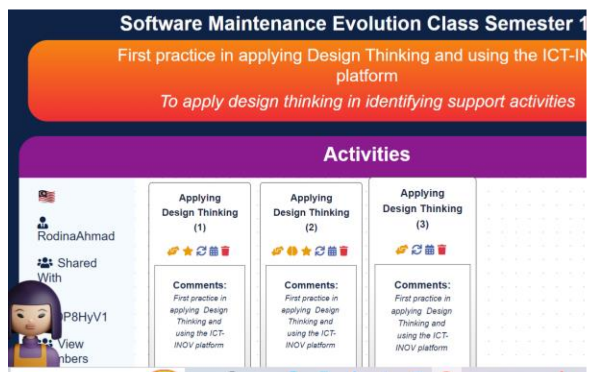
Step 5. Lessons learned.

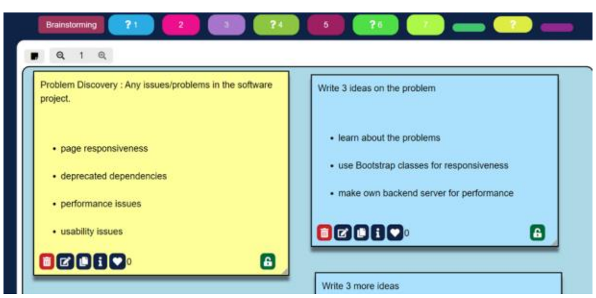
Students analysed issues, problems, or constraints encountered during implementation. They discussed the lessons learned through the analysis process.

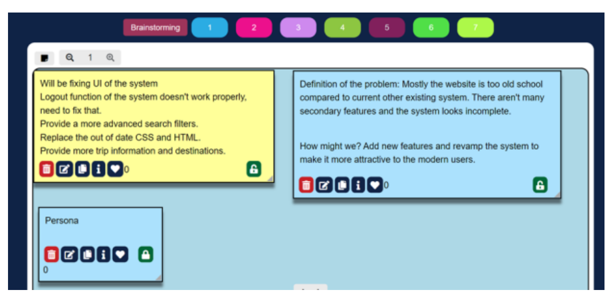












Co-funded by the Erasmus+ Programme of the European Union

Figure 28. Screenshots of student projects in the Software Maintenance and Evolution course, spring 2022.

5.3 Course WIA2005: Algorithm Design and Analysis

5.3.1 Description of the course

The course introduces students to the analysis and design of computer algorithms. Students learn basic design techniques, important classical algorithms, advanced data structures and their implementation in modern programming environments. The course takes place virtually.

5.3.2 Description of the participants

The course targets students enrolled full-time in the Bachelor of Computer Science program. In semester 2 of the 2021 – 2022 academic year 253 students attended the course.

5.3.3 Description of gamified design thinking activities

Design thinking, and more specifically, ideation and prototyping, were deployed in implementing the class project, in which students were required to introduce a solution to a specific problem using an appropriate algorithm.

The pedagogical approach applied in the course was project-based learning. The activities aimed at building student capacity to report on the performance of algorithms. More specifically, upon completion of the course, students were expected to be able to analyze a problem, design a solution algorithm, and develop a computer program that applies the algorithm in practice using Python® and supporting tools.

Students worked in groups of 6 individuals. They are assigned a problem to solve using the most appropriate algorithm that gives the best performance.

Work was organized in the following design thinking steps:

Step 1: Brainstorming and analysis.

In this phase, students analyzed the assigned problem's parameters and brainstormed potential solutions.

Step 2: Designing and coding.

Students designed a solution and coded a computer program using Python®. They used Padlet®, Google® Docs, and other necessary collaborative tools to document the brainstorming and ideation activity before focusing on software coding.

Step 3: Presentation and demo.

Students delivered in groups a 20 – 30 minutes demo and presentation. During the presentation, they justified the tools and algorithms developed to resolve the assigned problem. They further discussed the time complexity of the algorithms they developed. This activity took place over weeks 13 – 14 of the course.

1. Find shortest path for delivery, related to the Traveling Salesman problem.
   - Passing the list of locations selected including local distribution center, calculate the distance starting from the center , visit all location and back to the center
   - Calculate shortest path for delivery

*** Algorithm to find and calculate the shortest path distance between two stores with the local distribution center as the starting point and ending point*

Dijkstra shortest path algorithm from point A to point B without traveling back to point A

Possible downside: unsure on whether the traversed path is the shortest as computed

[7.5] Dijkstra Shortest Path Algorithm in Python

Traveling salesman problem using Google Distance Matrix API

Travelling Salesman Problem - FULL PYTHON CODING TUTORIAL

https://developers.google.com/optimization/routing/tsp

1 / 6 Update :

Use Held-karp algorithm (dynamic programming)

https://en.wikipedia.org/wiki/Held%E2%80%93Karp_algorithm

3. Below shows the location of the stores selected in Canada.

Selected stores:
Red - distribution center
Blue - other stores

4. Below shows the distance matrix, shortest path and total distance for the delivery.

Distance matrix:
[[0, 768288, 1174347, 1554417, 537454, 1536895],
[768452, 0, 1941540, 2285230, 1304647, 2267708],
[1180260, 1948093, 0, 1212592, 666416, 1195070],
[1555481, 2283062, 1212167, 0, 1158667, 26083],
[538128, 1305961, 665135, 1160154, 0, 1142632],
[1537753, 2265333, 1194439, 31806, 1140938, 0]]

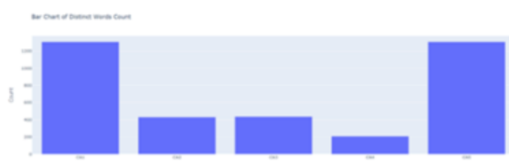
Shortest path : [0, 4, 2, 3, 5, 1, 0]
Total distance : 5475049 miles

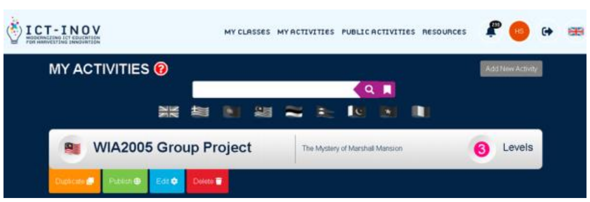
Canada(CA)

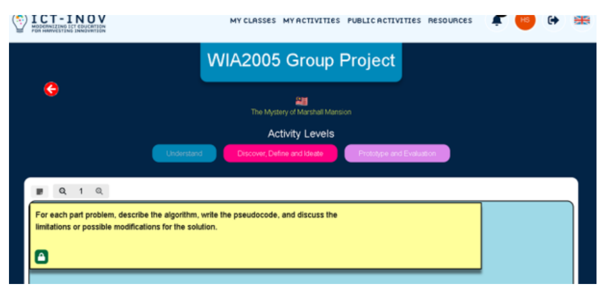
1. Below shows the analysis based on 5 articles about Canada.

Article	Original Words Count	Distinct Words Count	Stop Words Count	Positive Words Count	Negative Words Count	Positive Words Percentage (%)	Overall Sentiment
CA1	2928	1305	87	92	42	68.66	Positive
CA2	815	431	65	34	8	80.95	Very Positive
CA3	795	436	50	29	11	72.50	Positive
CA4	325	208	43	15	2	88.24	Very Positive
CA5	2794	1305	65	79	38	67.52	Positive

2. Below shows the graphs based on analysis on Canada.







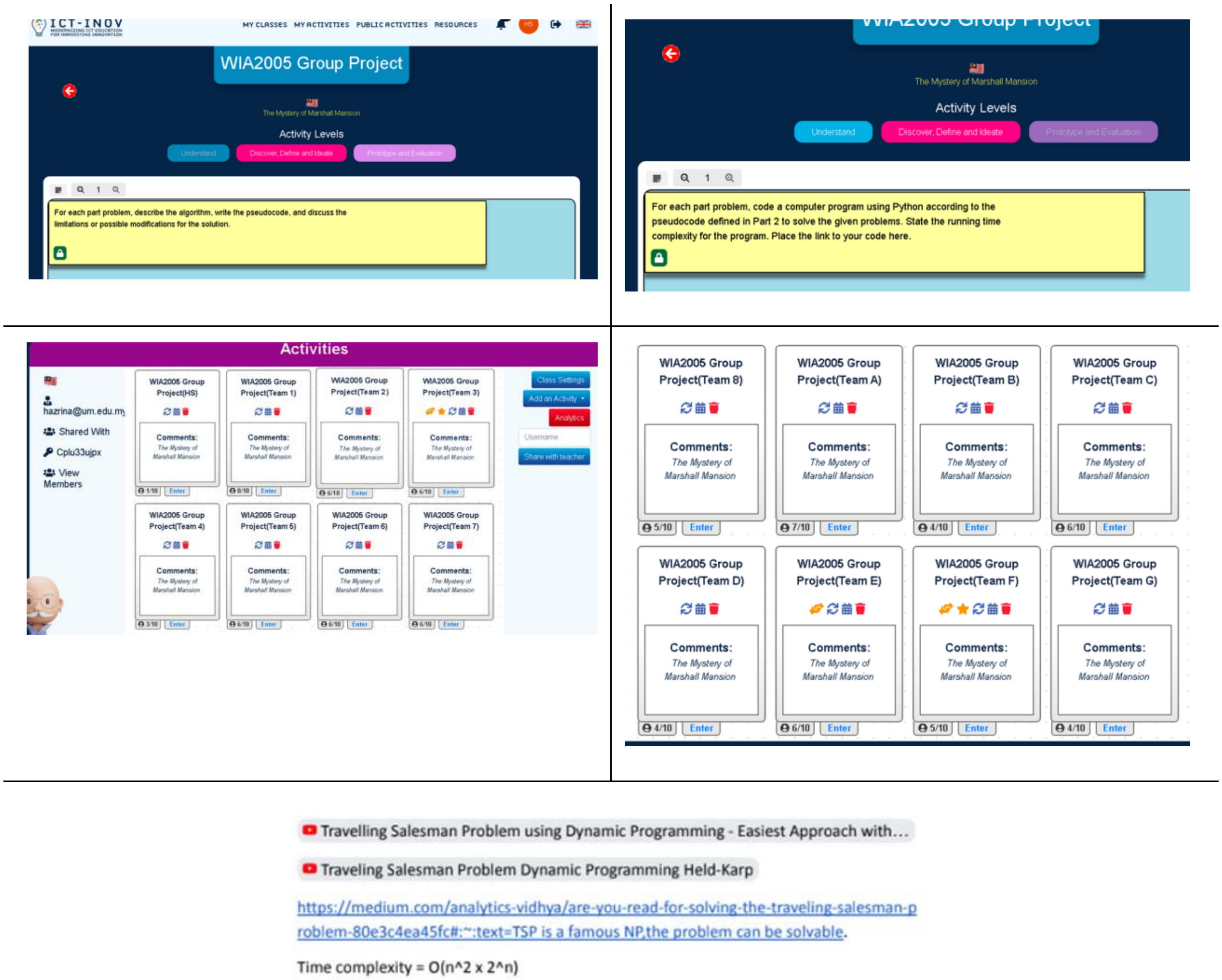


Figure 29. Screenshots of student projects in the Algorithm Design and Analysis course, spring 2022.

5.4 Course WIF3008: Real-Time Systems

5.4.1 Description of the course

The course introduces real-time systems. Content includes the differences between soft and hard real-time systems, system decomposition and scheduling techniques such as clock-driven scheduling and priority-driven scheduling of periodic, aperiodic and sporadic tasks. The course also covers issues such as multiprocessor scheduling and resource access control, fault tolerance and real-time communication. This course takes place virtually.

5.4.2 Description of the participants

The course targets students enrolled full-time in the Bachelor of Computer Science program. In semester 1 of the 2021 – 2022 academic year 40 students attended the course.

5.4.3 Description of gamified design thinking activities

Design thinking, and more specifically, ideation and prototyping, were deployed in implementing the class project, in which students were required to introduce a solution to a specific problem.

The pedagogical approach applied in the course was project-based learning. The project-based class activity aimed to empower students to solve problems related to real-time issues in communication networks with an emphasis on feature-sand capabilities for supporting real-time applications. More specifically, upon completion of the course, students were expected to be able to analyze a problem, design a solution algorithm, and develop a computer program that applies the algorithm in practice using Python® and supporting tools.

Students worked in teams of 6 individuals. They were challenged to consider “How can the Tello Drones be used to provide solutions for daily life problems?”. They were instructed to include control components and autonomous behaviour in their solutions.

Activities were organized in the following design thinking steps:

Step 1: Brainstorming.

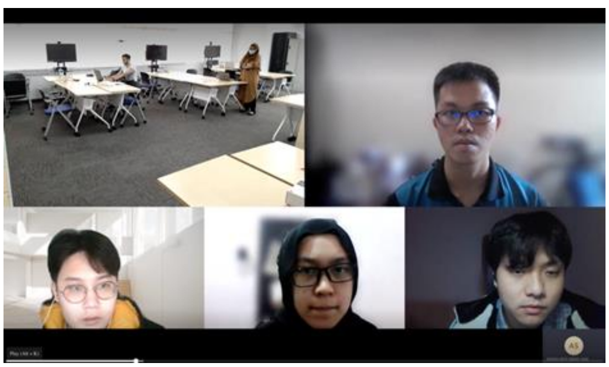
Students brainstormed within their group towards designing a proof-of-concept prototype that addressed the project's key question: using drones to solve real-life issues by integrating control components and autonomous behaviour. This activity took place on week 6 of the course. They recorded their ideas using Padlet®.

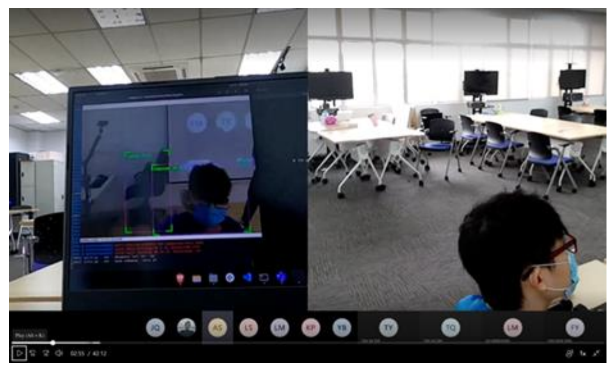
Step 2. Analyzing, designing, and prototyping.

Students analyzed potential solutions and developed a software prototype using Python® that addresses the problem in focus. Students consulted with the lecturer in pre-assigned timeslots to discuss the project scope. This activity took place on weeks 7 – 13 of the course.

Step 3. Presentation and demo.

Each student team delivered a 10 – 15 minutes presentation in which they presented their work and demonstrated their prototype solution.





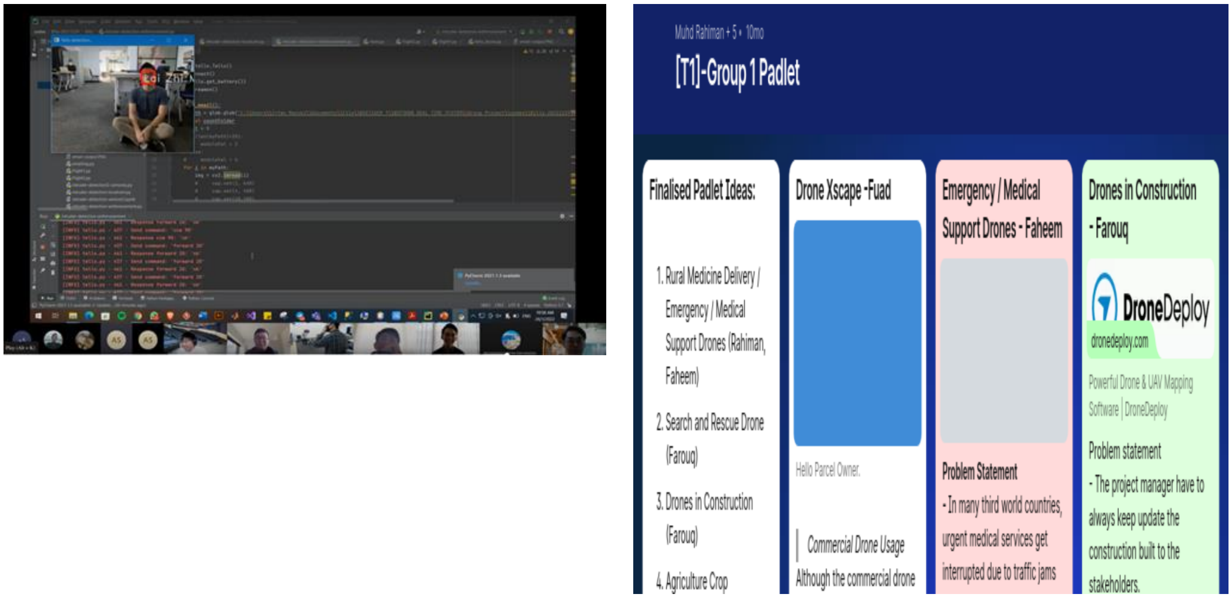


Figure 30. Screenshots of student projects in the Real-Time Systems course, fall 2021.

5.5 Course WIF2002: Software Requirements Engineering

5.5.1 Description of the course

The course covers the fundamentals of requirements engineering and discusses important requirements artefacts. The course covers core activities of Requirements Engineering, including elicitation, specification, documentation, negotiation, validation and management. The course takes place virtually.

5.5.2 Description of the participants

The course targets students enrolled full-time in the Bachelor of Computer Science program. In semester 2 of the 2021 – 2022 academic year 80 students attended the course.

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5.5.3 Description of gamified design thinking activities

Design thinking activities, and more specifically, empathy and ideation, were deployed in the context of the class project. The pedagogical approach applied in the course was project- and problem-based learning. During this course, a preliminary study on innovation skills development took place. The study aimed to investigate innovative skill sets applicable to software requirements engineering.

In the class project, students were asked to resolve problems faced by humans by analyzing software requirements. The project-based class activity aimed to introduce students to artefact requirements based on established standards and apply appropriate techniques and methods to elicit and analyze software requirements.

Students engaged in the following activities:

Step 1. Problem research.
Students selected a website, mobile app or both that they would like to improve on. An example of a selected project is focusing on challenges elderly individuals face, such as fear of mobility or being a burden. All 80 students in the class performed this particular activity.

Upon selecting a topic to focus on, students engaged in problem research through various means. They observed the target users to document behaviour and recorded findings. They further web-based research to describe the problem through photos, drawings, notes effectively, and article links posted on the ICT-INOV digital learning platform. They conversed with at least 6 individuals facing the problem and recorded their thoughts and feelings. They identified and recorded patterns.

Students were instructed to be curious during the problem research process and keep an open mind. For example, if elderly individuals already used an app, what was not working for them? If they did not use an app, what was the reason behind that?

Step 2. Problem statement definition.

Based on the problem research results, students were asked to define at least 3 different problem statements.

Step 3. Brainstorming.

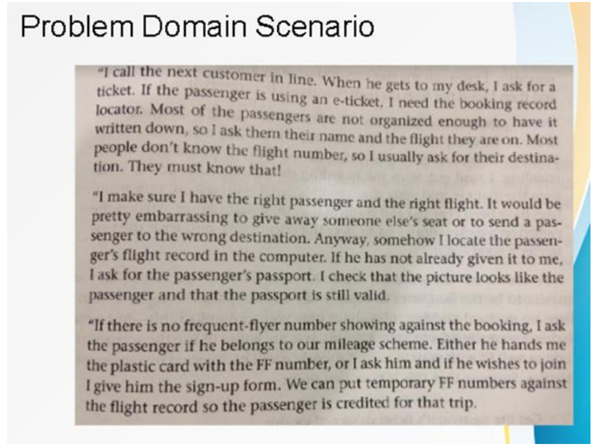
Students brainstormed in groups. They identified the main objectives of stakeholders as the basis for extracting user requirements.

Step 4. User requirements definitions.

Students identified and justified requirements elicitation techniques. They defined user and system requirements for each feature, functional and non-functional, including quality requirements and constraints. They extracted data requirements, which they documented in context and class diagrams. They further extracted user interface requirements, which they documented in mock-up screens. They designed and documented the main system components as activity and sequence diagrams.

Step 5. Lessons learned.

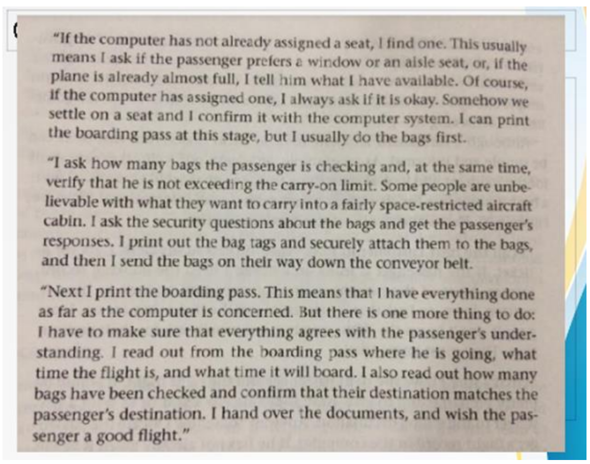
Students analyzed their requirements extraction process and introduced future recommended features for their system implementation. They further analysed issues, problems, or constraints encountered during implementation. They discussed the lessons learned through the analysis process. They documented their findings in a lightweight SRS.


Problem Domain Scenario

"I call the next customer in line. When he gets to my desk, I ask for a ticket. If the passenger is using an e-ticket, I need the booking record locator. Most of the passengers are not organized enough to have it written down, so I ask them their name and the flight they are on. Most people don't know the flight number, so I usually ask for their destination. They must know that!

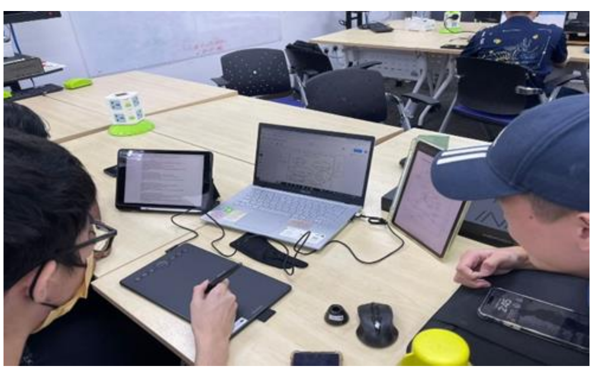
"I make sure I have the right passenger and the right flight. It would be pretty embarrassing to give away someone else's seat or to send a passenger to the wrong destination. Anyway, somehow I locate the passenger's flight record in the computer. If he has not already given it to me, I ask for the passenger's passport. I check that the picture looks like the passenger and that the passport is still valid.

"If there is no frequent-flyer number showing against the booking, I ask the passenger if he belongs to our mileage scheme. Either he hands me the plastic card with the FF number, or I ask him and if he wishes to join I give him the sign-up form. We can put temporary FF numbers against the flight record so the passenger is credited for that trip.


"If the computer has not already assigned a seat, I find one. This usually means I ask if the passenger prefers a window or an aisle seat, or, if the plane is already almost full, I tell him what I have available. Of course, if the computer has assigned one, I always ask if it is okay. Somehow we settle on a seat and I confirm it with the computer system. I can print the boarding pass at this stage, but I usually do the bags first.

"I ask how many bags the passenger is checking and, at the same time, verify that he is not exceeding the carry-on limit. Some people are unbelievable with what they want to carry into a fairly space-restricted aircraft cabin. I ask the security questions about the bags and get the passenger's responses. I print out the bag tags and securely attach them to the bags, and then I send the bags on their way down the conveyor belt.

"Next I print the boarding pass. This means that I have everything done as far as the computer is concerned. But there is one more thing to do: I have to make sure that everything agrees with the passenger's understanding. I read out from the boarding pass where he is going, what time the flight is, and what time it will board. I also read out how many bags have been checked and confirm that their destination matches the passenger's destination. I hand over the documents, and wish the passenger a good flight."



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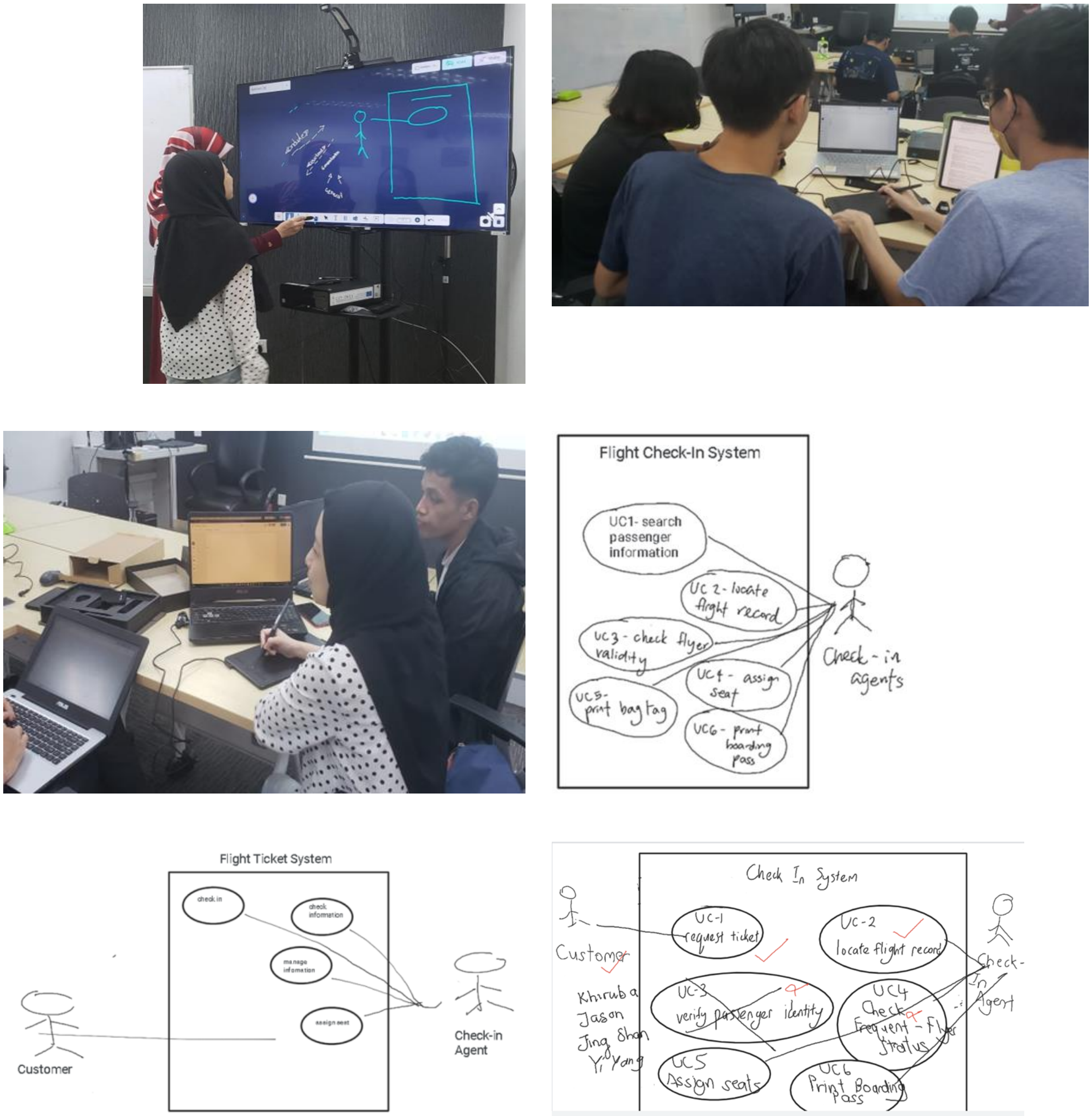

Figure 31. Students work on the Software Requirements Engineering course, spring 2023.

5.6 Course GIW1005: Mobile Typography Made Easy

5.6.1 Description of the course

The course offers practical hands-on experience in creating and styling their mobile typographic content interactively using typographic tools. The key design elements of typography covered are typeface, fonts, line length, leading, kerning and tracking. In addition, the course builds knowledge of typographic developments in Malaysia. The course takes place virtually.

5.6.2 Description of the participants

The course targets students enrolled full-time in the Bachelor of Computer Science program. In semester 2 of the 2021 – 2022 academic year 30 students attended the course.

5.6.3 Description of gamified design thinking activities

Design thinking activities, and more specifically, ideation and prototyping, were deployed in the context of the class project. The pedagogical approach applied in the course was project-based learning.

The objective of the activities was to build students' capacity to use typography with interactive tools in text editors and mobile apps. More specifically, the goal of the course was to demonstrate how design thinking can contribute to project planning and execution and to facilitate the design of an e-learning mobile application using the MIT App Inventor platform.

Students were divided into groups of 3 individuals. A total of 10 groups were formed.

Step 1. Preparation.

Students familiarized themselves with MIT App Inventor. They discussed the benefits of mobile applications. This activity was completed by the end of week 9.

Step 2. Team building.

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Students undertook a personality test and an innovation pre-test. The goal of the tests was to facilitate the assignment of team roles in the implementation of their project. Based on the results, students created a group contract to facilitate collaboration. This activity was completed by week 10 of the course.

Step 3. Project discovery.

Students worked with their team members to select a topic for their work within the larger scope of typography. They were instructed to describe the topic in a concise text. They further developed a topic presentation using pictures, videos and animations.

Subsequently, students performed research on user needs, applying empathy techniques. Each team created a quiz with at least 5 questions to test the user's knowledge of the topic. They used the quiz to perform at least 2 discussion sessions and to publish the results on the ICT-INOV digital learning platform.

Step 4. Implementation and prototyping.

Students implemented their project by developing a prototype. This activity was completed by week 12 of the course.

Step 5. Evaluation and reflection.

Students undertook an innovation post-test. They reflected on the results of their work. They presented their work to the class. This activity was completed by week 13 of the course.

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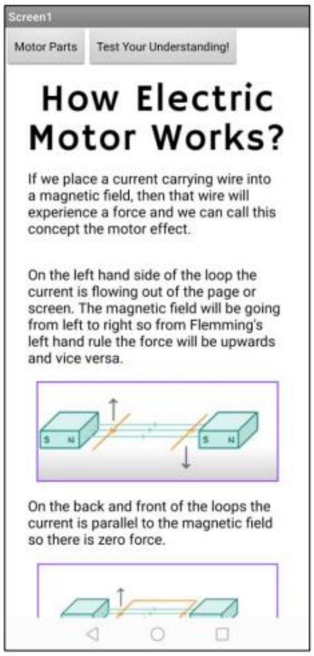
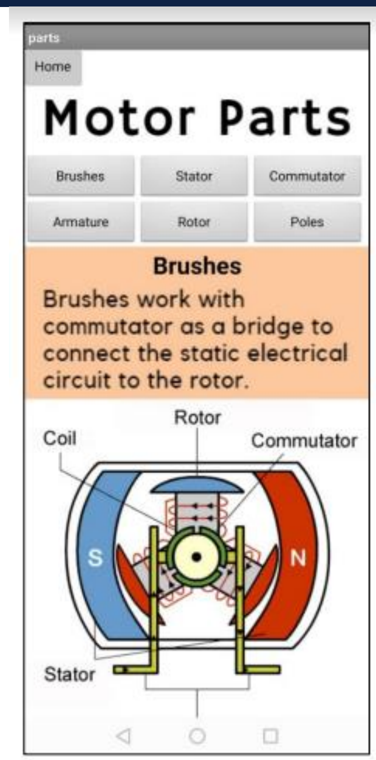
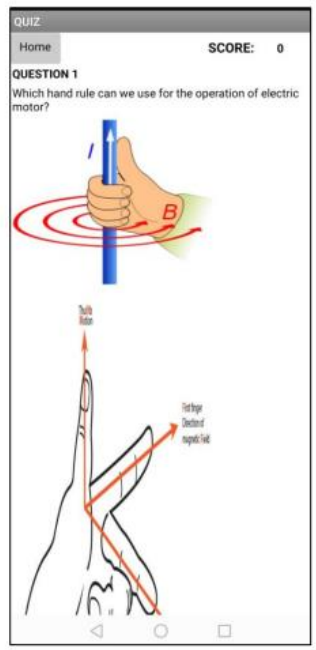
Online Monitoring for Mobile Typography Group Project (1)
Duplicate
Publish
Edit
Delete
Online Monitoring for Mobile Typography Group Project (13th June 2022)
Duplicate
Publish
Edit
Delete


Screen1
Motor Parts
Test Your Understanding!
How Electric Motor Works?
If we place a current carrying wire into a magnetic field, then that wire will experience a force and we can call this concept the motor effect.
On the left hand side of the loop the current is flowing out of the page or screen. The magnetic field will be going from left to right so from Flemming's left hand rule the force will be upwards and vice versa.
On the back and front of the loops the current is parallel to the magnetic field so there is zero force.


parts
Home
Motor Parts
Brushes
Stator
Commutator
Armature
Rotor
Poles
Brushes
Brushes work with commutator as a bridge to connect the static electrical circuit to the rotor.
Rotor
Coil
Commutator
S
N
Stator


QUIZ
Home
SCORE: 0
QUESTION 1
Which hand rule can we use for the operation of electric motor?
I
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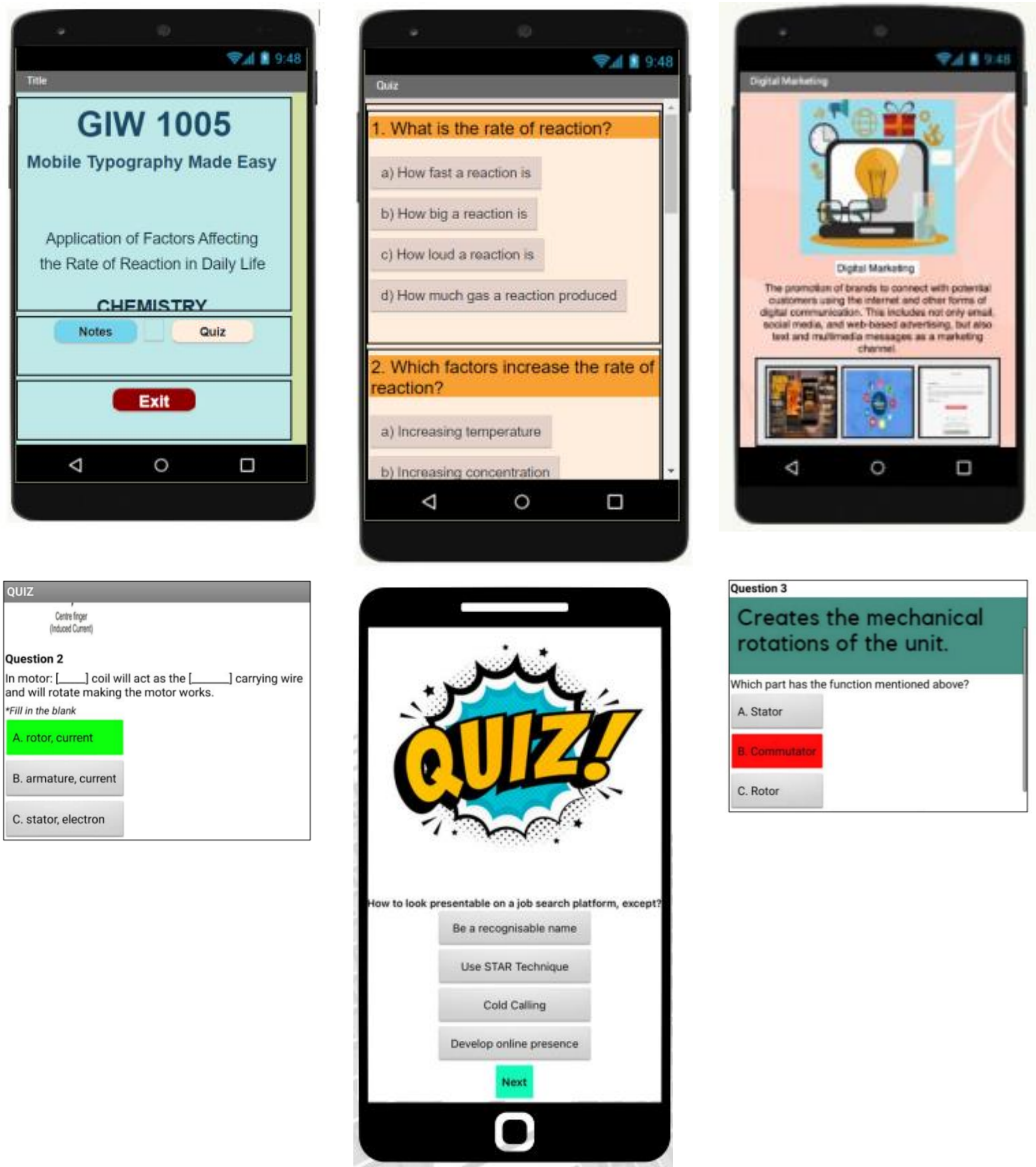

Figure 32. Screenshots of student projects in the Mobile Typography Made Easy course, spring 2022.

5.7 Course WIQD7010: Networks and Security

5.7.1 Description of the course

The course provides a practical survey of network security applications and standards. It emphasizes applications widely used on the internet and for corporate networks. It further emphasizes standards, especially internet standards that have been widely deployed. The course takes place virtually.

5.7.2 Description of the participants

The course targets students enrolled in the Master of Data Science program. In semester 2 of the 2021 – 2022 academic year 67 students attended the course, some of whom were enrolled full-time and some part-time in the Master’s program as they work in parallel with their studies, mostly in the IT field. The course is an elective. The student body was multicultural, with individuals from China, Egypt, Bangladesh, Pakistan, Saudi Arabia, Indonesia and Malaysia. Most students were in their final year of studies, undertaking the project paper required for their graduation.

5.7.3 Description of gamified design thinking activities

Each student was assigned an individual or group project in cryptography with applications in network security. Active learning was the predominant pedagogical methodology deployed in the course.

Students were encouraged to present their ideas and receive feedback in an interactive session. They further demonstrated their ideas by developing a multimedia prototype using a programming language of their choice.

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Activities took place in groups. Group members were jointly responsible for making the project a success. The project taught students how to apply cryptography techniques, including symmetric, asymmetric, hash and cypher block mode, and presented their findings.

Students engaged in the following steps.

Step 1. Researching mathematical applications for cryptography.

During the 1st part of the educational process, students used the Cryptool® application for interactive learning on cryptography. Cryptool® offers 2 interactive games named Number Shark. The purpose of the games was for the students to understand the concept of prime number factorization of integer numbers, which is mainly used in public key cryptography. More specifically, students selected the size of a shell square. Starting with a minimum of 20 numbers, they gradually increased the size. The biggest shell size supported in the application is 9.999. However, solving such a large puzzle would take years. Students were asked to take no more than 3 minutes to finish the 20-number selection. They played against the application and tried to beat the shark. If any of the selected numbers had any real factors, the shark would eat those factors. For numbers larger than 100, students typically formed groups of no more than 5 individuals. The game was very useful and enhanced familiarization with prime number selections in RSA and Diffie & Helman public key cryptography. In addition to the Number Shark application, students used interactive tools such as Digital Signature Demonstration and Number Theory Interactive Learning.

Step 2. Researching state-of-the-art network security applications.

During the 2nd part of the course, students engaged in a group-based active learning project. Students were asked to select recent applications or techniques in network security. Most selected a multimedia application, such as Canva® or any other video editing software, to present their work. The activity encouraged students to creatively present and explain their findings, contributing to their understanding of network security and improving their communication skills.

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Students were given instructions in tutorial sessions, during which study questions were introduced. They presented the results of their work using slides and video presentations.

Step 3. Empathy and implementation.

Students worked on assignments in which they used Cryptool® and Python® to solve problems assigned by the instructor. They worked in groups, looking at real-life applications of cryptography. Educators encouraged students to apply empathy by asking them what they believe are the key challenges related to the application of cryptography for network security.

Some of the projects proposed by students include:

- **Cyberattack case studies**. Case studies on recent cyber-attacks in network security and their solutions.
- **Social media security**. Case studies on social media security challenges and suggested solutions.
- **Applications of zero trust networks**. Breaking down large networks into smaller ones that do not overlap to minimize the consequences of a corporate network security breach.
- **Network security recent issues**. Case studies on network security in the modern world and suggested solutions.
- **Personal privacy in social networks**. Case studies on personal data privacy and suggested solutions.
- **Quantum cryptography and its applications**. A review of recent developments in the area.

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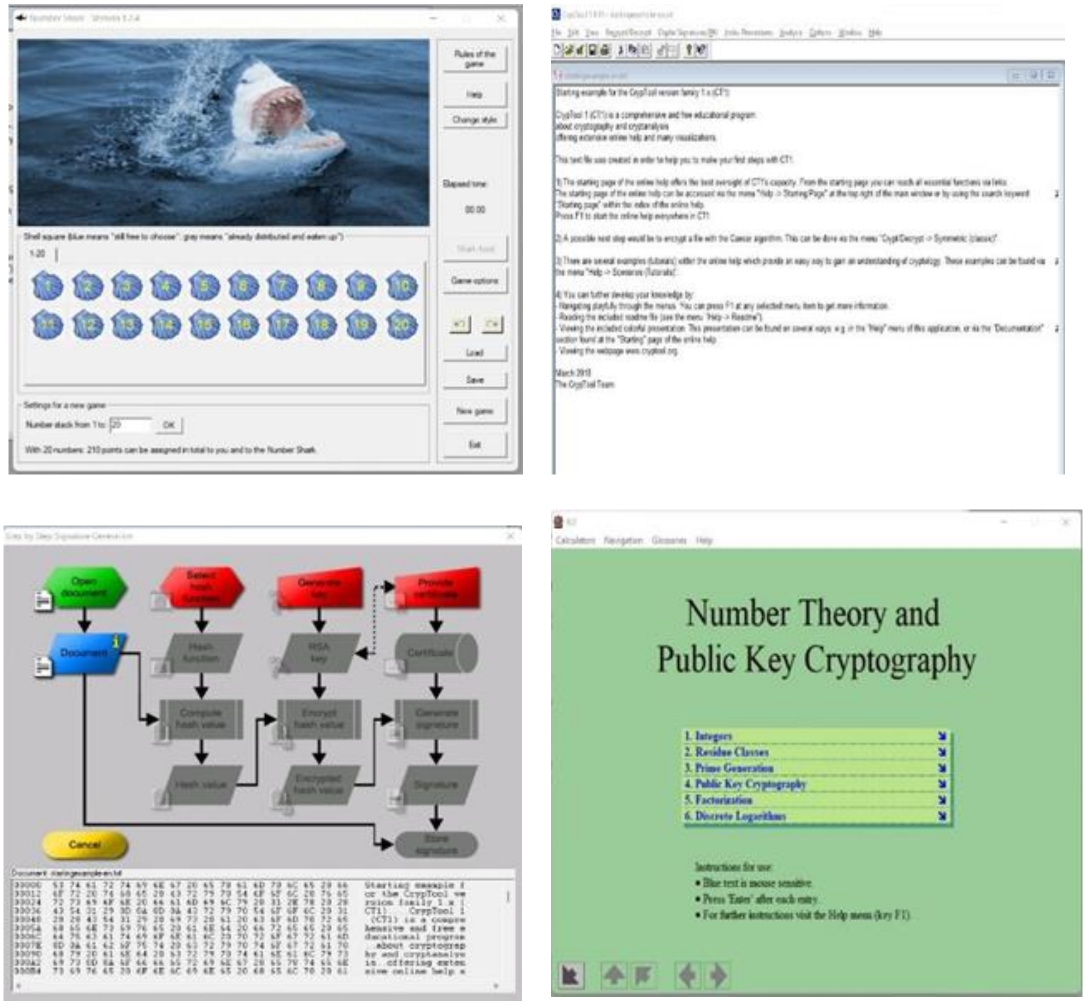

Figure 33. Interactive games in the context of the Mobile Cryptography Made Easy course, spring 2022.

5.8 Course WIX2001: Thinking and Communication Skills

5.8.1 Description of the course

The course builds effective communication and critical thinking skills. Topics related to communication include verbal and non-verbal communication skills, listening skills, presentation skills, persuasive language skills and analysis of communication barriers. Regarding communication barriers, topics include techniques for clarifying, analyzing and evaluating

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arguments and logical fallacies, problem-solving and decision-making. The course further focuses on effective methods for finding, evaluating and using information sources. The course builds individual, leadership and teamwork skills.

5.8.2 Description of the participants

The course targets students enrolled in the 2nd year of the Bachelor of Computer Science program. In semester 1 of the 2021 – 2022 academic year 392 students attended the course, of which 49 participated in the design thinking intervention. The course took place virtually.

Students who attended the course were registered in their second year of the Bachelor of Computer Science program. 392 students enrolled in the course in semester 1 of the academic year 2021 – 22, of which 49 students participated in the design thinking intervention. The course was conducted fully online during the COVID-19 pandemic. The student body was multicultural, with individuals from China, the United Kingdom, Bangladesh, and Malaysia.

5.8.3 Description of gamified design thinking activities

Students were expected to implement a project that benefits a community of choice. The project is titled Service-Learning Malaysia-University for Society. It constitutes a learning method focused on providing students with the opportunity to contribute knowledge, skills, and competencies in their field to solve problems or issues within communities. It is one of the initiatives of higher education in Malaysia aimed towards producing holistic and balanced graduates with an entrepreneurial mindset. The service-learning project is also one of the elements that characterize high-impact educational practices within the curriculum. It follows an initiative introduced by the Ministry of Higher Education in 2016.

The students participated in weekly meetings. At the beginning of each class, the course coordinator provided a 30-minute briefing on a specific design thinking stage. Students met their team members via a private channel created in their first class and worked with the group throughout the course. Students attended the course from their homes using their own workstations or laptops connected to the internet to participate in weekly group discussions. They used the MSTeams® platform to communicate and share material. Examples of the materials shared include lecture notes on design thinking, exercise activity sheets and templates for each phase of the design thinking framework.

A total of 49 students engaged in the design thinking intervention. They were divided into 8 teams. Teams were tasked to complete an assignment that lasted 14 weeks, namely the entire semester, by applying design thinking steps. Each team implemented a different project, resulting in 8 projects. At the beginning of the course, students were given a general problem statement: how can we support a community for a better quality of life post-COVID-19 across different domains, such as education, tourism, health, business and others? They were allowed to specialize further in their project topic. Each week, students brainstormed on different design thinking activities, such as empathy, ideation, prototyping and testing.

Student activities were organized into the steps below. In the example provided, the project focuses on finding a jogging partner during the COVID-19 pandemic.

Step 1: Finding a collaborator and problem discovery.

The activity's objective was to identify what is important to the collaborator and end-user.

Students participated in a discussion within their group. They identified a list of potential collaborators who were representative of target users and chose a domain according to the team’s interest, where each member produced several ideas and options. Teams set up a virtual meeting with their collaborator of choice. During the meeting, team members were interviewed in an informal setting, such as a chat. This meeting aimed to understand what matters were important to the collaborator concerning the topic in focus. Before the team met with the collaborator, the students were asked to prepare an interview script, namely a list of potential open-ended questions, that they would like to ask the collaborator during the virtual meeting.

Step 2: Empathy.

Students were challenged to put themselves into the end user's shoes to understand the user's challenges, experiences and motivation. Students achieved this goal through interviews. Based on the information collected, students created an empathy map and a user persona that described a characteristic user of the selected target group.

Step 3: Problem definition.

Students were encouraged to produce meaningful problem statements. They synthesized the observations gathered in previous steps. Students created a wall of ideas from the empathy map generated in the previous step. They grouped their ideas into themes using an affinity diagram, which is a visual representation of relationships between complex and large ideas. They created a point-of-view statement that represented the empathy map. The point of view statement reframed the design challenge into an actionable problem.

Each team created several problem statements, one for each type of end user. They then produced a list of "how might we" questions. Team members voted on the topic of their choice. This resulted in a single problem statement that resulted from team consensus for future implementation.

Step 4: Ideation. How can a team have a million ideas?

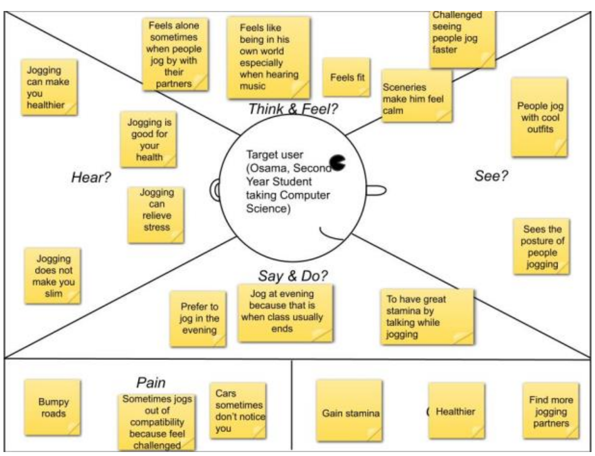
Students completed the ideation sprint exercise from Mural® (www.mural.co). Team members participated in several rounds of ideation. They were told that the goal of the activity was to generate as many ideas as possible or go for quantity during 4 rounds of ideation. Students were instructed to build on the ideas of others, stay on topic, defer judgment and welcome wild ideas.

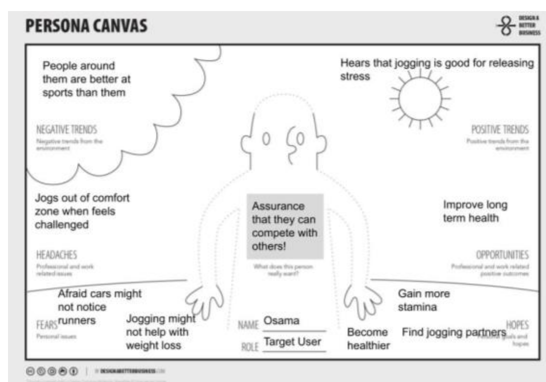
Step 5: Prototyping. How innovative can one get?

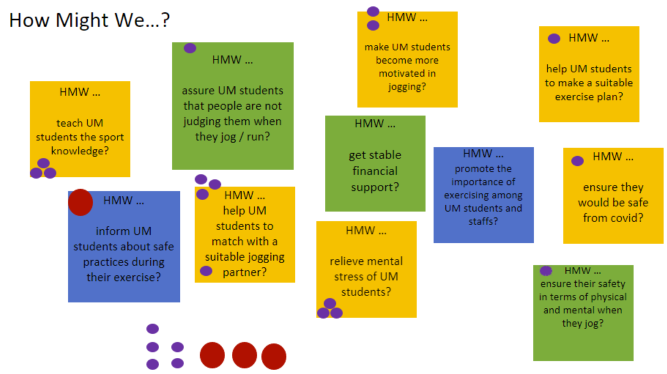
The facilitator shared several types of prototypes. Each team was asked to identify the most suitable prototype medium for implementation, depending on the type of solution the team developed, such as services or products. Some examples of potential media for prototyping include sketches and diagrams, paper interfaces, storyboards, Lego® constructions, role-playing and physical models. Each of these media is more suitable for a different type of prototype implementation. Students were provided with recommendations on selecting an appropriate medium for prototyping based on the kind of solution they decided to develop.

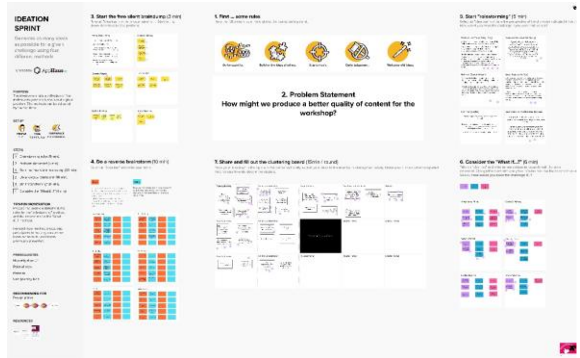
- **For services**, the facilitator recommended potential types of prototypes, such as role-playing, video, storyline, and flyer.
- **For products** such as cardboard models, Playdoh®, and more,
- **For digital services and products**, paper sketchers, apps and mockups.

Following are some screenshots of an example project in which the team used storyboards and sketches for prototyping.









Audience Outreach

Our project's advertisements will happen virtually on Instagram through our dedicated page. The page itself, along with the project will be shared through other social media platforms to maximize exposure. Posts made on the dedicated social media will also be posted on our collaborator, UMSU's instagram page.

The links to all social media platforms can be found on linktree that will be on our instagram bio.

Registration

Students will register through a google form that will be spread on all social media platforms. Through our advertisements, students will be able to directly navigate to our registration forms. Here they will have to provide us their personal information and a few other details important to their participation towards the program.

Introduction to Padlet

The benefits of using Padlet is all the participants will use Padlet to introduce themselves in order for them to get a jogging partner. They can potentially find a suitable jogging partner based on their preference time and distance. Besides that, our participants will be given the links to the program's official Padlet where they will receive the opportunity to mingle around with other participants and potentially find a new jogging partner.

Step 1: Get the link to access the Padlet

Step 2: Take a photo

Step 3: Post the information and photo in the Padlet to find the jogging partner.

Introduction to running app

We will announce the official running app that will be used for all the participants and add them into a community. The participants can get the link of running app in the linktree through our Instagram page.

Main purpose of the app:

- Create a jogging community in the app itself
- Involves participants in the leaderboard
- Keep track of jogging distance of the participants
- Introducing beginner a new way to start jogging during the pandemic

Figure 34. Empathy map, user persona, problem statement definition, ideation and prototyping of a vertical farming solution in the Thinking and Communication course, fall 2021.

5.9 Course GWF0017: Social Informatics

5.9.1 Description of the course

Social Informatics is a student empowerment program offered by the Faculty of Computer Science and Information Technology of the University of Malaya. The course is designed for all students in the university. The Computer Science faculty design the course structure. The course introduces social research perspectives on the use of ICT and its impact on contemporary social relations, exploring ways in which ICT has reshaped thinking and practice within society and communities. It also explores the various tools and techniques used in social networks. The course is conducted virtually. It deploys a 100% continuous assessment to evaluate students' understanding and knowledge. Upon completing the course, students can apply selected approaches to understand various dimensions and implications of social informatics and ICT.

5.9.2 Description of the participants

Students who attended this course were enrolled in multiple majors in a University Malaya undergraduate program. A total of 30 students were registered in the course in the 2021 – 2022 academic year. All students were Malaysian and were enrolled in programs by the Faculty of Business and Economics, the Faculty of Art, and the Faculty of Science. Most students were in the 2nd semester of their studies and had some informal technology background and understanding.

5.9.3 Description of gamified design thinking activities

Design thinking methodology was used to help students in their continuous assessment. The course methodology was problem-based learning. The medium of communication was English. MSTeams® was used to host the online discussion. The ICT-INOV digital learning platform was used to monitor student progress in pre-defined activities within designated weeks systematically. In addition, a MOOC platform provided by the University of Malaya was also used to disseminate notes and capture poster submissions for student projects.

Design thinking was deployed in the course semester project, which focused on social well-being in the new world of the Metaverse®. The project's objective was to encourage students to investigate innovative skill sets among students in innovating solutions for a given case in the new technology environment. More specifically, students were required to innovate a secure solution to protect data and identity. Students were asked to conduct a literature analysis as part of the empathy activity, followed by ideation. They worked in groups of 4 individuals. A total of 7 groups were created. Students were asked to develop a prototype using different techniques, mainly storyboarding. Students were encouraged to explore any technology-related design tools, such as video, editing, and analytic concepts to implement design thinking stages.

The activity was divided into the following steps.

Step 1. Registration and team building.

Students were asked to register for the course in the ICT-INOV digital learning platform and join their group's working space. They developed a team name and logo and presented them to the class. They conducted a short brainstorming session during the class to identify advantages and disadvantages, problems, issues, and challenges in the Metaverse®.

Step 2. Problem definition.

Students were asked to identify the problem they would like to focus on. This would become the basis of their proposed solution. They were challenged to describe their innovative solution's objectives, identify the technology needed for implementation, and define the target users.

Step 3. Solution design.

Students were asked to introduce innovative solutions to the problem in focus.

Step 4. Presentation.

Students presented a 3-minute video and a 1-page infographic poster describing their solutions.

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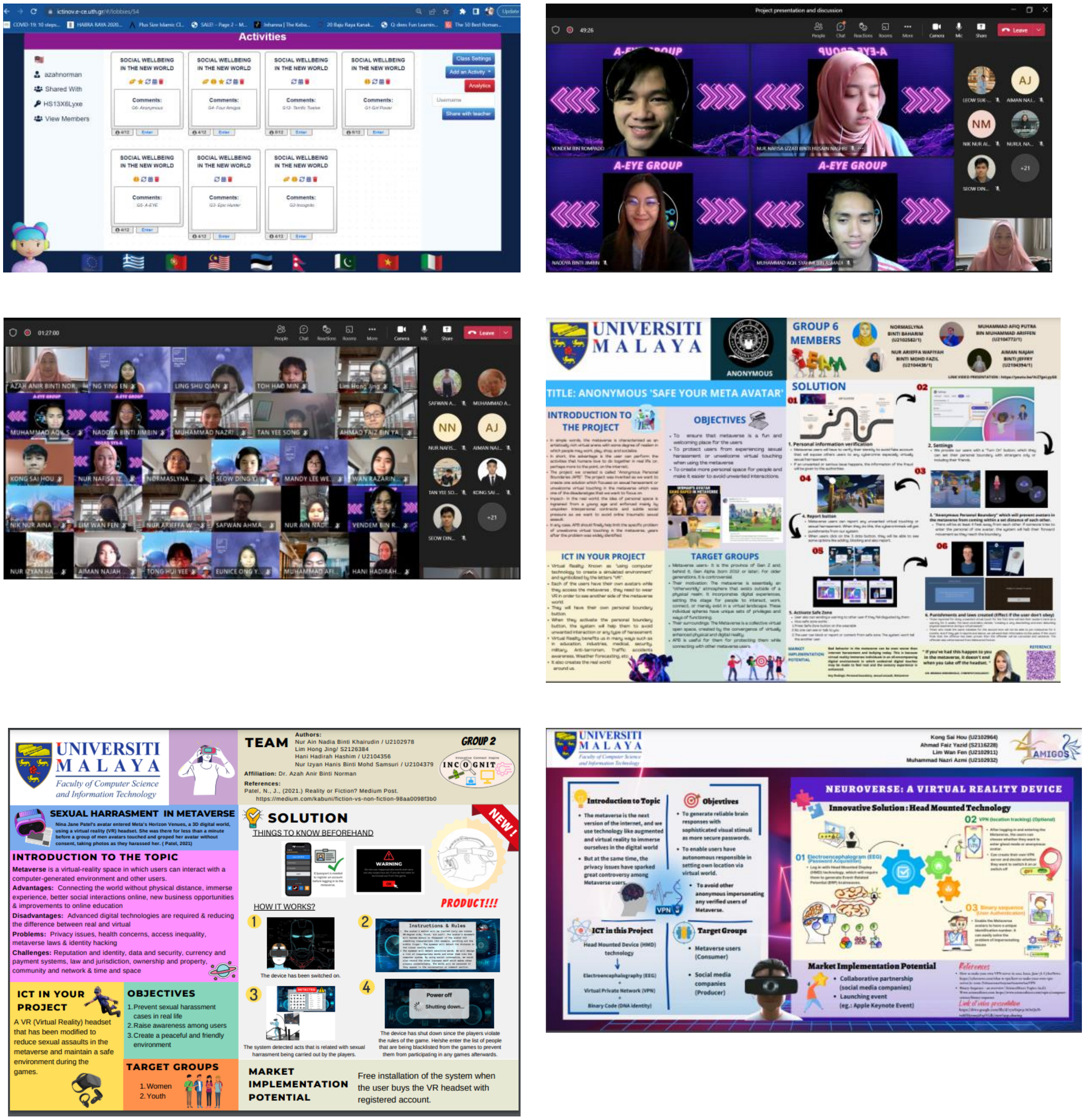


Figure 35. Students work on innovative solutions in the Social Informatics course, spring 2021.

5.10 Course WOA7001: Advanced Algorithms

5.10.1 Description of the course

The course introduces students to the analysis and design of computer algorithms. Students will learn advanced design techniques, important classical algorithms and data structures, and their implementation in modern programming environments.

5.10.2 Description of the participants

Participants are full-time students in the Master of Computer Science program with a focus on applied computing at the University of Malaya. 31 students attended the course in semester 1 of the academic year 2022 - 2023.

5.10.3 Description of Gamified Design Activities

The overall objective of project-based class activities was to:

- Implement the algorithms and data structures to solve real-world problems.
- Develop ICT solutions with algorithms and data structures.

The course included a class project that aimed to:

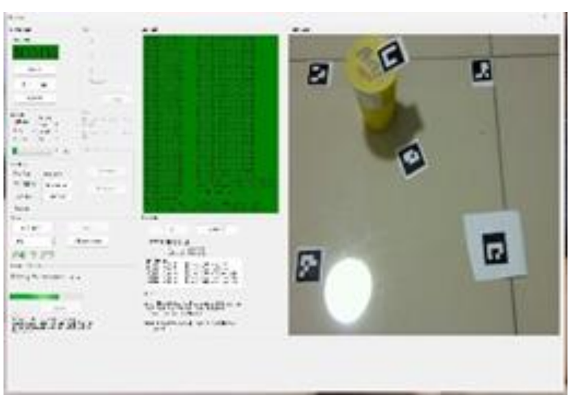
- Optimize the process of ploughing, planting, and harvesting paddy up to processing and packaging rice using a suitable algorithm.
- Design a suitable robot structure for the above algorithm through IOT prototyping.
- Apply the design thinking process using the ICT-INOV platform.

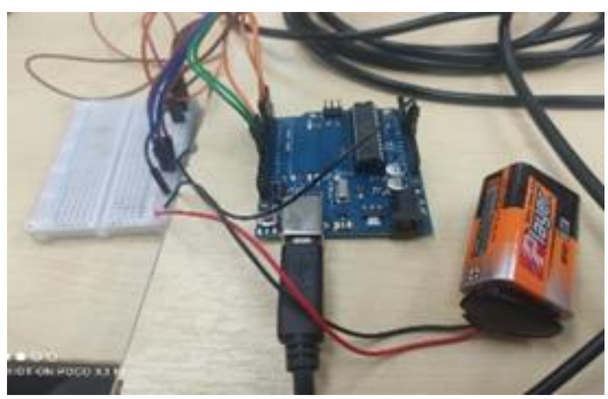
Students are asked to create a robot to optimize the following scenario: “The staple food for Malaysia is rice, which is the case for most Malay, Chinese, and Indian races. Currently, the process of ploughing, planting, and harvesting paddy up to processing and packaging rice uses certain types of machinery such as the Kubota and the auto rice mill – rice processing factory”.

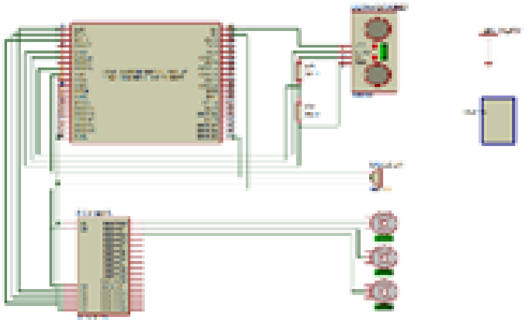
Each group was encouraged to select one of the following robot structures:

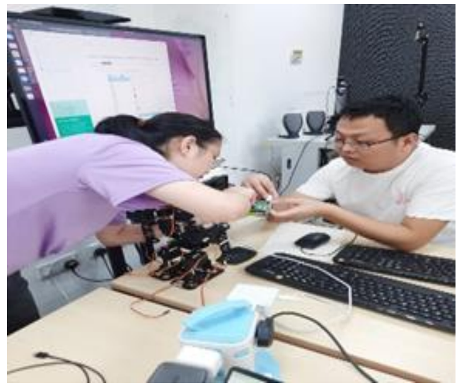
- A robot arm.
- A humanoid.
- A car.

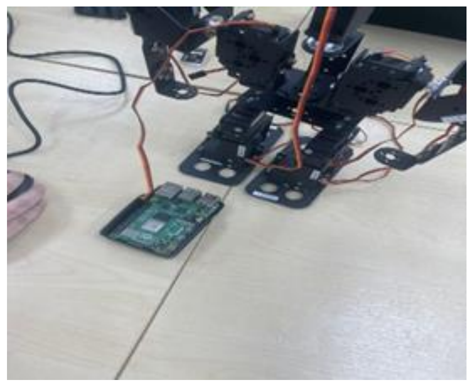
Each group was required to understand the ploughing, planting, and harvesting processes up to packaging and choose one process based on the robot structure to optimize the practice using a suitable algorithm using design thinking steps of empathy, definition, ideation, design, prototyping, and testing. An activity was designed in the ICT-INOV platform, divided into 10 stages to follow the 10-week semester schedule. Each week, each group was required to demonstrate progress by posting discussion points and solutions.











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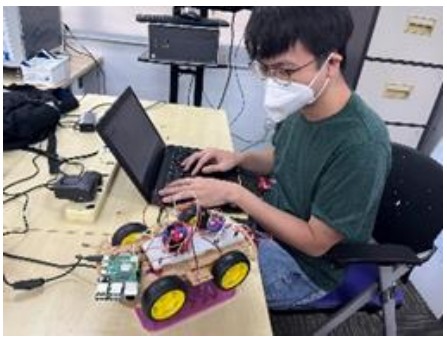
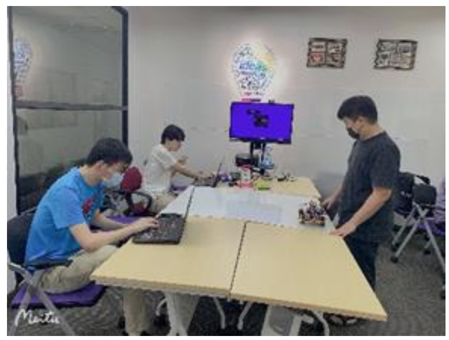
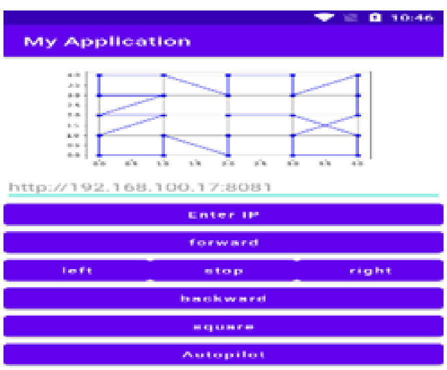
Debug hardware issues
WOA Members
WOC Members



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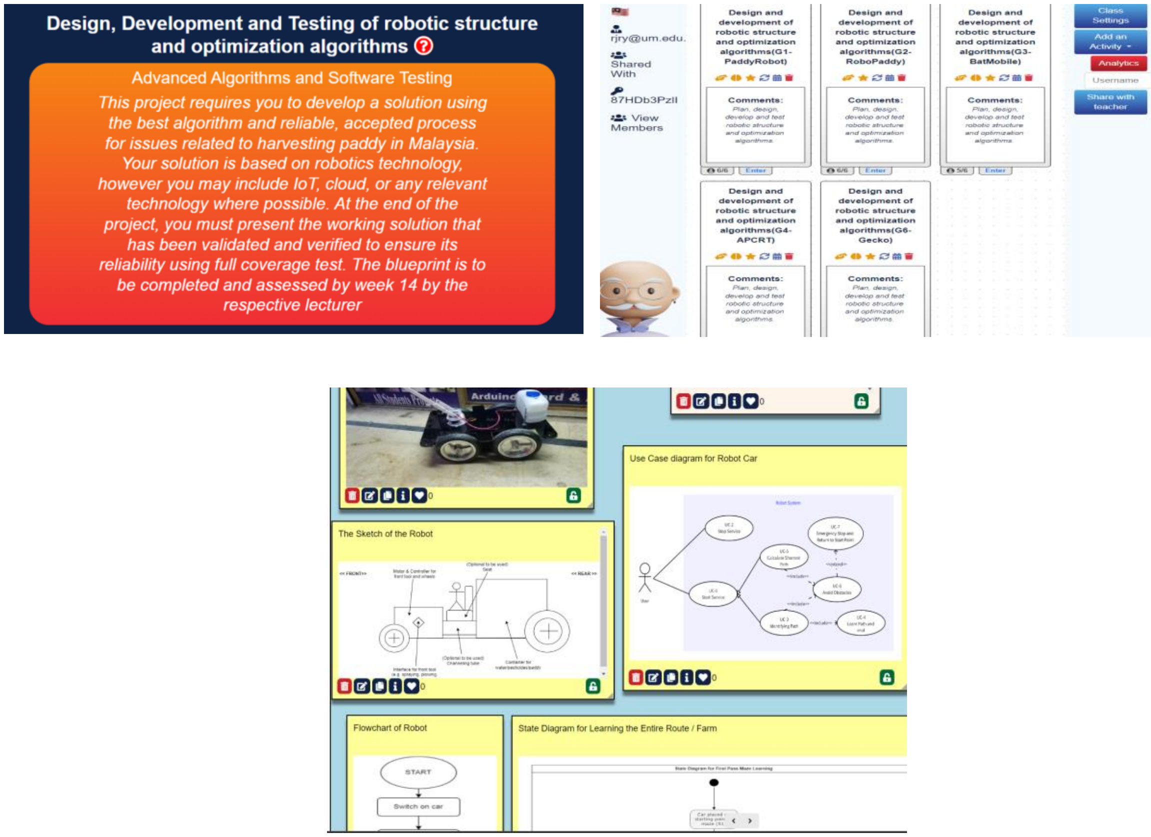


Figure 36. Students developing robots in the Advanced Algorithms course, fall 2022.

5.11 Course WOC7019L UX Design Studio

5.11.1 Description of the course

The course covers advanced topics related to human cognition, psychology, software engineering, formal methods principles, and models and techniques to represent user and interactive environments. Coursework is based on agile and lean user experience (UX) methodologies, taking into consideration universal accessibility for different ranges of users such as novice to expert, children to elderly, and individuals with disabilities. Project design and implementation in the context of coursework involves web UX, mobile UX, and other intelligent systems. Design and implementation concepts go beyond user interfaces to include sensors, controls, autonomous vehicles, ubiquitous computing in the context of IoT, social data analytics, and visualization. Interactive input may involve gestures, voice, eye movement, and facial expressions. Evaluation of the implemented human-interactive system uses techniques such as expert review, heuristics, usability testing, acceptance test, survey, active observation, or control environments. Factors that influence UX evaluation are related to ethical, societal, cultural, and usability goals.

5.11.2 Description of the participants

Participants are full-time students in the Master of Software Engineering program with a focus on Software Technology at the University of Malaya. A total of 9 students attended the course in semester 2 of the academic year 2022 - 2023.

5.11.3 Description of gamified design thinking activities

Project-based activities were deployed throughout the course. Two projects were implemented: project 1 and project 2.

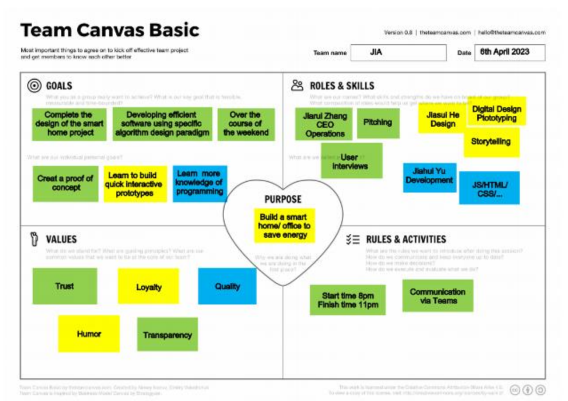
The objective of project 1 was to:

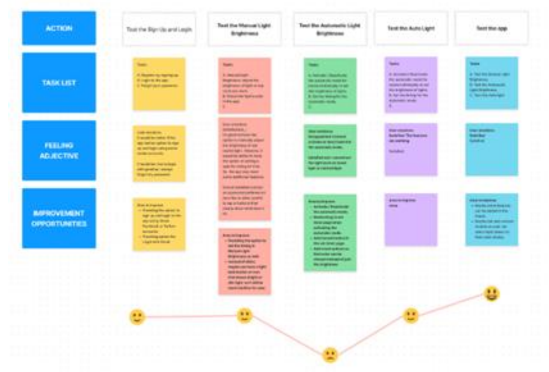
- Design and develop a smart home system to save energy with an emphasis of universal accessibility.
- Use the UX design cycle and design thinking elements through the agile scrum methodology.

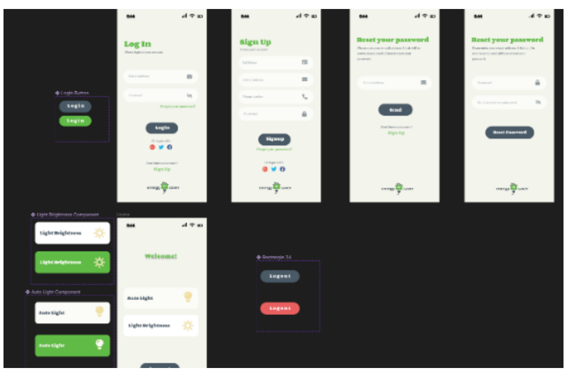
Students worked in teams of 2 individuals, following the weekly timeline described below:

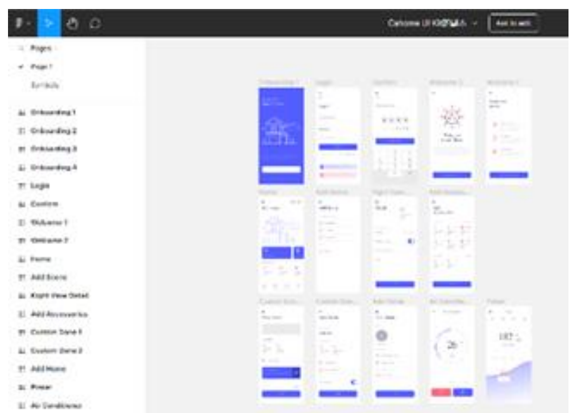
- Presented results of the discovery step.
- Presented results of the ideation step.
- Presented results of the prototyping step.
- Designed and developed a smart home system.
- Documented work on the ICT-INOV digital learning platform.

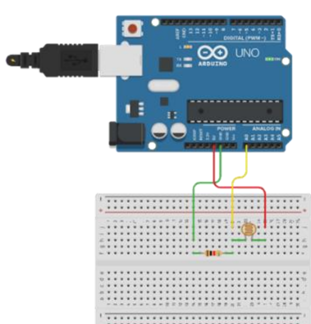
- Created a shared GitHub® account for the project that contains all the information.
- Submitted the project implementation report.

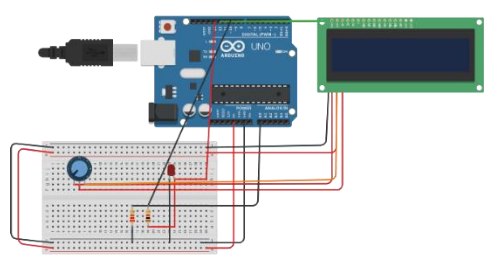












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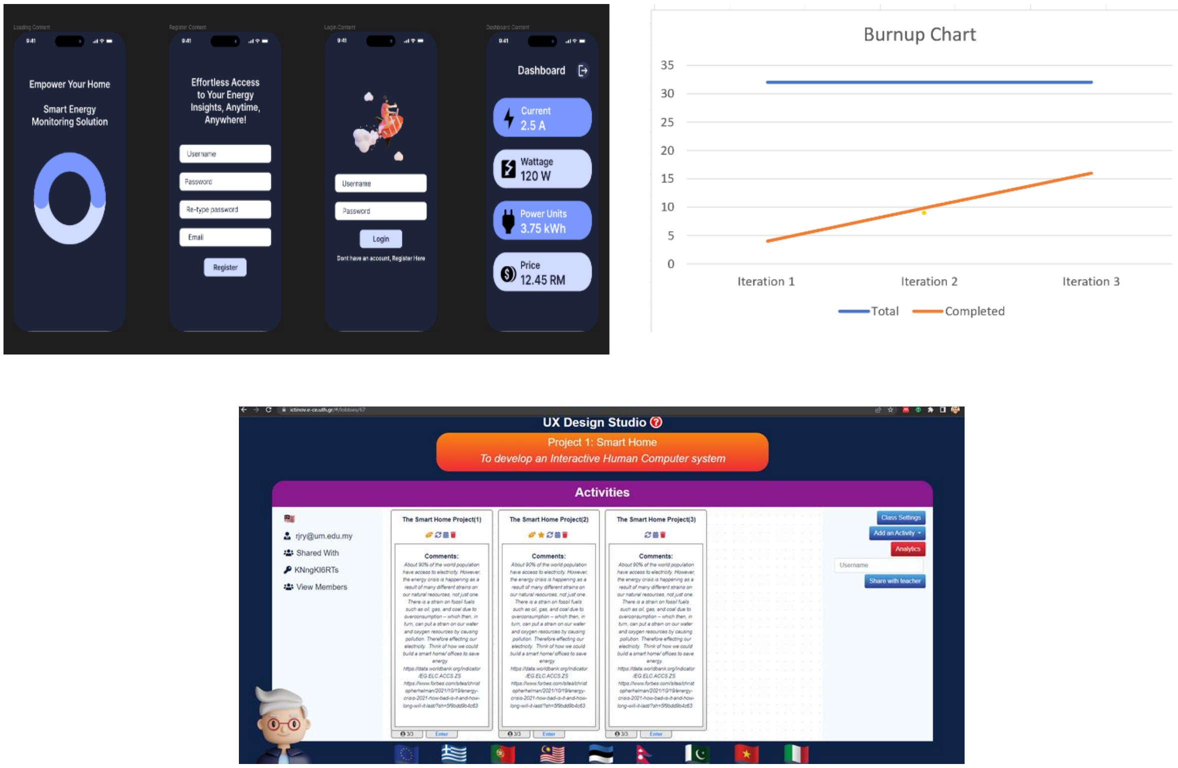


Figure 37: Student work in project 1 of the UX Design Studio course, spring 2023.

The objective of Project 2 was to:

- Identify the problems of people with anxiety and how robotic companionship may be a solution to the mental health issue.
- Design and create a simple DIY Robot that can provide companionship to individuals with anxiety.

The entire class body worked as one team to:

- Create a functional DIY robot that can provide companionship to individuals with anxiety. The robot should be able to take simple voice and image input, use machine learning and image recognition algorithms, and make simple movements based on certain conditions.

The robot should be able to learn from the user's interactions and adapt its responses over time.

- Use the ICT-INOV platform to record the progress of the project.
- Create a shared GitHub® account for the project that contains all the information.
- Write a project implementation report.

Students were asked to execute the project using agile scrum UX methodology, in which the design thinking steps of empathy, definition, ideation, design, prototyping, and testing were integrated. Specifically:

Step 1. Empathy and definition.

Students performed software requirements elicitation and analysis.

Step 2. Ideation.

Students sketched and structured the idea of how to design a mobile application.

Step 3. Design.

Students performed the conceptual design and wireframing of the user interface.

Step 4. Data processing and cleaning.

Students ensured that data was formatted and cleaned in a suitable way for visualization.

Step 5. Visualization.

Students analyzed and selected the most appropriate visualization techniques for each of the different goals of data visualization.

Step 6. User interface design.

Based on previous results, students designed an intuitive interface allowing users to easily upload and visualize their data.

Step 7. Prototyping.

Students coded and programmed a mobile application using a suitable programming language and platform.

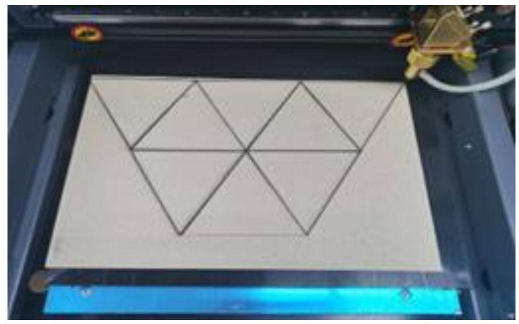
Step 8. Testing and refinement.

Students tested the application to identify bugs and issues. They refined the application to improve performance and user experience.

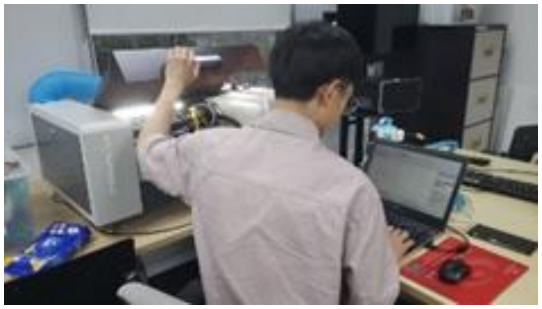
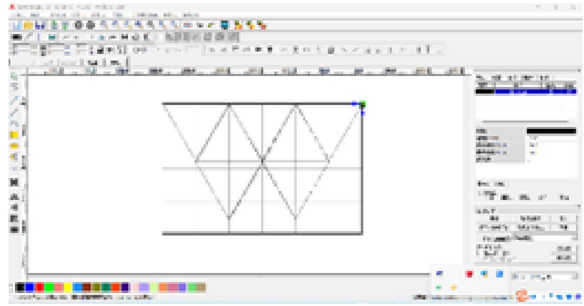
Students followed the weekly timeline presented below:

- Presented the project description and planning. Worked on empathy and definition steps. Created a group collaboration contract among team members.
- Presented the planning, empathy, and definition step results. Worked on ideation and design steps.
- Presented the ideation and design step results. Worked on prototyping (3 weeks).
- Presented prototyping step results. Tested the prototype.
- Delivered final presentation.
- Submitted project implementation report.







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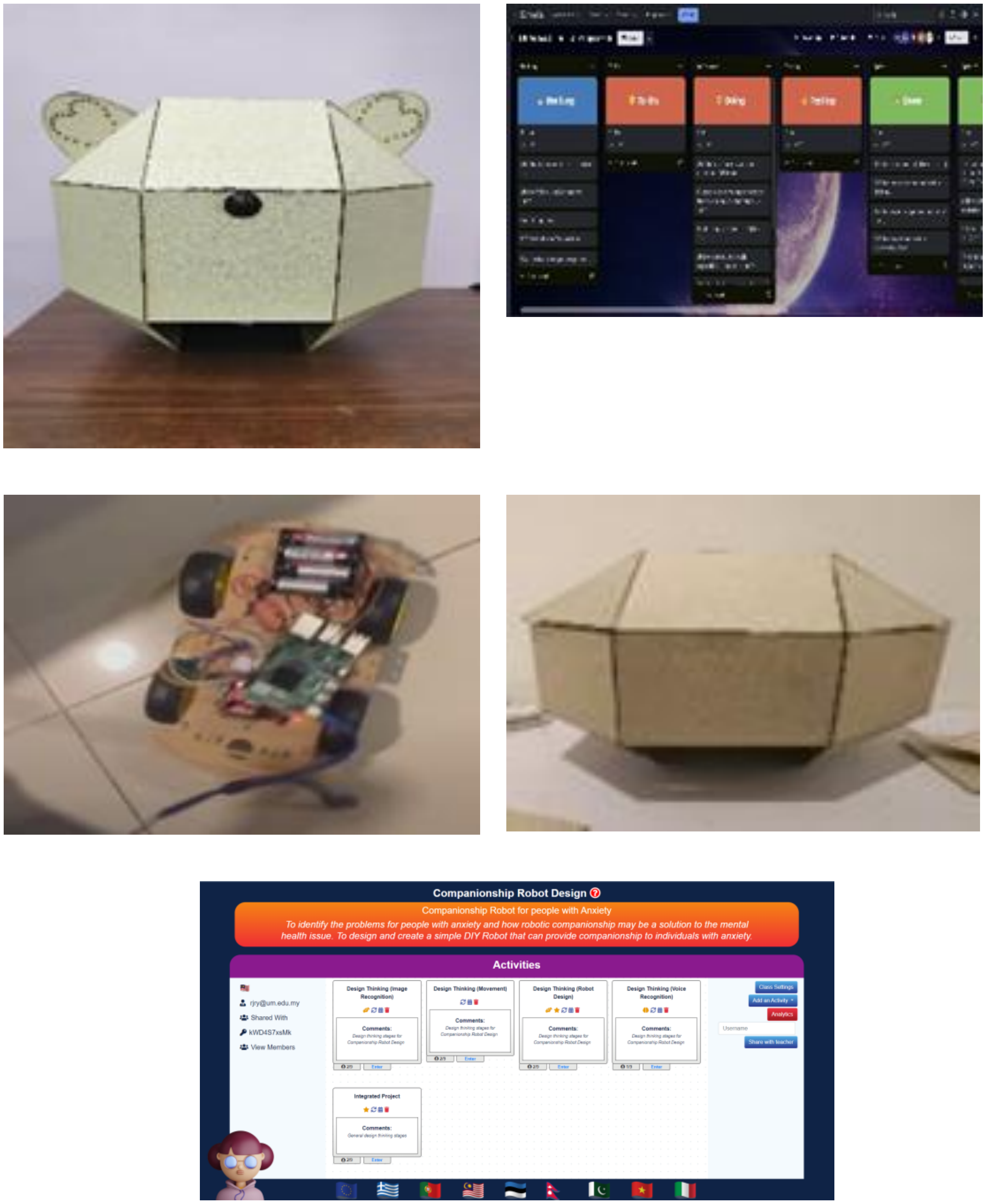


Figure 38. Student work in project 2 of the UX Design Studio course, spring 2023.

5.12 Course WOC7015: Software Verification and Validation

5.12.1 Description of the course

The course introduces the concepts, principles, techniques, and tools of software verification and validation within modern software development and its formal techniques. The course covers test design and plans in test-driven agile development to conduct tests using tools. The course also exposes students to the formal approach of static analysis and model checking to verify uncertainty in software design models and requirements.

5.12.2 Description of the participants

Participants are full-time graduate students at the University of Malaya. A total of 20 students attended the course in semester 1 of the academic year 2022 - 2023.

5.12.3 Description of gamified design thinking activities

Design thinking activities were deployed to strategize which appropriate testing techniques to use on the open-source code as part of a group project. The objective of the project-based class activity was to design a testing plan through appropriate evaluation of selected techniques based on requirements and specifications, design artefacts, or the source code.

Students worked in teams of 5 individuals. Activities were organized as follows:

Step 1. Organization.

Students organized the necessary activities to complete the blueprint of the testing plan documentation.

Step 2. Team building.

Students worked in groups, assigning a specific role and responsibilities to each team member, distributing and coordinating tasks appropriately to operate as a high-performing team. They developed and signed a group collaboration contract. Students recorded meetings using a meeting log.

Step 3. Proposing a test plan.

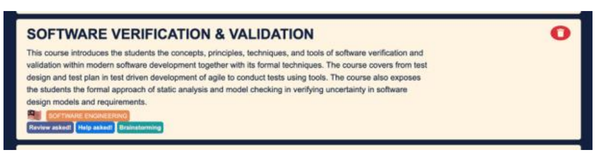
Students proposed a test plan to ensure the solution on paddy harvesting (see above course Advanced Algorithms) executes well. They recorded all activity or actions taken on the ICT-INOV platform. Teams formulated a test plan and test case specifications, paying particular attention to non-functional requirements.

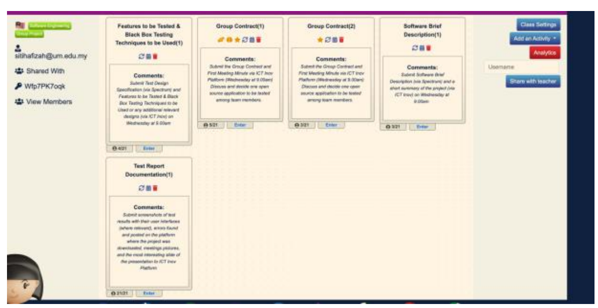
Step 4. Testing.

Students conducted the tests outlined in the test plan and recorded the results in a test log. They were challenged to predict the defect the software may produce and report the findings on a defect prediction report. They developed user acceptance testing using established questionnaire models and conducted the test. They developed a test report, including recommendations for the software development team in a test summary and completion section.

Step 5. Final presentation.

Students presented their test management plan blueprint and project work experiences to the class, outlining how they worked as a team, key decisions made, and test planning and reporting.





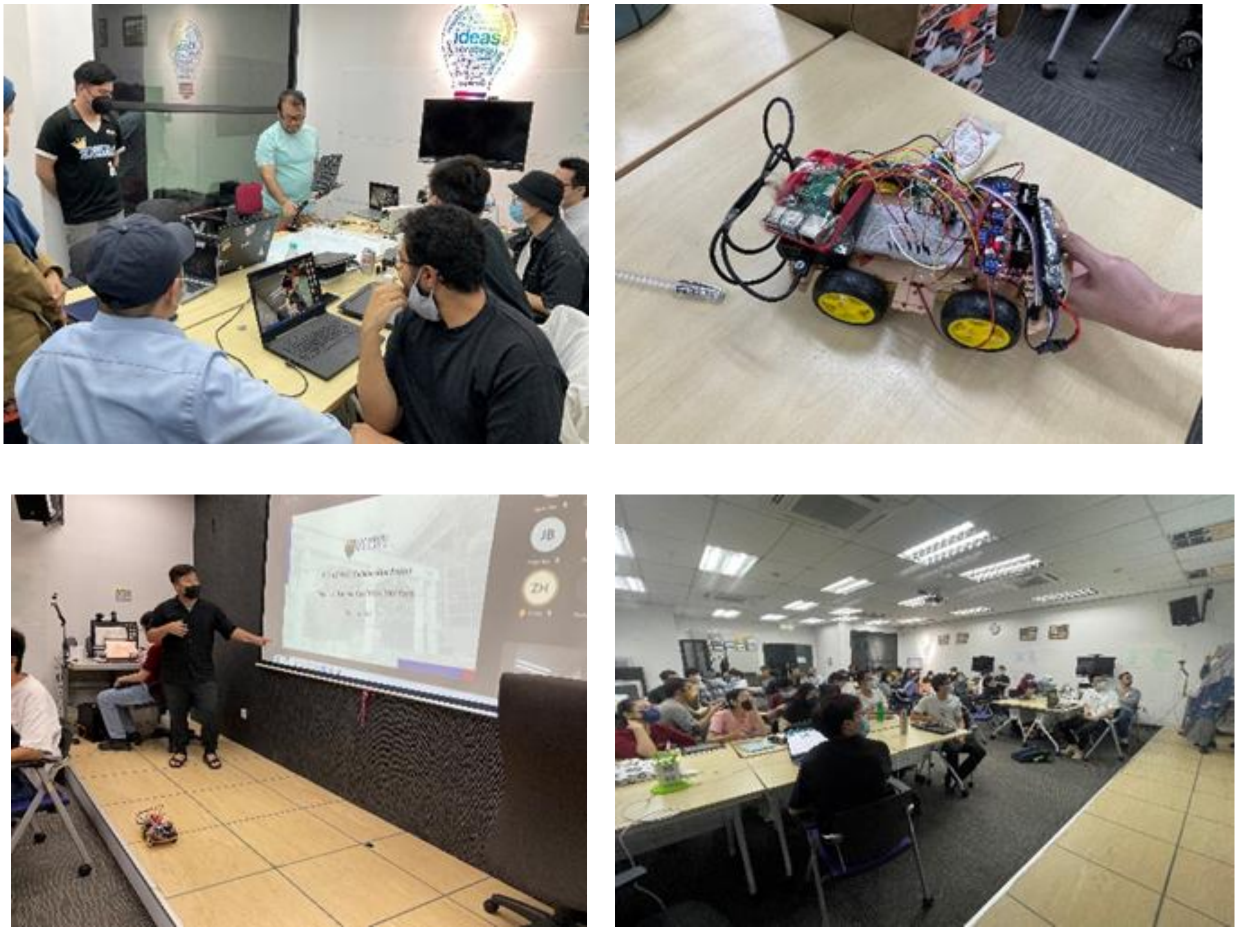


Figure 39. Students work in teams in the Software Verification and Visualization course, fall 2022.

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5.13 Course WOC7014: Framework-Based Software Design and Development

5.13.1 Description of the course

The course teaches students the fundamental principles of framework-based software design and development. Students gain knowledge and skills in designing framework-based software systems, mainly focusing on website applications using the Django® framework and Python® programming language. Moreover, students learn to develop innovative software projects using various programming languages, including Python®. The curriculum also emphasizes developing communication, critical thinking, problem-solving, and decision-making skills. By the end of the course, students are well-prepared to excel in software design and development and contribute effectively in professional settings.

5.13.2 Description of the participants

This is a graduate-level course. Participants are enrolled in the Master's of Software Engineering program. 46 students attended the courses in semester 2 of the academic year 2022 - 2023. The course was conducted using a blended approach, consisting of 70% online sessions and 30% in-person interactions.

5.13.3 Description of gamified design thinking activities

As part of the course assignment, students collaborated in groups to build a website application using an appropriate framework. They selected a topic, planned modules and functions, and documented their decisions while designing a brief user interface. At the end of the semester, they presented the completed application through a report, source codes, and slides. This assignment fostered teamwork, framework-based application development, communication, effective project progress and outcomes, and integrated design thinking practices.

Students worked in teams of 4 – 5 individuals. A total of 10 teams were formed.

Project work was organized around design thinking steps. Students applied design thinking principles within their teams. Specifically, work was organized in the following steps.

Step 1. Brainstorming and problem discovery.

Students participated in a discussion among their group members. They identified a list of potential topics and selected a domain to work on. Subsequently, they designed and delivered an interview to understand the challenges faced by the target users of their project.

Step 2. Empathy.

Upon understanding the users' challenges, experiences and motivation resulting from the interviews, students completed an empathy map describing a characteristic user.

Step 3. Definition.

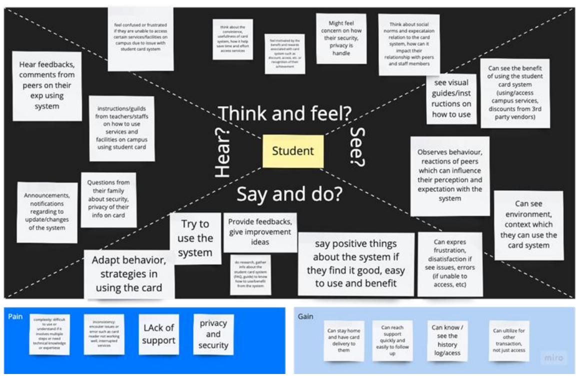
Students were encouraged to produce meaningful problem statements. As a result of their previous activities, students synthesized their observations about their users from the Empathize stage. They performed the following activities:

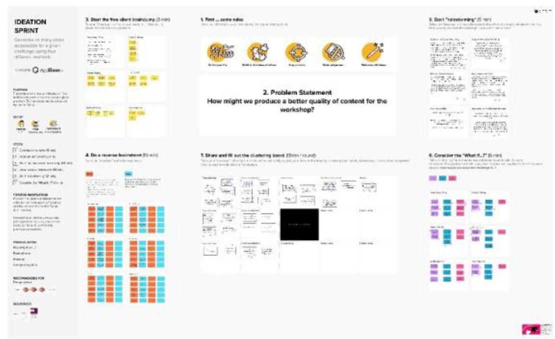
- Created a wall of ideas from the empathy map.
- Grouped the ideas into themes using an affinity diagram, a visual representation of the relationships between complex and large ideas.
- Created a point of view statement according to the aggregated empathy map, reframing the design challenge into an actionable problem statement.
- Produced a list of "how might we" questions. Team members voted on the most relevant question, which became the problem statement for the next phase of design thinking.

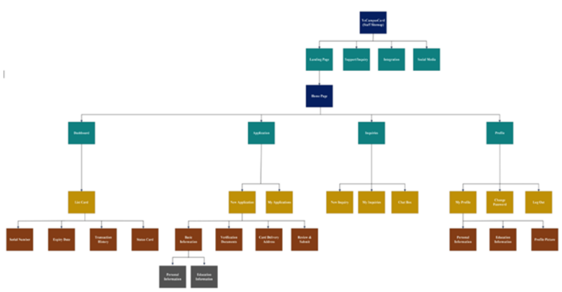
Step 4: Ideation and prototyping.

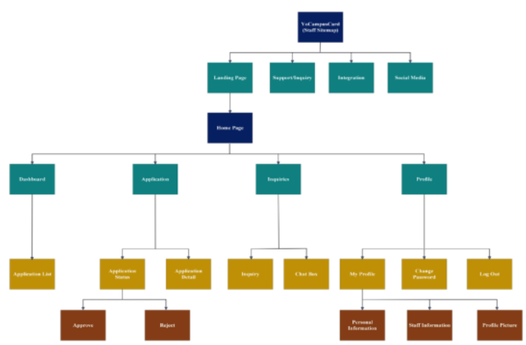
Students performed ideation activities and shared their ideas through Figma®, a tool that helped present sketches of user interfaces. The facilitator shared several prototypes, and each team was asked to identify the most suitable prototypes for implementation, depending on the type of solution the team developed namely service or product. Some of the recommendations given for prototype selection were:

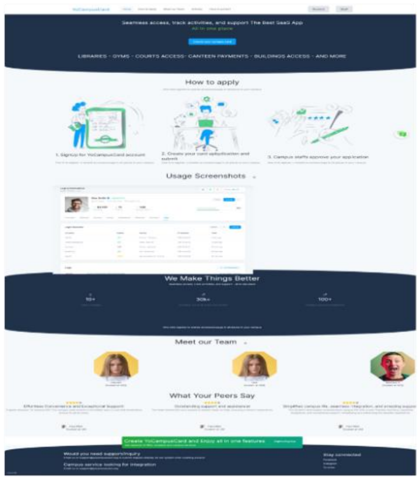
- For services, use role-playing, videos, storylines, or flyers.
- For products, to use cardboard models, playdoh, or other material.
- For digital services or products, to use paper sketches, applications, or mockups. Other tools included storyboards, website sitemaps, navigation charts, module breakdown sketches, system architecture, use-case diagrams, database design, and more.

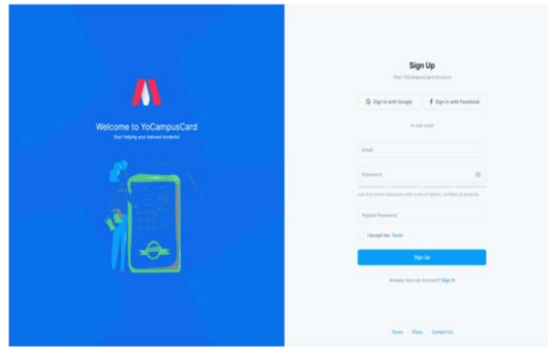


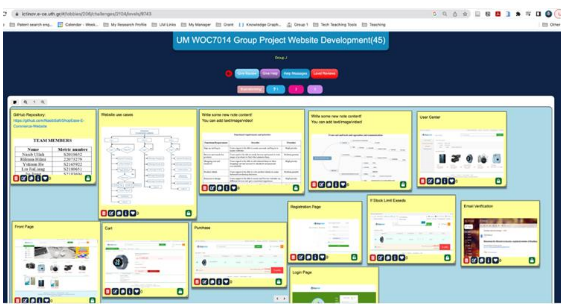


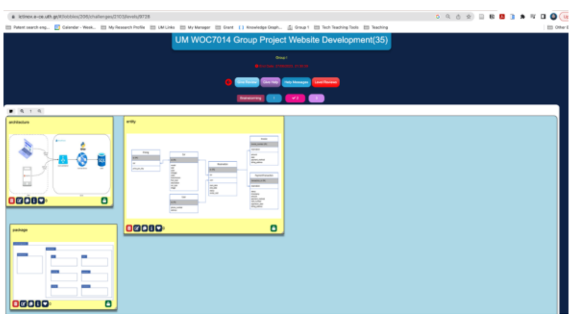












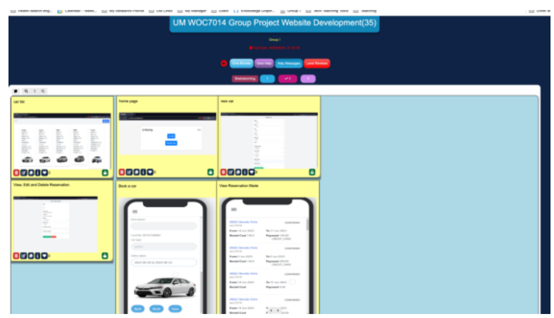


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Figure 40: Student designs, prototypes, and collaboration in the Software Verification and Validation course, spring 2023.

5.14 Course WOC7020: Advanced Internet of Things (IoT)

5.14.1 Description of the course

The course provides students with an in-depth understanding of the cutting-edge technologies, applications, and challenges in the rapidly evolving field of IoT. Building upon foundational IoT concepts, the course delves into advanced topics that enable students to develop innovative and scalable IoT solutions.

5.14.2 Description of the participants

This is a graduate-level course. Participants are enrolled in the Master of Computer Science or Master of Software Engineering programs. A total of 24 students attended the courses in semester 1 of the academic year 2022 - 2023. The course was conducted using a blended approach, consisting of 70% online sessions and 30% in-person interactions.

5.14.3 Description of gamified design thinking activities

Design Thinking methodologies and tools were applied to foster creativity and innovation. The objective was to improve problem-solving skills and enable students to develop innovative IoT solutions that addressed real-world challenges effectively. The course integrated a series of key design thinking steps and corresponding tools, empowering students to think from a user-centric perspective and approach IoT development iteratively. Students worked in groups of 4 individuals.

The students performed the following activities.

Step 1. Team building and project setup.

Students identified clear roles and responsibilities for each team member to ensure high performance.

Step 2. Selecting an IoT project.

Each group selected one specific field for IoT implementation, such as smart home, smart agriculture, or smart health.

Step 3. Literature review.

Teams conducted a systematic literature review of scholarly articles on IoT challenges in the chosen field, delivered in 2018 - 2023. They further developed a systematic literature review paper to analyze and summarize findings.

Step 4. Empathy.

Students engaged in empathy-building activities by conducting interviews, observations, and surveys with end-users and stakeholders. Using tools, such as empathy mapping, user persona creation, and journey mapping, they gained valuable insights into user needs and pain points.

Step 5. Define.

Students formulated well-defined problem statements and design challenges based on the gathered insights. Brainstorming sessions and affinity diagramming helped them refine the problem scope and identify specific areas where IoT technology could significantly impact.

Step 6. Ideation.

Students used ideation techniques, including brainstorming, mind mapping, and SCAMPER, to generate creative ideas and potential solutions for IoT challenges.

Step 7. Prototyping.

Students assembled the hardware required for implementing their IoT solution, such as LoraWAN®, Arduino®, or Rasberry Pi®. They further used sensors and actuators compatible with microcontrollers. They creatively used a 3D pen and laser cutter to design and prototype components for the IoT solution. They established wireless connectivity through LoraWAN® for seamless communication.

Step 8. Testing.

Students conducted usability tests and gathered feedback from potential users to evaluate the effectiveness of their prototypes. Observing user interactions enabled them to identify areas for improvement and refine their IoT designs accordingly.

Step 9. Development of final report.

Students wrote a comprehensive research paper on the IoT adoption journey and challenges in the specific field. They incorporated the findings from the systematic literature review to support the research.

Step 10. Oral presentation.

Students presented the completed IoT solution and project experiences in a 30-minute oral presentation. They highlighted teamwork, challenges faced, decision-making processes, and innovative aspects of the designs and implementations. They effectively communicated the comprehensive IoT adoption journey and showcased the application of design thinking methodologies in solving real-world IoT challenges in the chosen field.

Other design thinking principles used in project implementation include:

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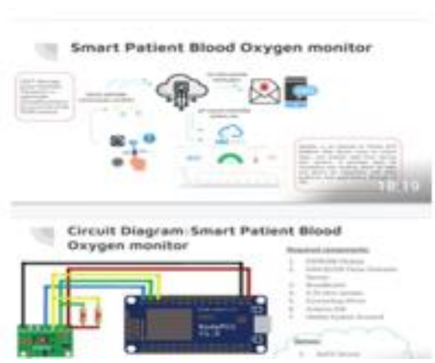
- **Iteration**. Based on user feedback and testing results, students iterated and refined their prototypes, continually improving their IoT solutions. This iterative approach allowed them to respond to evolving user needs and optimize their designs.
- **Collaboration and co-creation**. Students engaged in collaborative team projects throughout the course, fostering co-creation and group problem-solving. This collaboration encouraged diverse perspectives and enhanced students' ability to work effectively in interdisciplinary IoT teams.

By incorporating design thinking methodologies and tools in the Advanced IoT Course, students were empowered to approach IoT challenges with a human-centric mindset, create user-focused solutions, and develop the ability to tackle complex problems creatively. This multidimensional approach enhanced their technical skills and prepared them to become versatile and empathetic IoT innovators in the professional world.



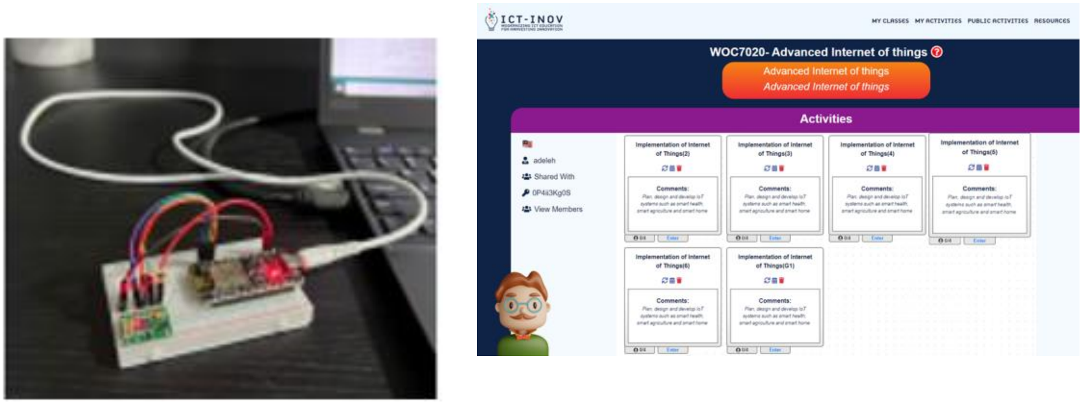


Figure 41. Student work on the Internet of Things course, fall 2022.

5.15 Course WIF3002: Software Process and Quality

5.15.1 Description of the course

This course covers software quality, software process, and software process improvement. It introduces software quality assurance and the importance of process quality. Various existing software development methodologies are also studied. The later part discusses software process improvement. Various models that support software process improvement are presented, including the CMMI, ISO 9000, SPICE, PSP and TSP.

5.15.2 Description of the participants

Participants are enrolled in the Bachelor of Computer Science Software Engineering program. A total of 66 students attended the courses in semester 2 of the academic year 2022 - 2023.

5.15.3 Description of gamified design thinking activities

The course includes a semester-long project in which students are challenged to develop a high-quality mobile or web application that uses data visualization techniques to give users powerful

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insights into their data. Students are asked to design the application with emphasis on usability, portability, maintainability, and reliability. They incorporate software improvement processes and software assurance plans to ensure the highest possible level of software quality. Students use design thinking to synthesize innovative solutions for software quality.

The application should be designed to:

- Support a range of different visualization goals, including comparison, trend identification, correlation, distribution, ranking, proportion, composition, exploration, explanation, prediction, anomaly detection, clustering, dimensionality reduction, decision-making, communication, feedback, forecasting, identification of patterns and outliers, evaluation, and user engagement.
- Incorporate a variety of visualization techniques, including bar charts, line charts, scatter plots, pie charts, histograms, box plots, tree maps, sunburst charts, infographics, heat maps, bubble charts, dendrograms, scorecards, KPI dashboards, and balanced scorecards.
- Offer an intuitive interface that allows users to easily upload their data, select the visualization techniques they want to use, and customize their visualizations to meet their needs. Incorporate interactive elements, such as zooming in and out of data, toggling between different visualization modes, and filtering data based on different criteria.
- Target various users, including business professionals, data analysts, researchers, and educators. It should be available on iOS and Android and designed to run smoothly on smartphones and tablets.

Work was organized in the following steps:

Step 1. Empathy and definition.

Students elicited and analyzed software requirements.

Step 2. Ideation.

Students sketched and structured their ideas on how to design the application.

Step 3. Application design.

Students introduced the conceptual design and wireframing of the application user interface. This activity further involved data processing and cleaning to ensure that data was suitably formatted for visualization. In addition, this task involved the selection of appropriate data visualization techniques. Finally, students designed an intuitive interface allowing users to upload and visualize their data easily.

Step 4. Prototyping.

Students coded and programmed the application using a suitable programming language and platform.

Step 5. Testing and refinement.

Students tested the application to identify bugs and issues and refine it to improve performance and user experience.

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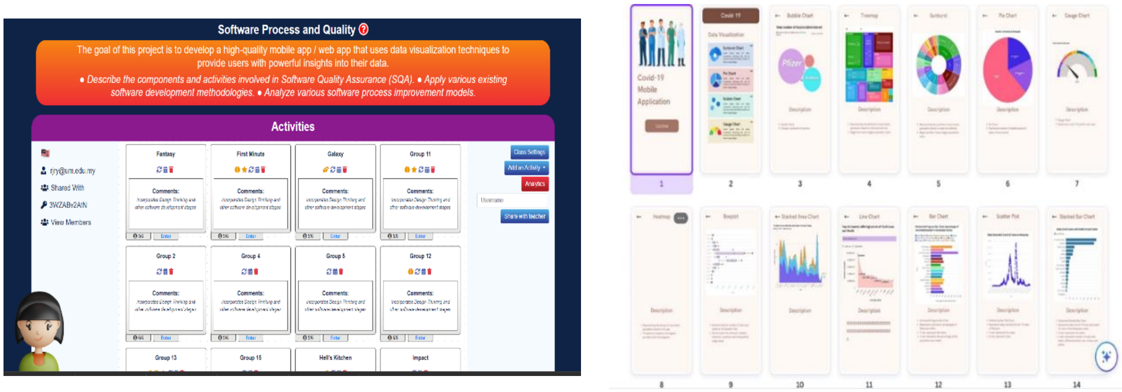

Figure 42. Students work on the Software Process and Quality course, spring 2023.

5.16 Course WIF3001: Software Testing

5.16.1 Description of the course

The course provides in-depth knowledge of software testing processes. It covers basic principles of software testing and test activities that include the test plan, design, monitoring, implementation, and closure. Students become familiar with test design techniques and methods used in both black-box and white-box testing of static and dynamic approaches. Upon completion of the course, students can recognize various types and levels of testing and categorize and apply software testing processes and techniques.

5.16.2 Description of the participants

Participants are full-time undergraduate students at the University of Malaya. 99 students attended the courses in semester 2 of the academic year 2022 - 2023.

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5.16.3 Description of gamified design thinking activities

Design thinking was used to analyze appropriate testing techniques to be applied to open-source code as part of a group project, and the objectives are to design a complete test plan and conduct tests for an open-source application to achieve full test coverage.

The course organization deploys project-based learning approaches. Some of the activities include:

- Downloading and executing selected open-source software.
- Elaborating the functionality of the software by listing the software requirements.
- Analyzing the structural and dynamic behaviour of the software's program code.
- Formulating the software test design specification using black box approaches.
- Designing the tests based on the strategies formulated.
- Executing the test cases with test data based on the test case and procedure specifications.
- Applying ethical principles, standards, and professional computer ethics.
- Functioning effectively as a team member.
- Checking the coverage of each test conducted.
- Communicating effectively on complex computer science activities through reports and presentations.

Students worked in groups of 5 individuals. They worked in their groups to identify clear roles and responsibilities for team members. Subsequently, they organized their semester-long work to deliver the documentation blueprint successfully.

Teams selected a project on the following topics:

- Mental healthcare.
- Agriculture.

- Environmental care.
- Smart homes.

They were required to analyze at least 10 requirements, not including login and registration, and develop a project description. Each team member conducted a complete test for at least 2 requirements. Teams were required to ensure the software could be executed well on their computers or an online system. They studied the software's functionality by reading the manual, if available, or executing it several times to understand the software requirements.

In the following steps, teams formulated the test plan, test design specification, and test case specification using black box approaches. They carefully specified test data either using equivalence partitioning or boundary value analysis. The work revolved around use case testing and precisely:

- GUI testing.
- State transition testing.
- Decision table testing.
- Error guessing testing.

Students categorized the test plan, design specification, and test case specification by test level, specifically unit, integration, or system test. Then, they refined the test procedure specification. Teams executed the tests and recorded the results in the test log, test incident report, test summary report, and test completion report. Finally, teams presented their test results and project work experiences via an oral presentation of 30 minutes. Specifically, they presented how they worked as a team, key decisions made, and a summary of tests concluded.

Work was organized in the following steps, and the results of each were published on the ICT-INOV digital learning platform.

Step 1. Team building and project assignment.

Students formed teams and developed a team collaboration contract. They became familiar with the project objectives.

Step 2. Discovery and project theme selection.

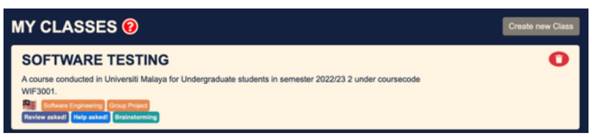
Students worked within their teams to decide on the application to be tested. They prepared a software brief description.

Step 3. Test process design.

Students design the test specifications based on black box testing techniques.

Step 4. Final project submission and presentation

Students submitted and presented a test report, which included the group contract, software brief description, test plan, test design specifications, test case specifications, test procedure specifications, test log, test incident report, test summary report, and test completion report.



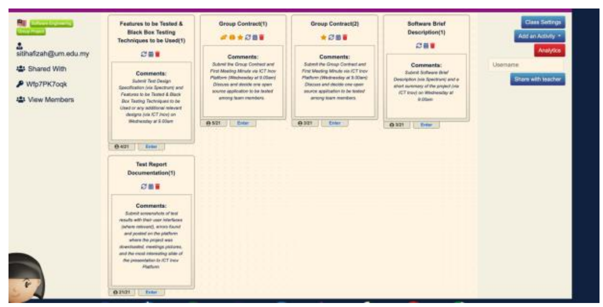


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Figure 43. Students work on the Software Testing course, spring 2023.

5.17 Course WIA2010: Human-Computer Interaction

5.17.1 Description of the course

The course addresses the human factors and technical methods of designing and evaluating interactive systems. Course topics include an overview of human-computer interaction, essential interaction design principles, user interface development process, and interface design and programming. More specifically, it focuses on humans, computers, and their interactions, user interfaces, usability, user experience (UX), and design thinking. The course further focuses on interface development processes, including topics on iterative design, user-centred design, design discovery, design exploration, and evaluation of user interfaces. Interface design and programming topics include visual information design, forms design, interface design patterns, prototyping and construction tools, and responsiveness issues. Three types of applications are covered: graphical user interfaces, web, and mobile devices.

5.17.2 Description of the participants

Participants are full-time undergraduate students at the University of Malaya. 106 students attended the courses in semester 1 of the academic year 2022 - 2023.

5.17.3 Description of gamified design thinking activities

The course included a semester-long project. The overall objective of the project-based class activity was to apply design principles, guidelines, patterns, and visual design elements to interface design and selected interface construction tools for the implementation of interactive systems. Design thinking principles integrated into the course project include ideation and prototyping.

More specifically, upon completion of the project, students were able to:

- Demonstrate ability to plan and execute the project using design thinking.
- Design an IoT project through prototyping.
- Apply design principles in mobile applications of interactive systems.

Students worked in groups of 6 – 7 individuals. A total of 12 teams were formed.

The theme of the project was “Designing a sustainable future”. Project work helped build problem-solving capacity by encouraging students to propose solutions to real-world issues facing Malaysia and the world, focusing on UN Sustainability Goals such as good health and well-being, quality education, and decent work and economic growth. Specifically, students were challenged to work on a project on running a business or NGO activity implemented in a village.

Work was organized in the following steps:

Step 1. Team building and project assignment.

Students developed a group collaboration contact. They took part in a personality and innovation test. They selected a project within the general umbrella of the UN Sustainability Goals.

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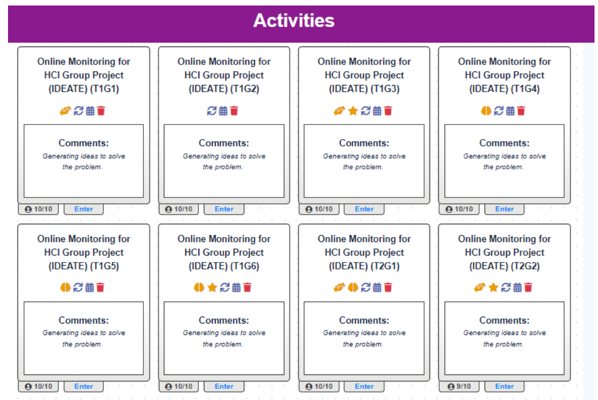
Step 2. Ideation.

Students brainstormed ideas towards synthesizing a solution.

Step 3. Prototyping.

Students developed a prototype solution using IoT technology.



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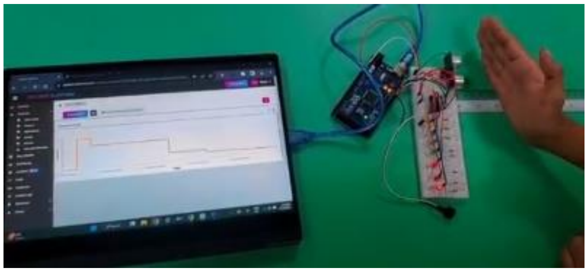


Connecting LoraWan


LoRaWan!!


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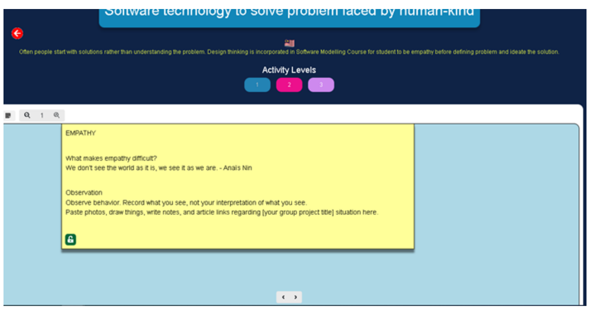
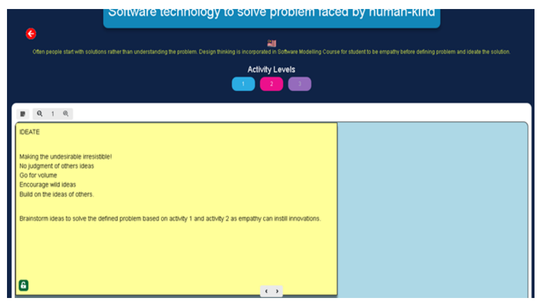

Often people start with solutions rather than understanding the problem. Design thinking is incorporated in Software Modelling Course for student to be empathy before defining problem and ideate the solution.
Activity Levels
EMPATHY
What makes empathy difficult?
We don't see the world as it is, we see it as we are. - Anaïs Nin
Observation
Observe behavior. Record what you see, not your interpretation of what you see.
Paste photos, draw things, write notes, and article links regarding [your group project title] situation here.


Often people start with solutions rather than understanding the problem. Design thinking is incorporated in Software Modelling Course for student to be empathy before defining problem and ideate the solution.
Activity Levels
IDEATE
Making the undesirable irresistible!
No judgment of others ideas
Go for volume
Encourage wild ideas
Build on the ideas of others.
Brainstorm ideas to solve the defined problem based on activity 1 and activity 2 as empathy can instill innovations.


Class Activity 1: Paste photos, draw things, write notes, article link regarding global food crisis situation here. - amirul
FOOD WASTE FROM RAMADAN BAZAARS
52,900kg
47,610kg
5,290kg
1.2kg
47,610kg
39,675
Global hunger crisis

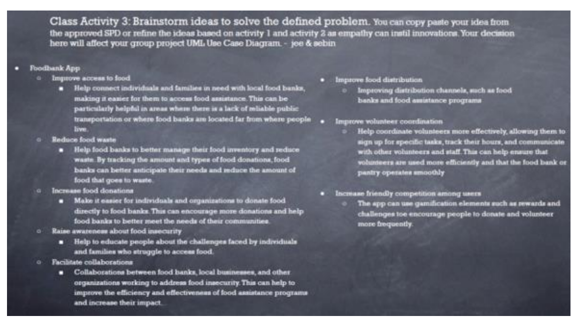

Class Activity 3: Brainstorm ideas to solve the defined problem. You can copy paste your idea from the approved SPD or refine the ideas based on activity 1 and activity 2 as empathy can instil innovations. Your decision here will affect your group project UML Use Case Diagram. - jee & sebin
Foodbank App
Improve access to food
Improve food distribution
Improve volunteer coordination
Reduce food waste

Figure 44. Students work on the Human-Computer Interaction course, fall 2022.

5.18 Course WIC3001: Mathematics In Networking

5.18.1 Description of the course

The course demonstrates how mathematical concepts and techniques can be applied to analyze and solve problems in the field of computer networking. Mathematics plays a crucial role in networking as it provides the foundation for various aspects of network design, analysis, and optimization. It teaches students topics to study an efficient programming language and algorithm about graph theory and planarity. By studying Mathematics in Networking, students gain the following:

- **Understanding network topolo**gy. Mathematics helps in studying and representing the structure and connectivity of computer networks. Graph theory, a branch of mathematics, is used to model and analyze network topologies, including concepts such as nodes, edges, connectivity, and paths.

- **Analyzing network performance**. Mathematics is used to analyze the performance of computer networks, including metrics such as throughput, latency, and packet loss. Probability and queuing theories are applied to model and analyze network traffic and performance, allowing administrators to optimize network resources and improve overall performance.
- **Routing and switching**. Mathematics is used to develop algorithms for routing and switching in computer networks. Optimization techniques, such as linear programming and graph theory, are applied to find the most efficient paths for data packets to traverse the network, minimizing delays and congestion.
- **Data analysis**. Mathematics is used to analyze network data, such as traffic patterns, user behaviour, and network performance metrics. Statistical analysis techniques, such as regression analysis and hypothesis testing, are applied to identify trends, anomalies, and patterns in network data, enabling network administrators to make informed decisions and troubleshoot network issues.

5.18.2 Description of the participants

Participants are enrolled full-time in the Bachelor of Computer Science program. A total of 5 students attended the course in semester 1 of the academic year 2022 – 2023 in a preliminary offering of the course.

5.18.3 Description of gamified design thinking activities

Students participated in weekly meetings. At the beginning of the class, the course coordinator provided a 30-minute briefing on design thinking. The students met their team members online.

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Course material, including design thinking activities sheets and templates, was shared through the MSTeams® platform.

Students worked in a group of 5 individuals. Their work was organized as follows:

Step 1. Understanding the problem.

Students performed research to gain a clear understanding of the problem at hand, which was determining whether a randomly generated simple graph is planar or not. They familiarized themselves with the concept of planarity and the criteria that define a planar graph.

Step 2. Research and information gathering.

Students conducted research to understand the properties and characteristics of planar graphs. They explored existing algorithms and techniques used to determine planarity. This step helped students gather information and insights to inform the design thinking process.

Step 3. Ideation.

Once they had developed a good understanding of the problem, students started generating ideas for determining planarity. They considered different approaches, algorithms, and techniques that could be applied to solve the problem. They brainstormed with others to come up with a variety of potential solutions.

Step 4. Prototyping solutions.

Students selected one or more ideas generated and created prototypes or models to test them. This involved implementing algorithms or using simulation tools to analyze randomly generated graphs and determine their planarity. The prototypes were designed to take input in the form of a graph and provide an output indicating whether the graph was planar or not.

Step 5. Testing and iterating.

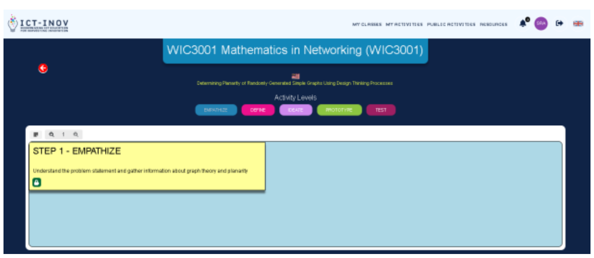
Students tested the prototypes using various randomly generated simple graphs to verify their accuracy and effectiveness in determining planarity. They evaluated the results and iterated on the prototypes when necessary. They collected feedback from users or experts in the field to further refine the solution.

Step 6. Refining and implementing.

Students refined the prototypes and developed a final solution based on the feedback and testing results. This involved improving the efficiency or accuracy of the algorithm, enhancing the user interface, or addressing any limitations or issues identified during testing.

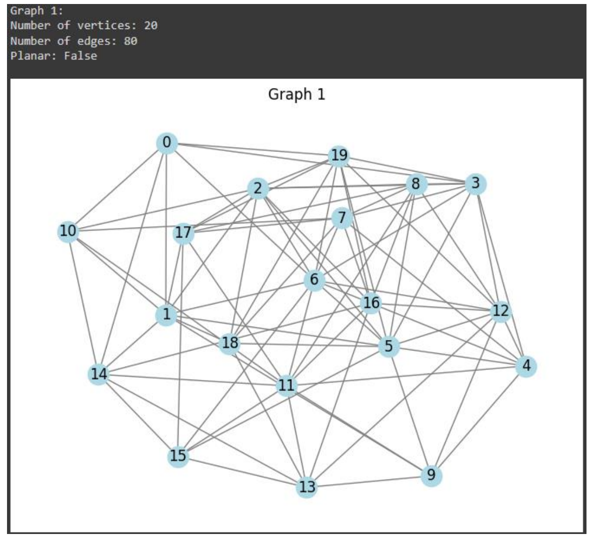
Step 7. Validating and deploying.

Students validated the final solution by testing it with a diverse set of randomly generated simple graphs. They ensured that it consistently provided accurate results in determining planarity. They deployed the validated solution in practical scenarios.



Source code:

```
import matplotlib.pyplot as plot
import networkx as nx

num_graphs = 10    # No. of graphs to generate
n = 20             # No. of vertices
p = 0.25           # Probability that an edge exists between vertices

# Set up the matplotlib figure for graph visualization
fig, axs = plot.subplots(10, 1, figsize=(6, 50))
axs = axs.flatten()

for i in range(num_graphs):
   G = nx.erdos_renyi_graph(n, p)  # Generate a new random graph for each
iteration

   pos = nx.spring_layout(G)
   nx.draw_networkx(G, pos, node_size=200, font_size=8)

   # Visualize the graph
   plot.sca(axs[i])
   plot.title(f"Graph {i+1}")

# Adjust the layout and display the graphs
plot.tight_layout()
plot.show()
```



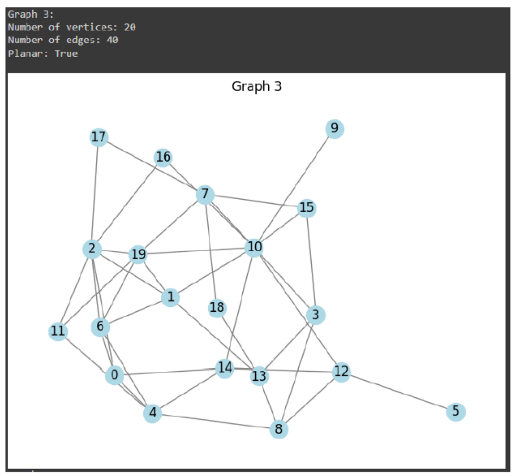


Figure 45: Students work on Mathematics in Networking exercises, fall 2022.

5.19 Course WIE3003: Information Systems Control and Security

5.19.1 Description of the course

The course provides students with knowledge and skills in information systems security controls from a physical and environmental perspective, application, and operation. It focuses on existing types of security controls for the organization of information systems, including methodologies, procedures, and implementation design. Students are also introduced to solving security problems in information systems using different methods, procedures, and controls. They are also taught to apply ethical values for each information security system development to comply with laws and policies for effective control.

5.19.2 Description of the participants

The course is an elective offered by the Faculty of Computer Science and Information Technology under the Department of Information Systems. Participants are enrolled in the Faculty of Computer Science Information Technology program. A total of 24 students attended the course in semester 2 of the academic year 2022 – 2023.

5.19.3 Description of gamified design thinking activities

Design thinking was used to help students in their continuous assessment in the context of project-based learning. Students worked on a semester-long project. The project objectives were to:

- Explore the current issues of information security in different sectors.
- Determine possible improvements to solve the problems in each sector selected.
- Ideate the improvement via a prototype to show its functionality and capability.

Students worked in teams of 4 individuals. A total of 6 groups were formed.

Students were allowed to explore any technology-related design tools, video, editing, and analytic concepts to help them answer each design thinking phase. For the discussion session, students were asked to use the ICT-INOV design thinking platform.

Work was organized in the following steps:

Step 1. Team building.

Students worked in teams to select a team name and design a team logo, which they uploaded on the ICT-INOV digital learning platform.

Step 2. Problem discovery.

Students identified problems and gaps in related cybersecurity issues using data collection. They identified advantages and disadvantages, problems, issues, and challenges through a small-scale data collection activity based on a survey. Through the data collection, they identified the requirements to improve the current process or system. This became the baseline for the design of an innovative solution.

Step 2. Definition.

Students identified user needs through a survey, the results of which they visualized in graph. They used the results to identify potential improvements. They further identified the specific problems that they wished to focus on. They discussed the objectives of the proposed innovative solution, the target audience, and the technology to be used in its synthesis.

Step 3. Ideation.

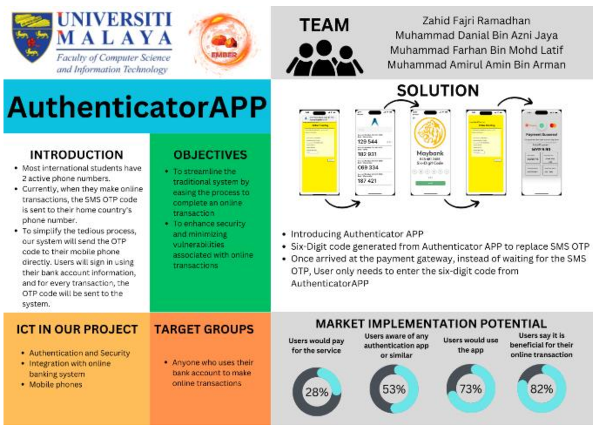
Students proposed solutions to the problem in focus. They provided drawings and illustrations of their ideas. They further tested their ideas for viability.

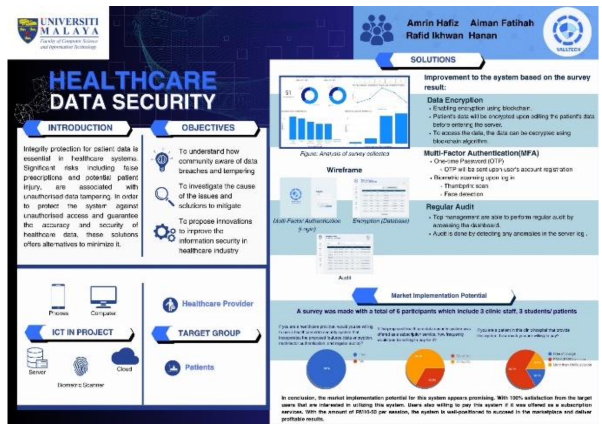
Step 4. Prototyping.

Students developed a prototype to demonstrate their ideas. The prototype was presented in the form of an infographic poster. Students drew and illustrated their innovative products on the poster.

Step 5. Testing.

Students evaluated their prototypes with users and developed a short evaluation summary.





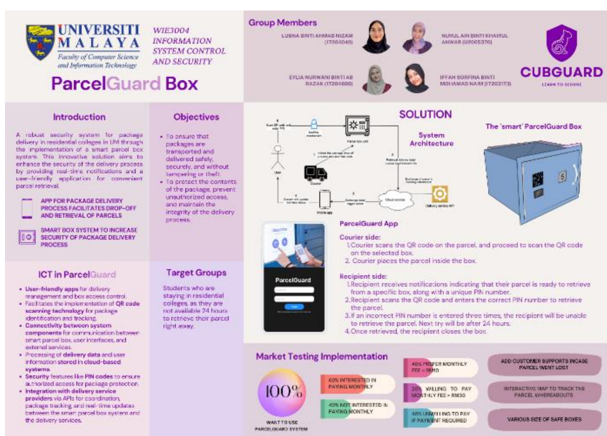


Figure 46. Student posters presenting innovative ideas generated in the Information Systems Control and Security course, spring 2023.

5.20 Course WIA3002: Academic Project I and II

5.20.1 Description of the course

This course introduces students to research methodologies and activities, including problem identification, literature review, data collection, writing the research proposal and project presentation, system analysis and design, system implementation, testing and evaluating the developed system, project presentation, and writing an academic report.

5.20.2 Description of the participants

Participants are enrolled full-time in the Bachelor’s in Computer Science program on Computer Systems, Networking, and Software Engineering. The course was conducted in semester 2 of the academic year 2022 - 2023.

5.20.3 Description of gamified design thinking activities

Students work on an academic project, the objectives of which are to:

- Identify a solution approach that is suitable for the stated problem.
- Conduct suitable requirement gathering, system analysis, and design techniques.
- Present project proposal paper.
- Develop a system based on the solution approach and method identified.
- Present the implemented project.
- Implement a system with ethics and professionalism.

Project themes can involve some of the following:

- Implement the automation of the feeding process for livestock.
- Implement a DIY robot for learning STEM and a web platform to market STEM resources.
- Implement “my buddy contractor” application.

- Implement an IoT solution for running and walking tracks.

During the implementation of the project, students used design thinking to synthesize innovative solutions. Work was organized in the following steps:

Step 1. Empathy and problem definition.

Students performed elicitation and analysis of the problem.

Step 2. Ideation.

Students sketched and structured their ideas on system design.

Step 3. Design.

Students outlined the conceptual design and wireframing of the interface. They performed data processing and cleaning, ensuring that data was formatted in a suitable way for visualization. They selected appropriate data visualization techniques. They designed the application user interface.

Step 4. Prototyping.

Students developed a prototype of their system through software coding in an appropriate language and platform.

Step 5. Testing and refinement.

Students tested their system to identify bugs and issues. They refined their system to improve performance and user experience.

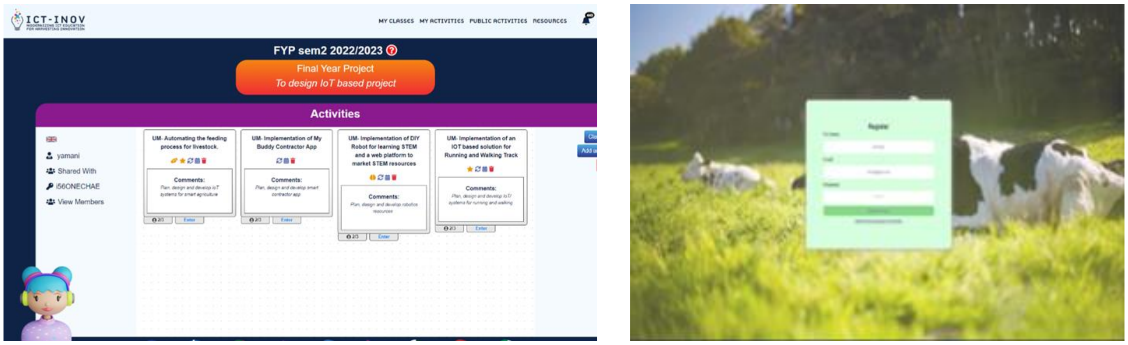


Figure 47. Student work in the Academic Project I and II activity, spring 2023.

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6. University Tenaga Nasional

6.1 Course CSEB4113: Software Quality

6.1.1 Description of the course

The course focuses on fundamental concepts of ensuring quality software. It has as a prerequisite the Software Engineering course, which introduces software design principles, including requirements extraction and analysis, requirements specification, functional and non-functional requirements, software design, project management, and software development methodologies. The course is designed, among others, to prepare students to work in the software industry, addressing software quality assurance processes, activities, and challenges. Topics include quality control, quality assurance, quality management systems, process and product quality, software configuration management, standardization, and audit.

The course includes a project assignment emphasising quality assurance activities, challenges, processes, and standards. Students are challenged to work in teams to solve a real software quality problem using the software quality assurance principles learnt in class. As a result of project ICT-INOV, the course has been updated to include design thinking activities. Students are exposed to design thinking concepts and deploy design thinking to complete their group assignments.

6.1.2 Description of the participants

This is a compulsory course in the 3rd year of studies in the Bachelor's in Computer Science program, Software Engineering strand, of the Computing Department, College of Computing and Informatics, University Tenaga Nasional. In the 2021 - 2022 academic year, the course was delivered in 2 semesters. In both cases, design thinking activities were applied. 62 students attended the course, 48 in the 2nd semester of the academic year and 14 in a special course offering in the 3rd semester.

6.1.3 Description of gamified design thinking activities

A learning activity based on design thinking was specifically designed for the course. The objective of the learning activity was to challenge students to design solutions for real software quality problems related to the usability, efficiency, security, and reliability of software. The activity is directly in line with course learning outcomes, which are to apply appropriate techniques and processes in solving software quality assurance implementation issues and perform the assigned tasks effectively in a team practising software quality assurance activities. Students worked in groups of up to 6 individuals.

The ICT-INOV educational platform provided instructors with flexibility in structuring learning activities based on well-accepted design thinking steps. The activity was structured as follows:

Step 1: Team building.

Students were encouraged to select a team name for team-building purposes. This activity provided teams with a sense of identity and affiliation. It also helped them to establish effective communication between team members. In addition, students were asked to put up one sticker each to introduce themselves. This was a good way for them to get to know each other better since teaching and learning were still fully online.

Step 2: Understanding the context.

Students were asked to perform research on software quality, the importance of ensuring quality in the developed software, and the consequences of low-quality software, which is the general theme of the proposed activities. They were also asked to post ideas and lessons learnt on the importance of quality software from the articles they read or videos they watched.

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Step 3: Problem definition.

Team members were asked to look around and identify software they had been using or had seen others using, which they believed had quality problems. Each team member was required to post a description of the software and the identified quality problem on the platform. Through this description, students had an opportunity to present their findings to the other team members. Teams were encouraged to engage in discussions and agree on the software they would like to work on further to solve the identified quality problem.

Step 4: Understanding users.

Students were exposed to the tools for discovering and documenting actual, as opposed to perceived, user needs. These included questionnaires and semi-structured interviews. It further included designing a user persona describing a characteristic user by considering what the user thinks, feels, says, and does.

Step 5: Ideation.

Students were challenged to redefine their originally perceived quality problem of identified software, considering the results of their research in the previous step, which helped them understand the problem from the user's point of view.

Step 6: Prototyping.

Students were asked to brainstorm to generate as many ideas as possible to determine the causes of the identified quality problem. They were encouraged to do the root-cause analysis, namely a fish bone diagram, to categorize the causes and their respective sub-causes. They were then asked to select one cause they wanted to provide the solution. Students collaborated with their team members to design and post their proposed solutions on the ICT-INOV platform.

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Students performed all activities and submitted their proposed solutions to the ICT-INOV educational platform before presenting them to the class. Some of the software and respective quality problems that the teams chose to provide solutions for include:

- **Software name:** No specific software chosen.

  Problem: Last-minute changes in software requirements.

  Chosen cause: Requirements change during project development.

  Chosen sub-cause: Changes in the recent technologies and/or environment.

  Proposed solution: The team proposed the development of a well-documented change control procedure that, amongst others, clearly states the types of requirements that can and cannot be changed once development begins and the extent of the change allowed. This approach can prevent last-minute changes that can reduce the quality of the software.
- **Software name:** Foodpanda® App.

  Problem: The search function does not return the expected food or shop.

  Chosen cause: Inefficient search algorithm.

  Chosen sub-cause: Unthorough search algorithm.

  Proposed solution: An improved search algorithm was proposed to address inefficiency issues such as avoiding the display of food outlets that are currently closed or do not exist, ensuring that the app displays both or all outlets that have the same name, and validating the algorithm.
- **Software name:** Terminal 5 (T5) Heathrow Airport Software.

  Problem: Lost baggage.

  Chosen cause: People.

  Chosen sub-cause: Undertrained staff.

  Proposed solution: A tailored training framework for airport management was proposed as a solution to this problem. The training module includes a 30-day tailored theoretical course, 30-day on-the-job training with actual software, and 30-day involvement with real scenarios.

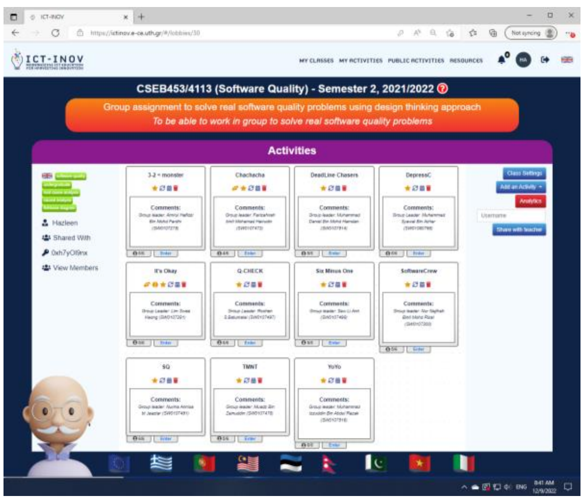
- **Software name:** ICT-INOV platform.

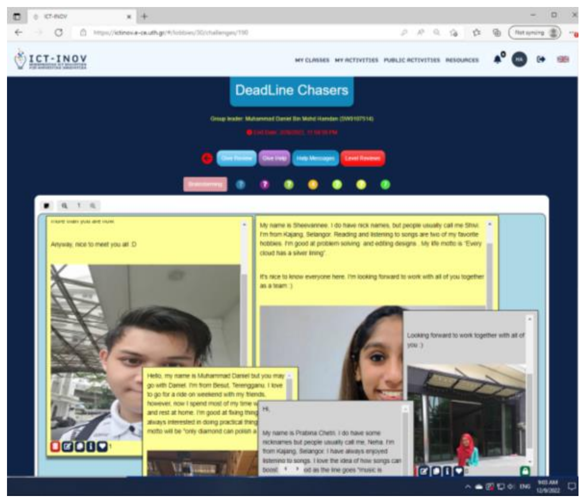
  Problem: Further enriching the user interface.

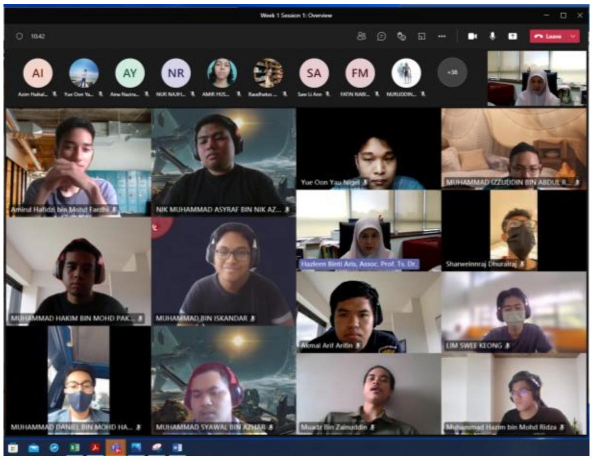
  Chosen cause: Perfecting the user interface.

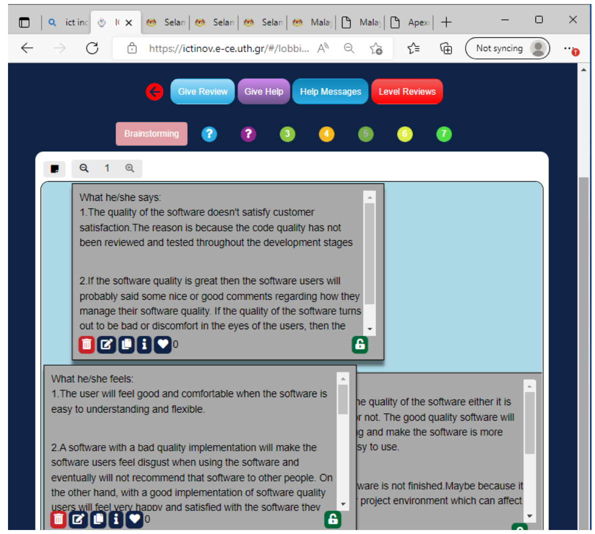
  Chosen sub-cause: Lack of user feedback system/feature.

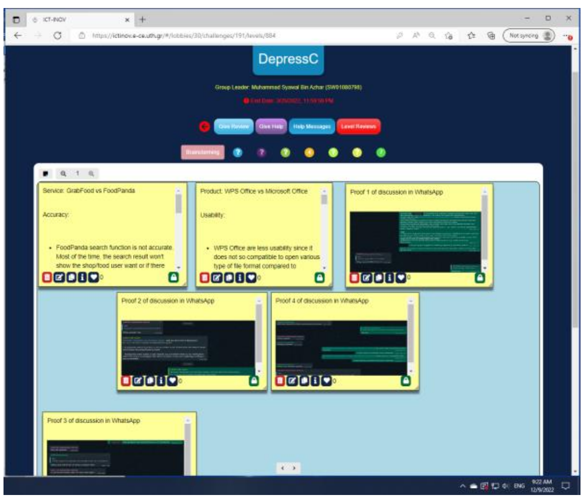
  Proposed solution: Two additional features were proposed. The 1st involves a form that users can fill in and submit whenever they have queries or comments about the platform. The other interface displays frequently asked questions (FAQs) that users can quickly refer to when they have problems that may have already been encountered and addressed. This will overall improve user experience.






Week 1 Session 1: Overview


Give Review
Give Help
Help Messages
Level Reviews
Brainstorming
What he/she says:
1.The quality of the software doesn't satisfy customer satisfaction.The reason is because the code quality has not been reviewed and tested throughout the development stages
2.If the software quality is great then the software users will probably said some nice or good comments regarding how they manage their software quality. If the quality of the software turns out to be bad or discomfort in the eyes of the users, then the
What he/she feels:
1.The user will feel good and comfortable when the software is easy to understanding and flexible.
2.A software with a bad quality implementation will make the software users feel disgust when using the software and eventually will not recommend that software to other people. On the other hand, with a good implementation of software quality users will feel very happy and satisfied with the software they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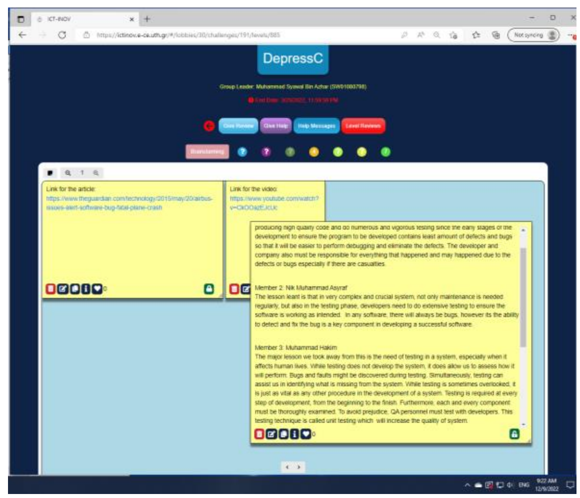
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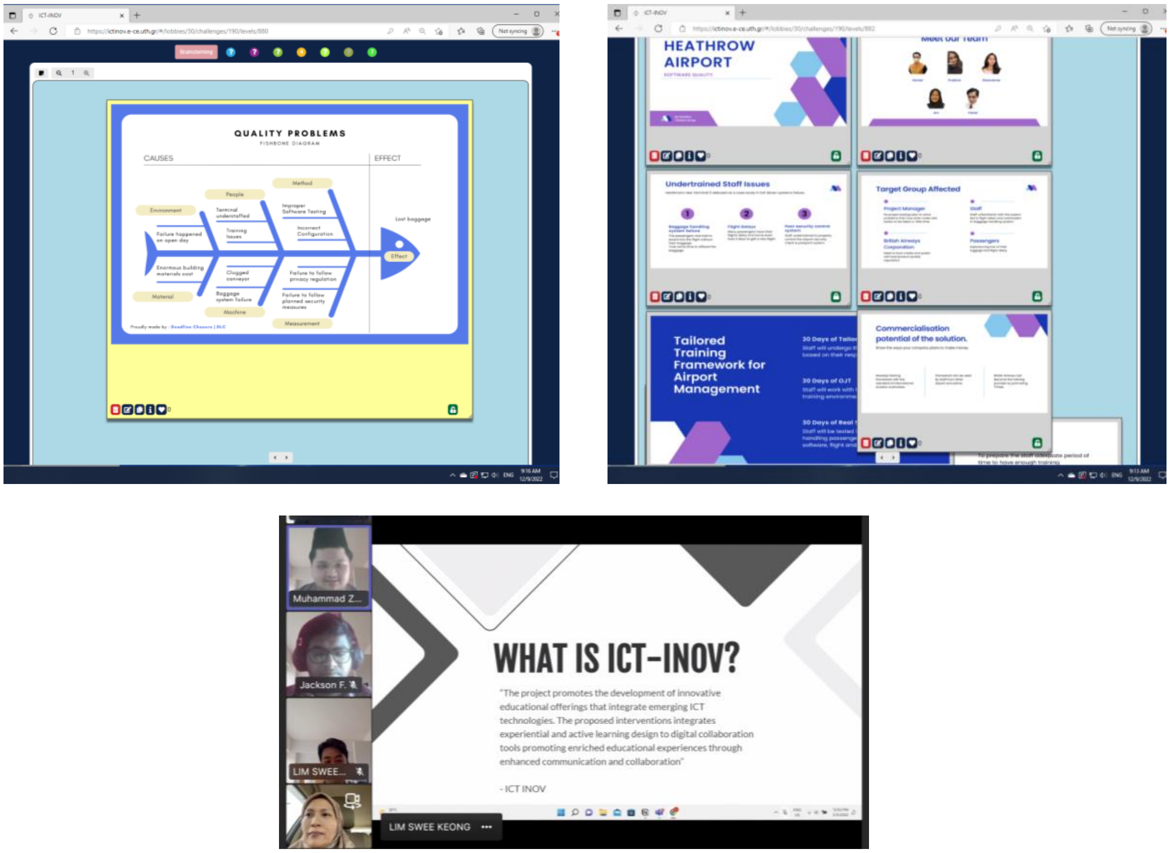

Figure 48. Screenshots of student projects in the Software Quality course, spring 2022.

6.2 Course CISB5213: Digital Business

6.2.1 Description of the course

This course provides insight into the emergence of digital business, key concepts, technologies, and strategic organization. Students develop a business plan for a business solution based on or supported by digital technologies and strategies. Subsequently, students deliver a business pitch based on their business plan. The implementation of customer support and change management issues are also discussed by examining practical management in certain organizations involved in creating and maintaining digital business solutions. At the end of this course, students can demonstrate the meaning, scope, and requirements of digital business and e-Commerce and their components, examine the business challenges and opportunities of introducing digital business and e-Commerce to an organization, and develop a digital business strategy and front-end application

Student assessment is based on quizzes, tests, assignments, class projects, and final examinations. The design thinking methodology is applied in the class project from week two until week 15 of the semester. The class project contributes 30% to the overall course assessment.

6.2.2 Description of the participants

This is a technical elective subject in the 2nd or 3rd year of studies in the Bachelor's in Information Systems program of the Informatics Department, College of Computing and Informatics, University Tenaga Nasional. In the 2022 – 2023 academic year 25 students in their 3rd year of studies attended the course.

6.2.3 Description of the design thinking activities

Six groups were formed: Adore, Daniel Online Tutoring System, Coffee2Door, MeDEX, DDS, and Online FoodTruck. Using the design thinking methodology, the work was divided into 4 project activities.

Step 1: Empathizing.

Work was further divided into 2 tasks. In the 1st task, students were asked to describe three business ideas based on their interests, passions, or desirable skills. They were asked to highlight the problem they would focus on and identify the business values that stem from it. The groups were further required to work on a team canvas to identify a name for their company and create a logo and a tagline to promote their business to their target market. As a result of this work, 6 business ideas were identified and assigned to the 6 student groups.

In the 2nd task, each group was required to conduct market research using the PESTEL® analysis tool to discover more information about the business idea and build their knowledge. This included further researching the business problem they would like to solve, researching potential solutions, identifying the customers or users, and identifying the added value of their business to the customers that would lead them to use or buy their proposed business solutions. The result of this work was a brief report. In addition, students logged into the ICT-INOV digital learning platform, joined the course, and posted their ideas.

Step 2: Problem definition.

Students are required to revisit the outcomes of stage 1 and improve the produced report with more information. Work focused on the business problem, particularly how the company could create value and profit from the proposed business solution. Students summarized their findings into a business model canvas and a value proposition canvas. They presented their findings to the class.

Step 3: Designing a business solution.

Students revisited the result of their work in step 2 and enriched it with additional content. I worked on designing the proposed business solution and making the business idea work. Students gathered more information on potential customers and their needs, competitors, business requirements, constraints, competitive advantage, and target market. Based on this information, they developed digital business strategies, a financial plan, and a digital marketing plan, in which they identified possible tools and platforms essential in marketing business solutions.

Step 4: Prototyping.

Students designed a high-fidelity product or service prototype prototype using software or apps, such as Wix.com®. They were encouraged to explore. Subsequently, students presented their prototype, described the customer journey, and recorded the pain and gain that were expected in the journey. Students revised and prepared a brief business presentation or business pitch to share ideas with future investors. The presentation consisted of the background of their company, the description of the business solution, the business model canvas, competitor analysis and discussion, digital business strategy diagram and description, digital marketing plan diagram and description, customer journey diagram and description, financial planning, and screenshots of the prototype. Finally, students demonstrated their prototypes to the class.

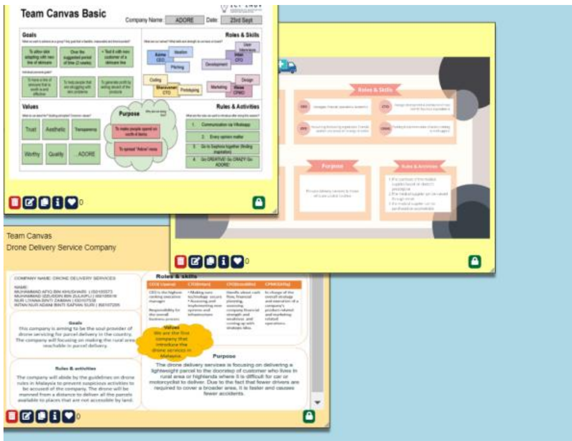

Figure 49. Students develop a team canvas and brainstorm in the Digital Business course, fall 2022.

6.3 Course CSEB3123: Software Engineering Principles

6.3.1 Description of the course

This course introduces an engineering approach to the development of high-quality software systems. It addresses the important software engineering concepts in various common software process models. Students build knowledge of the concepts and techniques used in each software development phase, including requirements engineering, software design, and software testing. The course exposes students to object-oriented representations through the UML format and tools for analyzing and designing software. Upon completion of the course, students will become familiar with most of the common software engineering concepts and techniques and be able to produce software artefacts and deliverables.

The course includes a project assignment in which students explore the campus to identify problems that can be solved using software solutions. Students work in groups to synthesize the solution following requirements engineering processes. As a result of project ICT-INOV, the course has been updated to include design thinking activities. Students are exposed to design thinking concepts and deploy design thinking to complete their group assignments.

Upon completion of the course, students can explain fundamental concepts of software engineering, produce software requirements models, software architecture, object-oriented design models, and test cases with state-of-the-art methods and tools for a real-world software engineering problem, and work effectively in a team to solve real-world software engineering problems.

6.3.2 Description of the participants

This is a compulsory course in the 1st year of studies in the Bachelor's in Computer Science program, Software Engineering strand, of the Computing Department, College of Computing and

Informatics, University Tenaga Nasional. A total of 47 students attended the course in the 2021 - 2022 academic year.

6.3.3 Description of the design thinking activities

A learning activity based on design thinking was introduced into the course. The activity was divided into the following steps.

Step 1: Identifying problems and proposing solutions.

Students were challenged to identify potential problems through observation. They brainstormed in teams to select one of these issues to focus on.

Step 2: Identifying the stakeholders.

Students were encouraged to meet with stakeholders to understand their needs.

Step 3: Identifying desirable features of the proposed system.

Students engaged in ideation to generate a pool of ideas towards solving the problem in focus.

Step 4: Identifying functional requirements.

Students identified the functional requirements of their proposed system, which described system functionality in detail.

Step 5: Writing non-functional requirements.

Students identified the non-functional requirements of their proposed system, which described restrictions or characteristics, such as dependability, availability, performance, and others.

Students performed all activities and submitted their proposed solutions through the ICT-INOV digital learning platform before presenting them to the class.

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CSEB3123 S120222023 Group List for Assignments

1 Each team **MUST** consist of **FIVE** members.
2 For those who do not belong to any group, you may join any group that still have empty slots.
3 Choose a professional name for your group and select one member to be the leader.
4 Please fill up the table according to the sequence group number (the first one who key in , put it in group 1 first, and the rest follow

Deadline to complete the grouping list : 17th October 2022 (Monday)

Group 1 Name					
No	**ID**	**Student Full Name**	**Email**	**Phone Number**	**Area of Case study**
1	SW01082144	Muhammad Zulfitri Hakeem bin Masiran	zulfitrih@gmail.com	013-362 6692	Mosque
2	CS01081781	Muhammad Ainnur Imran Bin Ruslan	muhdainnurimran@gmail.com	018-777 4382	
3	SW01082139	Muhamad Irfan bin Zuhaimin	muhamadirfan1q@gmail.com	019-477 6206	
4	CS01081009	Irfan Bin Ismail Sauki	irfan.ito.99@gmail.com	011-39691736	
5	SW01082806	Fazrina Imaan Binti Mohamed Riaz	fazrinaimaan@gmail.com	011-24176753	

Group 2 Name					
No	**ID**	**Student Full Name**	**Email**	**Phone Number**	**Area of Case study**
1	SW01081788	Luqman Hakim Bin Rosli	hakimluqman2601@gmail.com	017-5130762	Library
2	SW01081820	Muhammad Azmizani Bin Ab Aziz	azmizani2001@gmail.com	014-2913375	
3	SW01081835	Mohamad Hashimi Bin Mohd Zawawi	ashimi.muhammad8@gmail.co	012-9980664	
4	CS01081991	Alrashedi Rashed Triheeb K	rashedtrheb@gmail.com	011-3177 6592	
5	SW01081622	Amiin Hussein Jama	amiindls@gmail.com	011-21232557	

Figure 50. List of student projects in the Software Engineering Principles course, spring 2021.

6.4 Course CISB3323 and CISB213: Human-Computer Interaction and Multimedia Interface Design

6.4.1 Description of the course

The course introduces basic concepts of human-computer interaction. It focuses on interface design and evaluation, including principles and guidelines for designing interactive systems. Emphasis is also given to the development process for user interaction design. Development activities include requirements and task analysis, usability specifications, design, prototyping, and evaluation. The main goal of the course is to help students realize that user interface development is an ongoing process throughout the full product life cycle. During the course, the students explore real-problem software development projects. They are required to identify requirements, analyze the problem, form a solution, and present the solution in class.

6.4.2 Description of the participants

This is a compulsory course in the 1st year of studies in the Bachelor's in Information Technology program, Visual Media strand, University Tenaga Nasional. It is part of the program designed by the Graphics and Multimedia Department, College of Computing and Informatics, CCI, University Tenaga Nasional. Based on the program structure, the students are expected to take this course during the first year of their studies. A total of 6 students attended the course in the 2022 – 2023 academic year.

6.4.3 Description of gamified design thinking activities

Course activities included a hands-on exercise on the design and prototyping of a system, which is the first step in an iterative user-centred system design. The focus of the project was COVID-19 innovation. Students analyzed user needs, use cases, and use context. Based on the findings, students were encouraged to envision the actual system design based on real people's experiences, real tasks, and real needs. Activities enabled students to understand that user-centred system design is not an academic process where some cookbook formulas can be applied. Nor is it an intuitive process where a programmer can sit in their office and think they know the user and their tasks. Rather, it is a hands-on process that requires students to go out and identify the actual users, talk to them about potential solutions, and understand the context of their work. Students were encouraged to identify potential usability problems in early design in an iterative, continuous evaluation and refactoring process.

More specifically, students worked on their iterative designs of a particular system using task-centred system design methods and low-fidelity prototyping. The immediate purpose of this exercise was to build student skills in articulating clear task descriptions, using the task descriptions to decide upon system requirements, and brainstorming on low-fidelity prototypes based on the above. The outcome of this activity was a portfolio containing a list describing expected users of the system and their work contexts, a list of actual, representative tasks, a prioritized list of system requirements, system design, a mid- fidelity prototype, and testing.

Work was divided into the following steps.

Step 1: Team building.

Students were divided into groups of 3 individuals. Group work allowed students to be exposed to alternate design ideas, ways of looking at things, and more breadth at eliciting and interpreting evaluations. In real life, an effective team is comprised of individuals from diverse backgrounds with different perspectives, such as a project manager, a marketing expert, a programmer, a representative end user, and a help desk person who communicates with end users. To this end, the students were encouraged to build teams of individuals with different strengths. Picking a team with the 3 best programmers would not generate the best results.

Step 2: Brainstorming.

Students were asked to read articles and research papers on human-computer interaction, trying to focus on specific issues related to the COVID-19 pandemic, such as human-computer interaction or older adults, individuals with special needs, and more. They brainstormed with team members to generate a rich pool of ideas towards a potential solution. Each team selected 3 different project ideas, designed a rough user interface sketch and wrote a concise proposal for each.

Task 3: Ethnography.

Students were encouraged to observe the target users of the proposed system doing their tasks in real-life settings. Subsequently, students selected one of the tasks to focus on and study. For the chosen activity, students were asked to observe several individuals perform the task and take detailed notes about the series of steps they go through, any objects ("artefacts") they use, whether they interact with other individuals and, if so, the step-by-step details of this interaction. Students further conducted one or two unstructured interviews with end users. Examples of activities that students focus on include registration processes, form filling, information browsing, giving directions, and appointment scheduling.

Students submitted a report that consisted of a one-paragraph justification on why they selected a particular activity to focus on, followed by an overview of the activity, the end users they engaged with, and the artefacts involved, such as paper, pencil, mobile phone, or machine. In addition, the reports included a more elaborate description of the activity and any related variations and the results of interviews, including user quotes that supported the student conclusions.

Step 4: Design.

Students designed their solution based on the results of the previous steps of analysis. They presented the user interface in the form of a storyboard. Students were asked to establish links between the theoretical principles of design presented in lectures and their suggested solutions.

Task 5: Prototyping.

Students developed a portfolio of several mid-fidelity prototypes of designs that they believed would satisfy the requirements.

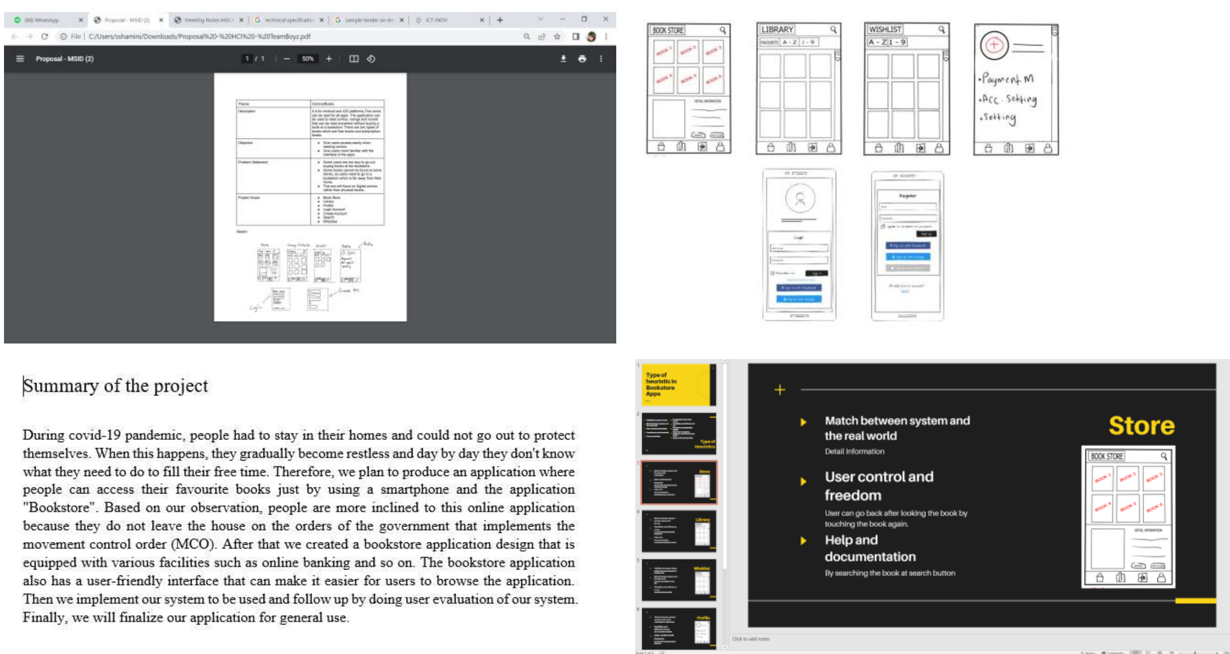


Figure 51. Results of team building, brainstorming, ethnography, design, and prototyping in the Human-Computer Interaction and Multimedia Interface Design courses, fall 2022.

6.5 Course CMPF144: Introduction to Problem-Solving and Basic Computer

6.5.1 Description of the course

ICT-based problem solving is essential today, as most of the business domains available in the market in our society involve ICT. This course aims to expose students to the concept of problem-solving. Students are educated on problem analysis techniques to identify relevant inputs, outputs, and processes involved in solving a problem. This is followed by transferring relevant algorithms into computer programs using Python® programming language software tool.

Upon completing the course, students will be able to describe the fundamentals of problem-solving techniques in programming contexts, illustrate algorithms for a particular problem using correct problem analysis and control structure, and develop a computer program based on the selected algorithm.

6.5.2 Description of the participants

This is a core course for Foundation in Computer Science (FCS) and Foundation in Information Technology (FIT) students enrolled in the College of Computing and Informatics (CCI), Universiti Tenaga Nasional. Students are expected to complete this course within their one-year foundation study program. In the 2022 - 2023 academic ICT-INOV design thinking activities were implemented in lecture and lab sessions. A total of 30 students attended the course.

6.5.3 Description of the design thinking activities

This course implemented design thinking activities which are aligned with the course learning outcomes. Specifically, students were challenged to describe the fundamentals of problem-solving techniques in the programming domain, illustrate an algorithm for a particular problem using correct problem analysis and control structure, and develop a computer program based on the selected algorithm. Using the design thinking methodology, the course project was divided into 5 main project objectives: empathize, define, ideate, prototype, and test.

Stage 1: Empathy.

Students from different backgrounds were required to work collaboratively by forming groups. They were required to select which role they would like to actively assume in their respective groups: leader, programmers, or documentation writers. They later filled out their names, student IDs, group names, and project titles in a folder shared with the class and the instructor.

Stage 2: Problem definition.

The first-course learning outcome requires the students to describe the fundamentals of problem-solving techniques in the programming domain. As such, for their group project, students were given 2 different case studies and were asked to analyse, identify, and elaborate on the suitable techniques to solve the given problem-solving tasks. They were required to choose one case study to brainstorm in their respective group. They were encouraged to imagine what the user would do if they put themselves in the user's perspective before developing the system based on the questions listed in the case studies.

Stage 3: Ideation.

After forming their respective groups and choosing the case study they wished to work on, students brainstormed in class. Several brainstorming activities were implemented in-class sessions, during which they were required to generate ideas for solving the case study of their choice. The objective at this stage was to enable students to illustrate an algorithm for a particular problem using correct problem analysis and control structure before transforming the algorithm into code for the system development process.

Stage 4: Prototyping.

Students transformed their algorithms into computer programs. They were directed to document their algorithms towards a solution as specifically as possible to facilitate the software development process.

Stage 5: Testing.

Students tested their computer program developed and documented earlier. Software testing is the process of evaluating and verifying what a software product or application does compared to what it is supposed to do. The students were made aware of the benefits of testing, including preventing bugs, reducing development costs, and improving the performance of the system they developed.

CMPF144 - Group Project Details	
Project Title: Cloud4 - Bruce Wayne LRT Ticketing System	
Group Name: Cloud4 ™	
Group Member's Name:	Student ID
Leader/Programmer 1 - Muhammad Emir Na'eim Bin Ruzainee	AT1081989
Programmer 2 - Muhammad Amir Irfan Bin Khasnizal	AK1082131
Programmer 3 -	
Writer - Noha Nabil Mohammed Jarallah	AK1083256
Writer - Nur Qairunisa Solehah Binti Nor Zaidi	AK1083003
Project Title: UNITEN Business Development	
Group Name: Bits N' Bytes	
Group Member's Name:	Student ID
Leader/Programmer 1 - MOHAMMED ALZUBAIR ALMAHBOUB FARAJALLA	AK1082993
Programmer 2 - MAKKI ELSIDDIG MAKKI	AK1083002
Programmer 3 -	
Writer - SHEIKH HAMDAN BIN SOBHAN	AK1083001

CMPF144 Introduction to Problem Solving and Basic Computer
College of Computing & Informatics
Universiti Tenaga Nasional

Group Assignment – Option 1

You and your team members have been hired by UNITEN Business Development Unit which is based in UNITEN Putrajaya to build a rental system for their new facilities. Your program should consist of the following functions:

1. Allow the user to **choose the type of facilities** they wish to book
2. Give option to **choose between Student/Staff and Public** (since student/staff and public different price)
3. **When** they would like to book it (since weekend and weekdays different price)
4. **How many hours** user would like to book it?
5. **Display total amount** that need to be paid by user
6. **Display the balance** that should be given back to user if they paid the amount of payment more than the payment requested from the system.



Figure 52. Results from the team building, case selection, brainstorming, and testing activities in the Introduction to Problem-Solving and Basic Computer course, fall 2022.

6.6 Course CMPD293: Programming 2

6.6.1 Description of the course

The course gives students a good comprehension of higher-level programming languages integrated with existing programming techniques such as classes, data abstraction, strings, stream processing, and file input/output.

Upon completion of the course, students will be able to identify appropriate methods to be applied in high-level programming languages in the context of introductory object-oriented design. Specifically, students can:

- Describe programming concepts using the selected programming language
- Practice appropriate techniques for solving computing problems
- Construct programs using C++ features

As a result of the ICT-INOV project, the course has been updated to include design thinking principles. Students are exposed to design thinking and deploy design thinking to work collaboratively and complete their group assignment that integrates emerging pedagogies and latest technology.

Co-funded by the Erasmus+ Programme of the European Union

6.6.2 Description of the participants

This is a core compulsory course for Diploma in Computer Science (DCS) students from the College of Computing and Informatics (CCI), Universiti Tenaga Nasional. Students are expected to complete this course in their second year of studies. In the 2022 - 2023 academic year, ICT-INOV design thinking activities were implemented in both lecture and lab sessions. A total of 11 students attended the course.

6.6.3 Description of the design thinking activities

The course implemented design thinking activities aligned with learning outcomes. Using the design thinking methodology, the course project was divided into 5 main project objectives: empathize, define, ideate, prototype, and test.

Stage 1: Empathy.

Students were required to form groups and work collaboratively. From day one of the class sessions, they sat together with their group members to select which role they would like to actively assume in their respective groups based on their preferences, such as a leader, programmer, or documentation writer.

Stage 2: Problem definition.

Students were required to describe programming concepts using selected programming languages. This activity was then followed by developing a computer program for their group project. Students brainstormed over a case study given in class. They were also briefed regarding the assessment rubric and marks allocation for this group project to enable them to plan and strategize their collaborative work properly.

Stage 3: Ideation.

Co-funded by the Erasmus+ Programme of the European Union

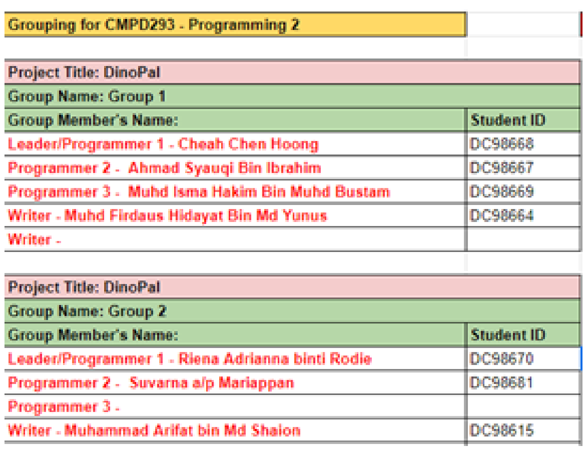
After forming their respective groups, students brainstormed collaboratively. The brainstorming session spanned several sessions. It took place both inside and outside of the classroom. The purpose of this activity was to enable students to practice appropriate techniques in solving computing problems and to help them generate useful ideas before transforming their ideas and algorithms into coding for system development.

Stage 4: Prototyping.

Students worked collaboratively to produce a prototype for their group project. They were required to transform their algorithms into an equivalent computer program. Each group prepared and presented their group project documentation, contributing to 5% of the total mark distributions.

Stage 5: Testing.

Students tested their computer programs and demonstrated their functionality to the class.



Grouping for CMPD293 - Programming 2	
Project Title: DinoPal	
Group Name: Group 1	
Group Member's Name:	Student ID
Leader/Programmer 1 - Cheah Chen Hoong	DC98668
Programmer 2 - Ahmad Syauqi Bin Ibrahim	DC98667
Programmer 3 - Muhd Isma Hakim Bin Muhd Bustam	DC98669
Writer - Muhd Firdaus Hidayat Bin Md Yunus	DC98664
Writer -	
Project Title: DinoPal	
Group Name: Group 2	
Group Member's Name:	Student ID
Leader/Programmer 1 - Riena Adrianna binti Rodie	DC98670
Programmer 2 - Suvarna a/p Mariappan	DC98681
Programmer 3 -	
Writer - Muhammad Arifat bin Md Shaion	DC98615

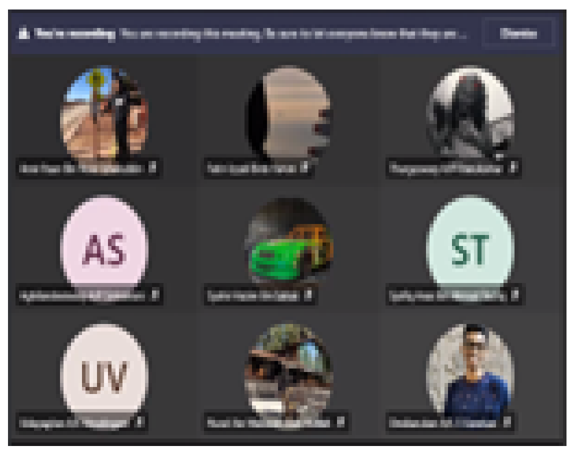


Figure 53. Student work in the Programming 2 course, fall 2022.

6.7 Course CMPD343: Data Structures and Algorithms

6.7.1 Description of the course

The course exposes students to the fundamental concepts of abstract data structures such as arrays, stacks, queues, linked lists, trees, graphs, sorting, and searching. It aims to enable students to choose and apply appropriate data structures and algorithms given a particular computing problem. The actual implementation of abstract data structures uses the C++ programming language. Upon completion of the course, students are able to describe the concepts and operations of data structures and common algorithms, apply the appropriate data structures and algorithms to solve computing problems and develop computer programs using data structures and related algorithms.

As a result of the ICT-INOV project, the course has been updated to include design thinking principles. Students are exposed to design thinking and deploy design thinking to work collaboratively and complete their group assignments integrating emerging pedagogies and the latest technology.

6.7.2 Description of the participants

This is a core compulsory course for Diploma in Computer Science (DCS) students from the College of Computing and Informatics (CCI), Universiti Tenaga Nasional. Students are expected to complete this course in their 3rd year of studies. In the 2022 - 2023 academic year, design thinking activities were implemented in both lecture and lab sessions. A total of 100 students attended the course.

6.7.3 Description of the design thinking activities

This course implemented design thinking activities aligned with learning outcomes. Using the design thinking methodology, the course project was divided into 5 main project objectives: empathize, define, ideate, prototype, and test.

Stage 1: Empathy.

Students formed groups to work collaboratively. They were required to select which role they would like to actively assume in their respective groups based on their preferences: leader, programmer, or documentation writer.

Stage 2: Problem definition.

Students were briefed on their group project. The briefing included an explanation of assessment rubrics and marks allocation to enable students to strategize their plan for computer program development. Students were encouraged to imagine what the user would do if they put themselves in the user's perspective before developing the system based on the questions listed in the case study.

Stage 3: Ideation.

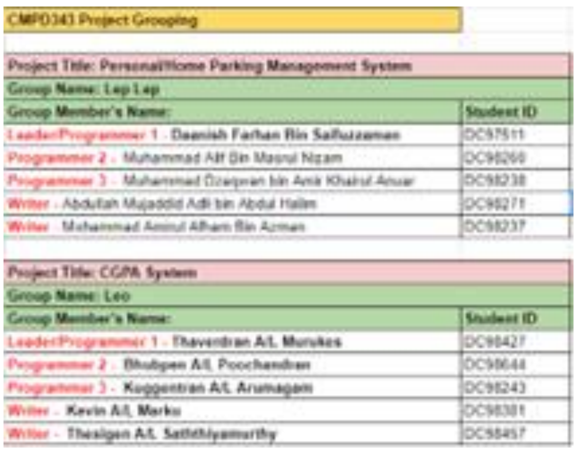
Students brainstormed in groups both online and in face-to-face class sessions to generate creative ideas before putting these ideas into algorithms in system development.

Stage 4: Prototyping.

Students worked collaboratively to produce their project prototype. They transformed their algorithms into an equivalent computer program and produced a prototype documentation.

Stage 5: Testing.

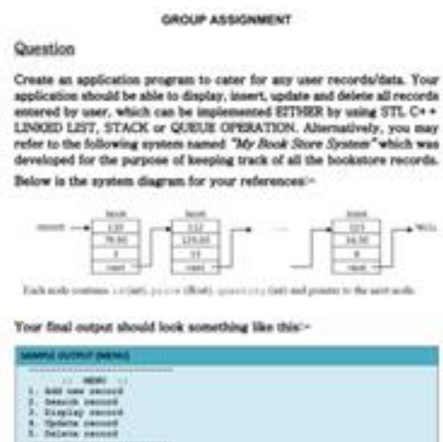
Students tested their computer programs and demonstrated their functionality to the class.



CMPD343 Project Grouping

Project Title: Personal/Home Parking Management System	
Group Name: Lep Lep	
Group Member's Name:	Student ID
Leader/Programmer 1 - Daanish Farhan Bin Saifuzaaman	DC97511
Programmer 2 - Muhammad Alif Bin Masrul Nizam	DC98260
Programmer 3 - Muhammad Dzaqwan bin Amir Khairul Anuar	DC98238
Writer - Abdullah Mujaddid Adli bin Abdul Halim	DC98271
Writer - Muhammad Aminul Alham Bin Azman	DC98237

Project Title: CGPA System	
Group Name: Leo	
Group Member's Name:	Student ID
Leader/Programmer 1 - Thavendran A/L Murukes	DC98427
Programmer 2 - Bhubpen A/L Poochandran	DC98644
Programmer 3 - Kuggentran A/L Arumagam	DC98243
Writer - Kevin A/L Marku	DC98381
Writer - Thesigen A/L Saththiyamurthy	DC98457



GROUP ASSIGNMENT

Question

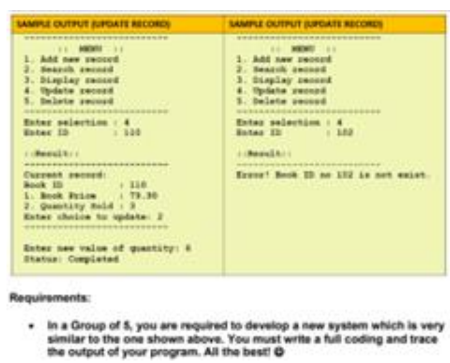
Create an application program to cater for any user records/data. Your application should be able to display, insert, update and delete all records entered by user, which can be implemented EITHER by using STL C++ LINKED LIST, STACK or QUEUE OPERATION. Alternatively, you may refer to the following system named *"My Book Store System"* which was developed for the purpose of keeping track of all the bookstore records.

Below is the system diagram for your references:-

Your final output should look something like this:-

SAMPLE OUTPUT (MENU)

```
:: MENU ::
1. Add new record
2. Search record
3. Display record
4. Update record
5. Delete record
```



SAMPLE OUTPUT (UPDATE RECORD) | SAMPLE OUTPUT (UPDATE RECORD)

Requirements:

- In a Group of 5, you are required to develop a new system which is very similar to the one shown above. You must write a full coding and trace the output of your program. All the best! ☺

Figure 54. Team building, case assignment, brainstorming, and prototyping in the Data Structures and Algorithms course, fall 2022.

618768-EPP-1-2020-1-EL-EPPKA2-CBHE-JP

7. National Universities of Computer and Emerging Sciences

7.1 Course CS2007: Human-Computer Interaction

7.1.1 Description of the course

The course focuses on cognitive aspects of design, design thinking and evaluation of user interfaces. More specifically, it focuses on cognitive aspects of usability engineering, prototyping using wireframes, task analysis, user-centred design, conceptual models, metaphors, software design and game design. The above are applied in simple formal experiments to evaluate usability hypotheses. Upon completing the course, students will be able to design usable systems that are seamlessly integrated into everyday life and provide solutions. More specifically, students are able to use design thinking in problem-solving contexts, design application front-end prototypes using visual studio and wireframes, design applications and systems that comply with cognitive aspects of design and evaluate applications using multiple methods, including user testing.

7.1.2 Description of the participants

The course targets Bachelor of Science in Software Engineering program students. In the spring semester of the 2021 - 2022 academic year 110 students attended the course.

7.1.3 Description of gamified design thinking activities

A learning activity based on gamified design thinking was specifically designed for the course. The objective of the learning activity was to challenge students to design and deliver applications that more effectively address user interests. The activity was implemented as a semester project. Students were briefed about design thinking through a workshop in the 2nd week of the semester. Several tools and resources were used in the workshop to facilitate and better carry out the activities, including markers, A4 sheets, laptops and Microsoft® Word. A supervisor and researcher coordinated the workshop. Students worked in teams. Two sessions took place over the course of the week, each with a duration of 1 hour 15 minutes. Students submitted reports on assigned research questions at the end of each session. The activities included the following steps.

Step 1. Team building and empathy.

The workshop coordinator introduced students to design thinking. Students formed teams and were asked to introduce a team name and create a team logo. They worked on the team canvas, which included the documented goals, roles, skills, values, activities, and purpose of the team. The purpose of the canvas was to encourage team members to reflect on what and why they focused on. Subsequently, students performed creativity exercises. In this warmup activity, students were encouraged to think outside the box and create something useful with given shapes, such as a car, stick person, broom, hospital, etc. Finally, students documented in a map the activities each team member worked on and developed individual texts on their talents and strengths that could support the team to succeed.

Step 2. Problem assignment.

The high-level theme of the workshop was sustainable food production. The workshop coordinator introduced the topic and described it by saying that there is limited land available for food production, with the rapidly increasing world population resulting in a rapidly increasing demand for food production, while traditional methods are just not enough to meet this increased demand.

Students looked into the problem space to discover design possibilities that might lead to a solution concentration. To accomplish this, team members had to agree on a single view of the design problem by identifying the most significant data. Each team selected a single problem and briefly described it.

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Co-funded by the Erasmus+ Programme of the European Union

Step 3. Problem discovery.

Different activities are carried out to formulate the problem with different perspectives by applying immersion, shadowing, and associations.

Students performed some problem-discovery exercises to help them understand that looking at a problem from different perspectives can contribute to designing an effective solution. Exercises included the neighbourhood watch, in which students walked around their neighbourhood alone and accompanied by specialists, such as an engineer, gardener or others, documenting each time what they saw. Another exercise was immersion, in which students followed user steps in a typical problem to understand their experiences. In the shadowing exercise, students followed around a non-expert, documenting memorable experiences, events that surprised them and information they discovered. In the establishing associations exercise, students documented 3 ideas related to each problem: the problem and people, the problem and places and the problem and feelings. They created a problem map in which they colour-coded problems with respect to feelings, locations and people. Finally, they researched the problem on the internet, describing it with images, text, video and links.

Next, students performed user observation exercises, which are also considered to be part of problem discovery. Exercises included interview preparation, in which students prepared questions in advance and interview documentation, in which each team interviewed different persons filling in an interview card. Students then created an empathy map describing a characteristic user and what the user sees, hears, thinks, feels, says, and does, all of which help document the pain and gain of the user.

Step 4. Point of view, ideation, and idea evaluation.

Based on the problem discovery phase results, students defined the problem they would like to focus on in a who-what-how statement. Subsequently, students generated ideas that addressed the problem statement. To be innovative, students were encouraged to consider different perspectives. Ideation exercises included listing an idea that starts from each letter of the alphabet. This solution could be implemented if resources were unlimited, a solution that could be implemented with very limited resources, namely 100 rupees, a solution that makes someone uncomfortable and a solution that can be implemented with magic, a code name for the technology.

Finally, students evaluated their ideas by selecting the most innovative, the most unlikely, the most reasonable or the simplest that can be turned into a prototype. Some of the ideas suggested by students include:

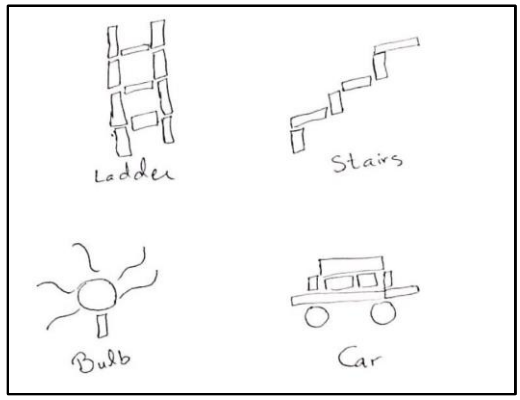
- Add more filter plants on farms.
- Buy more area.
- Create.
- Decrease time consumption in farming.
- Enhance the farming process.
- Fetch more seeds.
- Gain a competitive advantage by buying more land.
- Hire a farming consultant.
- Increase food production and profits.

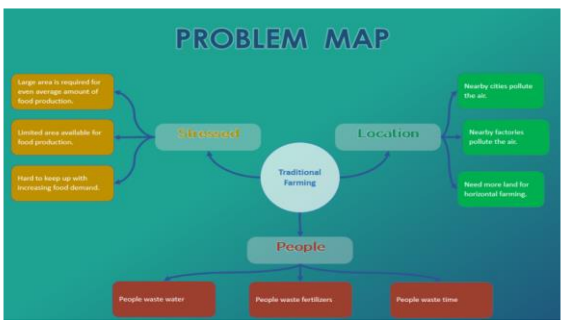
Step 5. Prototyping.

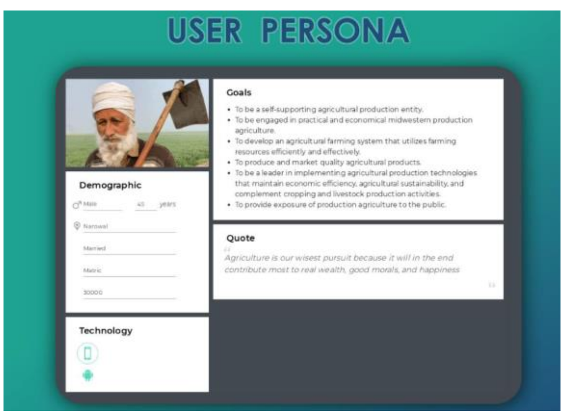
Students developed a tangible prototype of their solution of choice. The prototype was a manifestation of their theoretical idea into paper and tools. The selected idea was turned into a poster with different sections representing the entire design thinking process along with the problem statement and its solution.

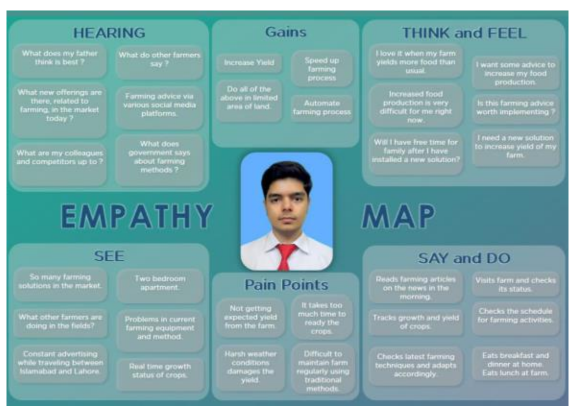
Step 6. Reflection.

Students reflected on their workshop engagement, including the most memorable experiences, the biggest surprises, and the discoveries that enhanced their learning.









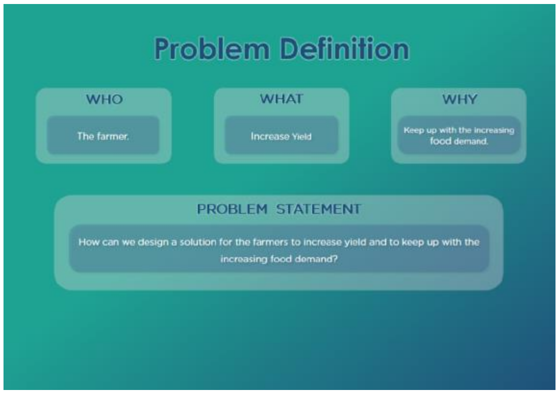


Figure 55. Logo creation, team canvas, problem map, interview preparation, user persona, empathy map, problem definition and solution poster of a project in the Human-Computer Interaction course, spring 2022.

7.2 Course CS5007: User Experience Design

7.2.1 Description of the course

The course introduces the exciting and growing field of UX research and design. It aims to equip students with the theoretical and practical foundations of integrating UX research and UX design to create great products through understanding user needs, rapidly generating prototypes, and evaluating design concepts. Students gain hands-on experience with taking a product from the initial concept, through user research, ideation and refinement, formal analysis, prototyping, and user testing, applying perspectives and methods to ensure a great user experience at every step. After completion of the course, the students are able to understand how UX research and design techniques can contribute to a better understanding of user needs and create a great user experience, incorporate UX research and design methods to design a complete product from an initial concept to an interactive prototype, apply a human-centred design process in the conception, design, prototyping, and evaluation of the real product, independently research topics in UX design, research, and latest trends and formally present the project-work to the peers, apply and evaluate the state of the art UX design and research tools and practices related to the emerging areas of web, mobile, and related technologies such as smart and wearable devices, and execute a complete UX project from ideation to design, prototype, and evaluation while working in a team and using the skills and knowledge gained through the course.

7.2.2 Description of the participants

A total of 115 students attended the course in spring 2021. The students were enrolled in the Bachelor of Science in Computer Science, Software Engineering, Artificial Intelligence, and Cyber Security programs.

7.2.3 Description of gamified design thinking activities

Design thinking was integrated into the course's semester project. Students worked in groups of 3 individuals. Work was divided into the following steps.

Step 1. Empathy.

Students were instructed to use design thinking as the project design methodology. Students were given an overview of the design thinking process. They were asked to select the problem area to work on, such as the crowd in the cafeteria during peak hours. They were further instructed to select a sub-problem area using association techniques and to associate the topic of their choice to 3 people, 3 locations, and 3 feelings. Subsequently, students narrowed the problem to a specific area and selected a suitable problem title.

Students narrowed down their stakeholder groups and identified characteristic users, primary and secondary. They created a user profile, added a name, and also had the option of adding a picture to describe the target group. They developed a demographic profile, including personal backgrounds, professional backgrounds, user environments, physical, social, and technological, and psychographics, such as attitudes, interests, motivations, and pain points), and user objectives in using their solution.

Students developed a plan to discover user needs information, including tools such as interviews. They created a feature list of users' problems, issues, wishes, and wants.

Upon completing this step, students submitted the project title, associations, user persona, information discovery plan, feature lists, and user wishes and wants.

Step 2. Problem definition.

Students used the outcomes of their research in the previous step to identify user needs and accurately define their problem. For example, suppose interviews highlighted that the user is a technically savvy student who is facing issues in synchronizing reminders on her different calendars for different events. In that case, students may conclude that the user needs a full daily task scheduling solution, which includes setting reminders that help her remember appointments from a single point of access. Upon completion of this step, students submitted the project scope and objectives. They converted the desirable feature list for their solution into user stories using a standard format. They were encouraged to include prototype designs where necessary in the story cards on how the screen would appear in their solution. To achieve these goals, students used the popular applications Figma® and Wireframe®.

Step 3. Ideation.

Students were challenged to generate ideas for addressing the user's pain. They applied brainwriting, a brainstorming technique in which team members write down their thoughts. For example, suppose the problem in focus is that users cannot separate degradable from non-degradable waste. In that case, a potential solution is an app that informs the user of the nature of each item. Upon completion of this step, students submitted their ideas.

Step 4. Prototyping.

Students were challenged to create rough prototypes for their solutions. The prototypes would be accepted, improved, re-examined, or rejected based on user experiences. Students used

Figma® or Justinmind® to prototype the user experience. They were instructed to consider interaction design principles, design rules, cognitive aspects, and multimodal interaction for all kinds of users. For example, they must ensure their solution is accessible to visually impaired individuals.

Step 5. Evaluation and reporting.

Students were instructed to test prototypes using Nielson's heuristics and revise their solutions and tools, such as usability review questionnaires.

Problem	Ideas (each team member) Note: idea could be in the form of a picture	What ifs (against each idea)	Crowd storming results
I am hugely bugged by the garbage collection method used by our cleaners. There is no concept of keeping degradable stuff separate from non- biodegradable.	idea 1: an app that categorizes the garbage into biodegradable and non-biodegradable stuff by analyzing garbage pictures. Idea 2: an app with a list of all the possible items that tells you if it is degradable or not.	**What if** the item is not in the list? **What if** the picture is not clear enough?	@FB Question posted: same as problem Options provided same as ideas Results: 80% voted for idea 1 20% asked for intelligent bins

Figure 56. Student ideas documented through brainwriting in the User Experience Design course, spring 2021.

7.3 Course SE5007: Research Methodology

7.3.1 Description of the course

This course teaches the basics of research methodology. Topics include introduction to research, types of research, literature review and its types, and research designs and descriptions. The course prepares students to conduct a literature review for their thesis by performing mock exercises on given topics. The course further addresses the rules of scientific writing applied when preparing research proposals or papers. At the end of the course, students are expected to submit a research proposal including a viable research problem statement, research design and literature review.

7.3.2 Description of the participants

This course is mandatory for Masters and PhD students. In the spring 2022 semester, it was attended by 42 students enrolled in Master’s degrees and 4 PhD students. The students were mostly enrolled in the Software Engineering and Computer Science Departments.

7.3.3 Description of gamified design thinking activities

For this course, using design thinking as a teaching and learning method was very unconventional. At the start of the course, students were introduced to design thinking activities in the context of a workshop. Later, during the course, students were encouraged to use design thinking to identify their research problem and propose solution ideas. The focus of student work was not on solution authentication but on learning the design thinking process. Students used design thinking steps to identify a research problem and to ideate on possible solutions stemming from their literature review.

Students worked on a semester-long project organized around design thinking principles and steps.

Step 1. Identifying a research problem and developing a definition of the problem statement.

Students identified a research problem based on their early literature review and developed a problem statement.

Step 2. Developing a research design.

Students were asked to develop a research design to solve the problem in focus. To achieve this, they extended the literature review.

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Step 3. Solution synthesis.

Students were asked to synthesize a solution to their research problem and demonstrate it through any possible method. Some students presented their solutions through prototypes, while others used mock experiments.

Figure 57. Students work on Research Methodology course projects, spring 2022.

7.4 Course SE5007: Responsible Design

7.4.1 Description of the course

The course teaches responsibility in design. It focuses on high, low, and user interface design concepts. Topics addressed include responsible design, security, safety, privacy, and other usability-related concepts such as architectural design, object-oriented design, and interface design.

7.4.2 Description of the participants

The course is an elective for Master's students. In the spring 2023 semester, it was attended by 35 students in the final semester of their studies enrolled in all departments of the School of

Computing, namely Software Engineering, Data Science, Cyber Security, and AI. 1 PhD student further attended the course.

7.4.3 Description of gamified design thinking activities

Students were introduced to design thinking principles through a workshop. Later, during the course, students were encouraged to use design thinking to identify a research problem and propose its solution ideas. The students were free to choose any design problem from their domain of study related to aspects such as architectural design, usability, security, safety, or privacy. Most students opted to work on issues relevant to large language models (LLMs). For instance, the bias in LLMs or how to cater to privacy issues in social media applications.

Students worked on a semester-long project organized around design thinking principles and steps.

Step 1. Identifying a research problem and develop a definition of the problem statement.

Students identified a research problem based on their early literature review and developed a problem statement.

Step 2. Developing a research design.

Students were asked to develop a research design to solve the problem in focus. To achieve this, they extended the literature review.

Step 3. Solution synthesis.

Students were asked to synthesize a solution to their research problem and demonstrate it through any possible method. Students opted to present their solutions through position papers and mock experiments.

Figure 58. Students collaborate in the Responsible Design course, spring 2023.

7.5 Course SE1001: Introduction to Software Engineering

7.5.1 Description of the course

This course introduces students to the fundamental principles and methodologies of Software Engineering. It covers traditional and modern software development life cycle stages with practical examples and case studies. Topics include design, architecture, testing, project management, and software process improvement models.

7.5.2 Description of the participants

The course is mandatory for 1st-year undergraduate students enrolled in Software Engineering. In the spring 2023 semester, 250 students attended the course divided into 6 sections.

7.5.3 Description of the Gamified Design Thinking Activities

Students were introduced to design thinking principles through a workshop. Later, during the course, students were encouraged to use design thinking to identify the topic of their course

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project and propose solutions. They combined design thinking with agile SCRUM practices to develop software solutions.

Students worked on a semester-long project organized around design thinking principles and steps.

Step 1. Identifying a research problem and develop a definition of the problem statement.

Students identified a research problem through hands-on, collaborative activities.

Step 2. Ideation.

Students generated a rich pool of ideas towards solving the problem in focus. They engaged in ideation exercises, such as identifying solutions that start from each alphabet letter.

Step 3. Solution synthesis.

Students were asked to synthesize a solution to their research problem and demonstrate it through any possible method. Students opted to present their solutions through prototypes.

Figure 59. Students collaborate in the Software Engineering course, spring 2023.

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8. ISRA University

8.1 Course: Operating Systems

8.1.1 Description of the course

The course is an introduction to concepts of operating systems. The course develops an understanding of design and implementation issues of operating systems. Students develop knowledge of operating system components, their function, design and implementation. Concepts discussed include process management, process synchronization, memory management, storage management, file systems, security and management.

8.1.2 Description of the participants

This course is compulsory for students in Software Engineering, Computer Science and Information Technology. The course is offered in the 2nd year of studies in the Department of Computer Science, ISRA University, Hyderabad, Pakistan. In the July 2022 semester, 39 students attended the course.

8.1.3 Description of gamified design thinking activities

Students were challenged to implement different operating system tasks/processes as small projects. These activities were carried out in groups of students during classes and practical lab hours throughout the semester. Students were asked to choose any OS process/problem to work on.

Step 1. Problem discovery.

Students were challenged to research a problem area of their interest and select an activity for implementation in operating systems management. For example, one group opted to work on concurrency in C++ programs; students were challenged to discover whether there was any possibility of executing two programs concurrently in a given scenario. Another group chose to implement a file copy command in the command-line interface.

Step 2. Problem re-definition.

Students were challenged to re-define the problem, namely the operating system process, which they opted to implement in the problem discovery phase. They were asked to observe different operating systems, including Windows®, Linux® and Android® with reference to their problem. They were asked to re-define and document the problem in their own words.

Step 3. Ideation.

Students were challenged to research and synthesize solutions to their well-defined problems. For example, in the case of concurrency implementation, students were challenged to find out which system calls can be used for such tasks and how, in C++, those system calls can be integrated into a program. Further, they were asked to develop algorithms for solving the problem in focus as per definition requirements.

Step 4. Prototyping.

Students developed a model prototype that constituted an implementation of the algorithms they defined in the ideation phase by using library interfaces wherever required. These prototypes implemented operating system processes, such as concurrency, file copying and kernel module development for Linux®.

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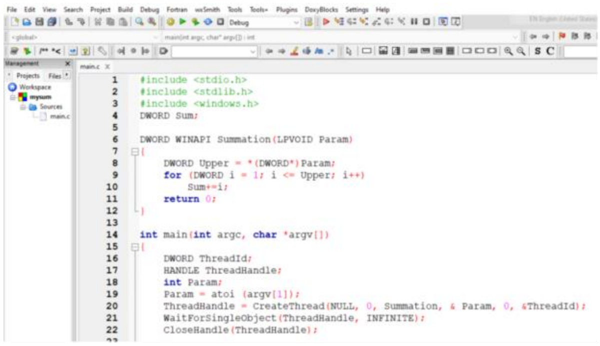

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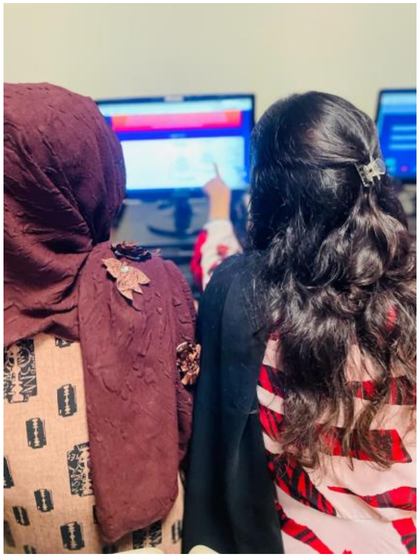

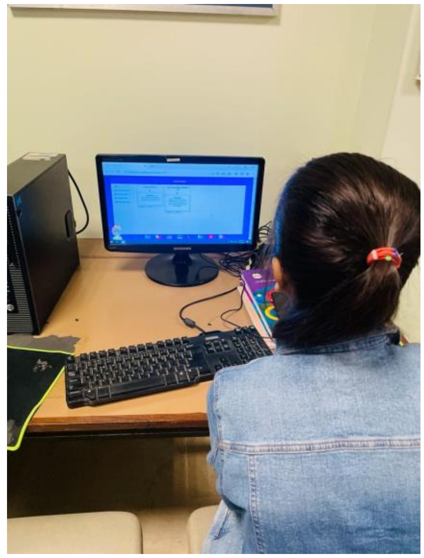

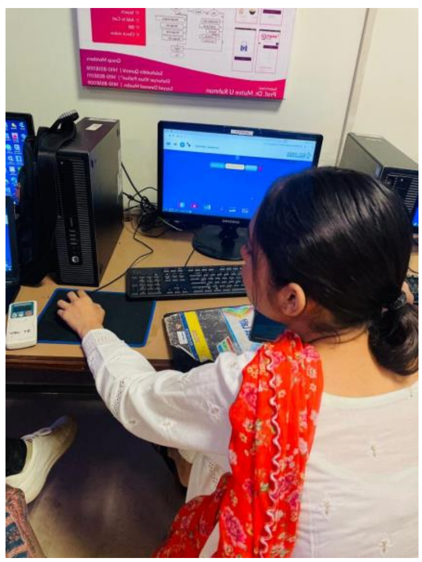

Figure 60. Students collaborate in the Operating Systems course, July 2022.

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8.2 Course: Formal Methods in Software Engineering

8.2.1 Description of the course

The course is an introduction to formal methods applied in Software Engineering. The course builds an understanding of how formal methods help produce high-quality software. The course further addresses formal modelling and specification languages in general and Alloy® in particular. Students develop knowledge on extracting and documenting formal requirement specifications and how these specifications can be used for validation and verification of different components of a software system during software engineering phases. The focus is also on automated verification of formal specifications to ensure system correctness.

8.2.2 Description of the participants

This is a compulsory course for Software Engineering students and an optional course for Computer Science and Information Technology students. The course is offered in the 4th year of studies in the Department of Computer Science, ISRA University, Hyderabad, Pakistan. In the July 2022 semester, 35 students attended the course.

8.2.3 Description of gamified design thinking activities

Students were asked to develop and verify simple static models of data representations, or instances, in Alloy®. Students were further challenged to identify constraints, overcome problems in instances, and revisit models to integrate new constraints. Students regenerated and rechecked instances for errors. The process continued incrementally until no errors were identified in the models. Students worked in groups of 3 individuals. Activities were organized in the following steps.

Step 1. Problem discovery.

Students were challenged to reflect on how a simple-looking static model can be erroneous. They were asked to design a simple relational model representing data items in any data structure. Initially, students designed and represented the model in Alloy® format. Subsequently, they were asked to develop test cases for model verification and compare them with Alloy® generated model instances. They were then asked to describe the problems they found in their designed models.

Step 2. Problem re-definition.

Students were challenged to re-define their model, focusing on the problems they identified in the problem discovery phase by defining constraints for every issue they identified. They were asked to redefine their model with formal specifications while considering new constraints to ensure correctness.

Step 3. Ideation.

Students were challenged to introduce as many ideas as possible towards defining constraints. They were asked to define constraints differently, for example, by representing the same constraint in different logical equations supported in Alloy®. They were asked to define the constraints as facts in the model and verify these facts as assertions. They were further challenged to consider different solutions for problems they encountered. Students discussed different constraint definitions and formed equations or formulas. They were finally asked to remove the functionally duplicate constraints for optimization.

Step 4. Prototyping.

Students defined a model prototype with facts representing constraints in the Alloy® Analyzer environment. They developed formal model definition scripts. Prototype models were static data structures or types representations in specific software engineering solutions.

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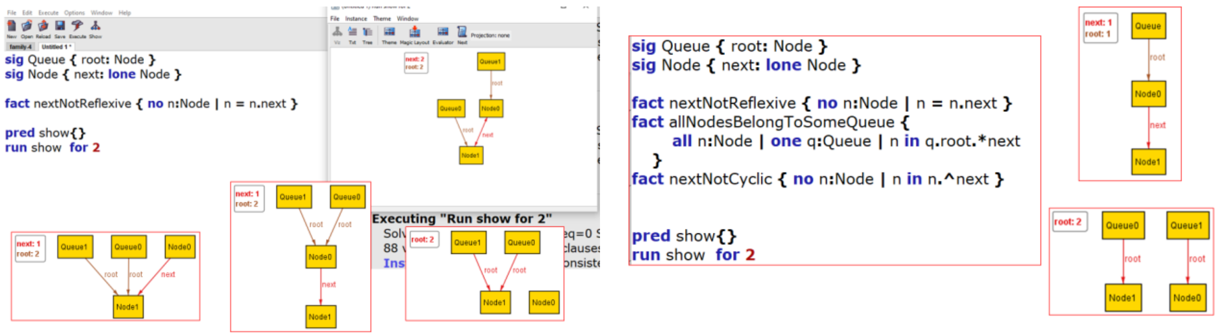

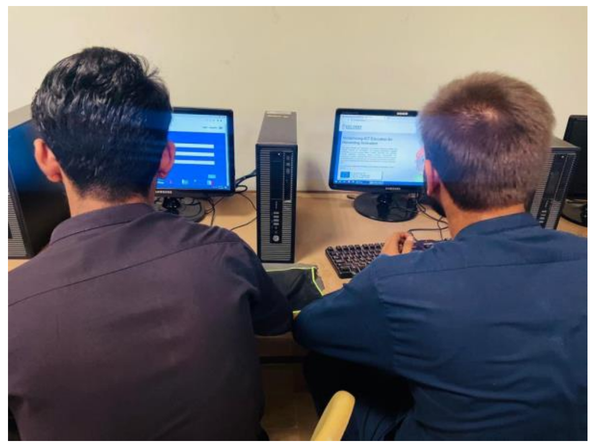

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Figure 61. Students collaborate in the Formal Methods in Software Engineering course, July 2022.

8.3 Course: Human-Computer Interaction

8.3.1 Description of the course

The course introduces students to analysing, designing, and evaluating the interaction between people and information and communication technologies. The aim is to give students an adequate understanding of usability, user experience, and user-centred design concepts.

8.3.2 Description of the participants

This course is compulsory for Computer Science, Software Engineering, and Information Technology students. The course is offered in the 3rd year of studies in the Department of Computer Science, ISRA University, Hyderabad, Pakistan. In the July 2023 semester, the course is attended by 36 students.

8.3.3 Description of gamified design thinking activities

In Human-Computer Interaction (HCI), gamified design thinking activities were introduced as a semester project, combining design thinking principles with the engaging elements of gamification to create an interactive and immersive learning experience for students. This semester project aimed to enhance the students' understanding of design concepts, problem-solving skills, and creativity while making the learning process enjoyable and rewarding.

Students were introduced to various design thinking methodologies and principles throughout the semester, such as empathy, ideation, prototyping, and testing. The project was divided into several stages, each representing a specific phase of the design thinking process.

Step 1. Problem discovery.

In problem discovery, students were challenged to research the world of visual programming by exploring different programming constructs and tools. They gained a solid understanding of the fundamental concepts and techniques required for creating interactive visual applications.

Step 2. Problem re-definition.

Students focused on understanding the needs and preferences of potential users or clients. They were engaged in activities such as conducting user interviews, creating personas, and analyzing user feedback. These activities helped students develop empathy for their target audience and gain insights into their motivations, pain points, and desired outcomes.

Step 3. Ideation.

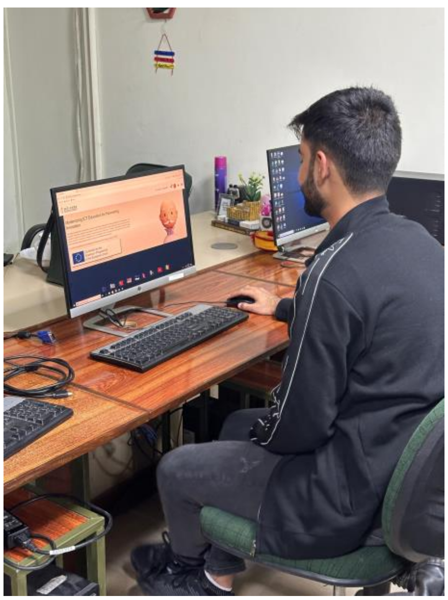
Students participated in brainstorming sessions and collaborative activities to generate innovative ideas for their human-computer interaction projects. They learned techniques like mind mapping, mood boards, sketching, and rapid prototyping to translate their ideas into tangible concepts and designs.

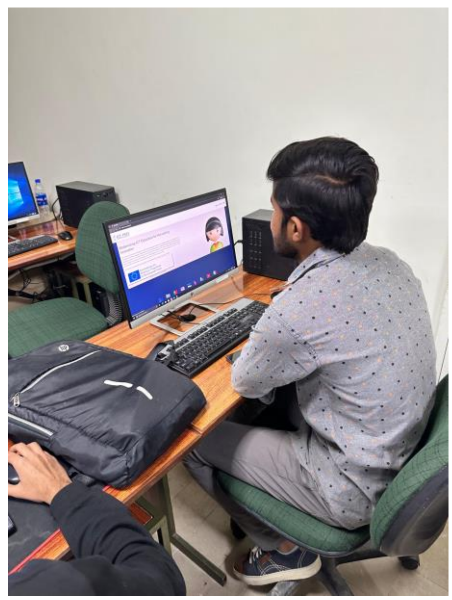
Step 4. Prototyping.

Students brought their ideas to life by creating interactive prototypes of their human-computer interaction projects. They utilized appropriate Figma® to develop functional prototypes that showcase their designs' core features and functionalities.

Step 5. Testing.

Students showcased the interactive prototypes of their human-computer interaction projects and conducted user testing sessions to gather feedback on the prototypes from the target users. They observed how users interacted with the prototypes and gathered insights into what works well and needs improvement. Students also improved their design based on feedback, making necessary refinements and adjustments to improve usability and address any identified issues.






MOVIE THEATRE APP
American SteakHouse App
Chanda Bai
AMARTA DEVI


THE FUN FACTORY
KUSHAM KUMARI

Figure 62. Students collaborate in the Human-Computer Interaction course, July 2023.

8.4 Course: Software Project Management

8.4.1 Description of the course

The course introduces the primary project management concepts related to managing software development projects. Students also become familiar with the different activities involved in software project management. They build knowledge on how to plan and implement a software project management activity successfully and to complete a specific project in time with the available budget.

8.4.2 Description of the participants

This is a compulsory course for Software Engineering and Information Technology students and an optional course for Computer Science students. The course is offered in the 4th year of studies in the Department of Computer Science, ISRA University, Hyderabad, Pakistan. In the January 2023 semester, 54 students attended the course.

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8.4.3 Description of gamified design thinking activities

Students were asked to select a software project of their choice and write the scope and objectives for this project. They were also tasked to develop a work breakdown structure (WBS) for their chosen project. These activities were carried out in groups of students during classes throughout the semester. Students worked in teams of 3 individuals. Work was organized as follows.

Step 1. Problem discovery.

Students were challenged to research the problem area of their interest. Teams engaged in interactive activities to provide background information on their chosen project, including its purpose, vision, and strategic objectives. Activities helped students to develop a shared understanding of the project's context and set the foundation for the subsequent activities.

Step 2. Problem re-definition.

Students were challenged to redefine their chosen project in the problem-discovery phase. They were asked to observe relevant work. They were asked to redefine and document the scope and objectives of their project in their own words.

Step 3. Ideation.

Participants engaged in gamified brainstorming sessions and idea-generation games. The gamification elements incorporated into these activities, such as time pressure, scoring systems, and competitive challenges, encouraged students to think creatively, explore diverse perspectives, and generate innovative ideas for the project scope and objectives.

Step 4. Prototyping.

Students developed the work breakdown structure (WES) of the project they defined in the ideation phase. The purpose of the activities was to help students break down the project's scope and objectives into manageable tasks and sub-tasks. Students participated in interactive exercises and card sorting games. They used collaborative software tools designed to facilitate the creation of a hierarchical WBS.

Figure 63. Students collaborate in the Software Project Management course, spring 2023.

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8.5 Course: Visual Programming

8.5.1 Description of the course

The course introduces computer programming using Visual Basic®, an object-oriented net programming language. Emphasis is placed on event-driven programming methods, including creating and manipulating object classes and using object-oriented tools such as the class debugger. Upon completing the course, students could design, code, test, and debug at a beginning level.

8.5.2 Description of the participants

This course is optional for Computer Science, Software Engineering and Information Technology students. The course is offered in the 3rd year of studies in the Department of Computer Science, ISRA University, Hyderabad, Pakistan. In the spring 2023 semester, 36 students attended the course.

8.5.3 Description of gamified design thinking activities

Gamified design thinking activities were introduced as a semester project that combined design thinking principles with the engaging elements of gamification to create an interactive and immersive learning experience for students in visual programming. This semester's project aimed to enhance student understanding of design concepts, problem-solving skills, and creativity while making the learning process enjoyable and rewarding.

Students were introduced to various design thinking methodologies and principles throughout the semester, such as empathy, ideation, prototyping, and testing. The project was divided into several stages, each representing a specific phase of the design thinking process.

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Step 1. Problem discovery.

Students were challenged to research the world of visual programming by exploring different programming constructs and tools. They gained a solid understanding of the fundamental concepts and techniques required for creating interactive visual applications.

Step 2. Problem re-definition.

Students focused on understanding the needs and preferences of potential users or clients. They were engaged in activities such as conducting user interviews, creating personas, and analyzing user feedback. These activities helped students develop empathy for their target audience and gain insights into their motivations, pain points, and desired outcomes.

Step 3. Ideation.

Students participated in brainstorming sessions and collaborative activities to generate innovative ideas for their visual programming projects. They learned techniques like mind mapping, sketching, and rapid prototyping to translate their ideas into tangible concepts and designs.

Step 4. Prototyping.

Students brought their ideas to life by creating interactive prototypes of their visual programming projects. They utilized appropriate Visual Basic® tools to develop functional prototypes that showcase their designs' core features and functionalities.

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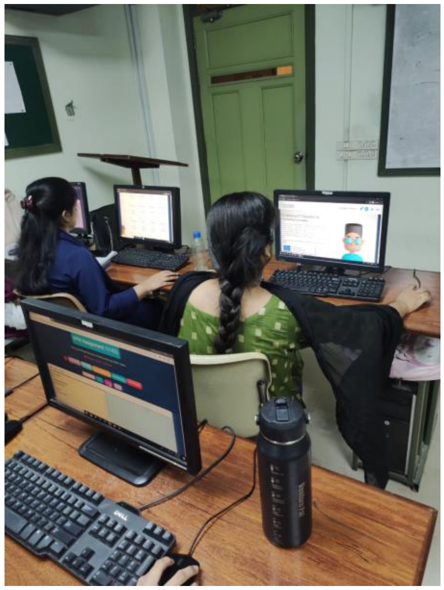

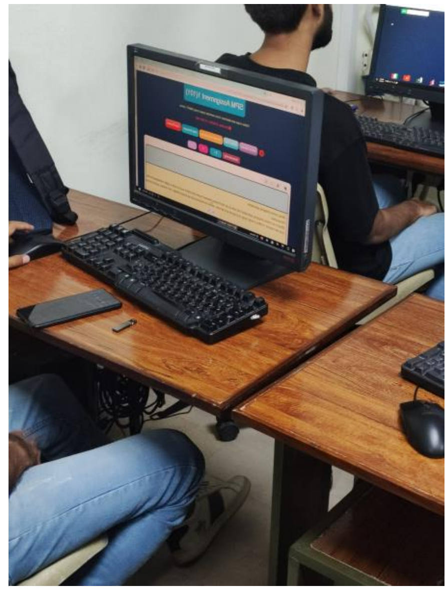

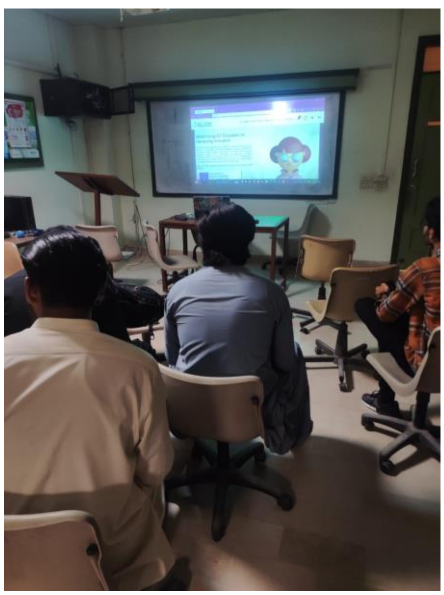

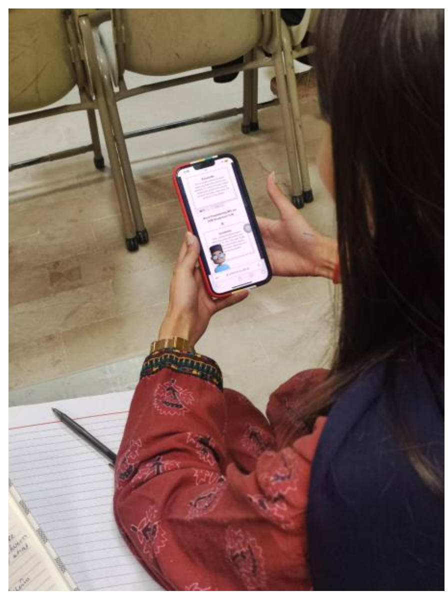

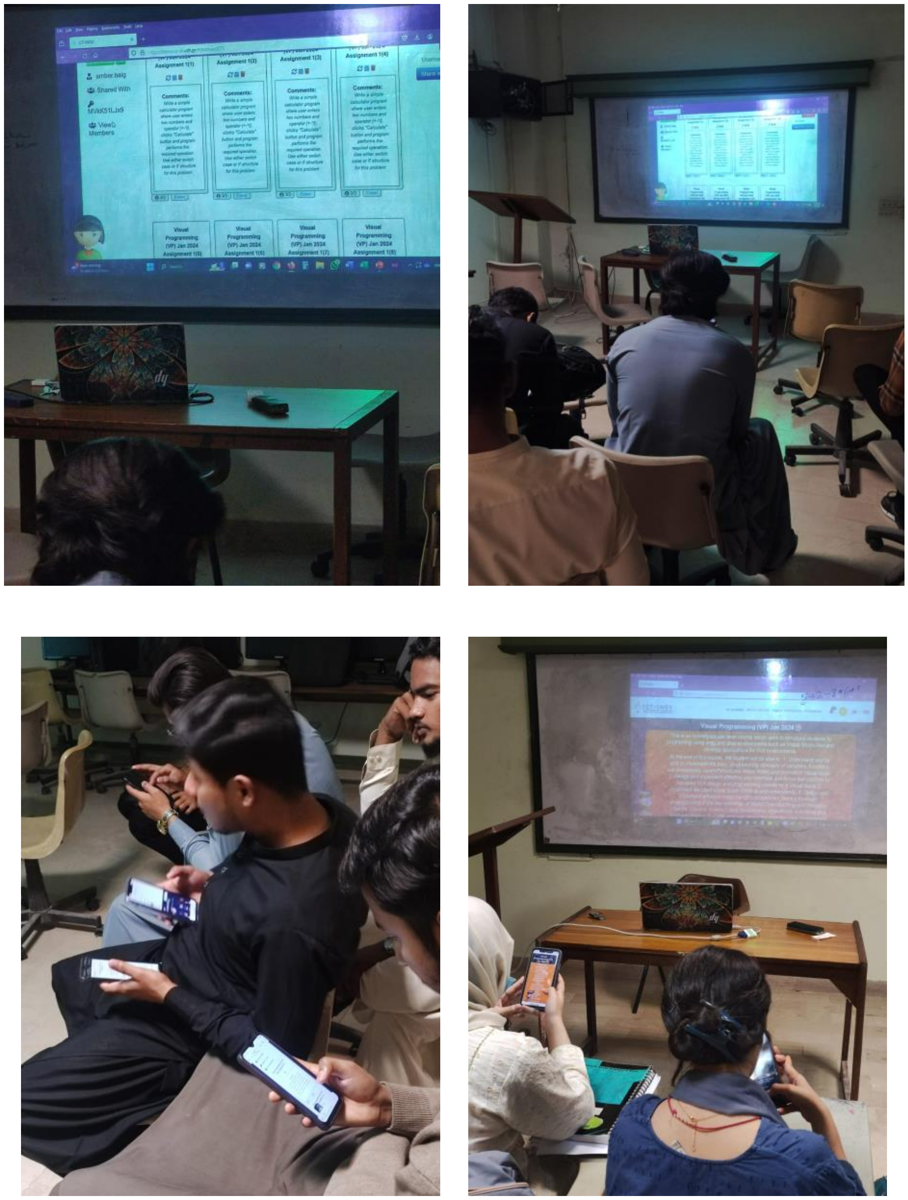

Figure 64. Students collaborate in the Visual Programming course, spring 2023.

8.6 Course: Artificial Intelligence

8.6.1 Description of the course

The course is an introduction to artificial intelligence (AI), machine, and deep learning concepts. The Focus is to understand AI systems' working, design, and implementation issues. Students are expected to learn about data engineering, building machine learning models, and using these models. Course topics include machine learning, deep learning, AI in computer vision, natural language processing, CNNs, RNNs, machine and deep learning libraries, sequences and time series data, and using AI models.

8.6.2 Description of the participants

This is a compulsory course for Computer Science students. At the same time, it is an elective for Software Engineering and Information Technology students. The course is offered in the 3rd and final year of studies in the Department of Computer Science, ISRA University, Hyderabad, Pakistan. In the spring 2024 semester, 33 students attended the course.

8.6.3 Description of gamified design thinking activities

Students were challenged to answer what, why, and how questions in different machine-learning problem scenarios. They were asked to go through the design thinking process, which included empathy, ideation, and testing of their answers in the above context. These activities were carried out in groups of students during classes and practical lab hours throughout the semester. Through the following steps, students were also asked to perform design thinking activities on the ICT-INOV digital learning platform.

Step 1. Problem discovery.

Students were challenged to research a machine learning problem area of their interest. They were asked to identify an image classification problem, such as identifying types of animals, recognizing handwritten digits, or detecting objects in images.

Step 2. Ideation.

Students were asked to redefine the problem considering the Exact-Load-Transform process. This included defining data extraction and preprocessing, loading data into the model, and transforming the output for analysis.

Step 3. Prototyping.

Students were required to draw and explain the key components of their solution, the component interactions, and the interface of their solution. The overall flow of the application was defined through suitable tools.

Step 4. Data preparation, training, testing, and evaluation.

Students gathered and preprocessed datasets relevant to their image classification problem. This process included data collection, cleaning, augmentation, and splitting into training, validation, and testing sets.

Subsequently, students software coded their solution using appropriate libraries and frameworks, such as TensorFlow® or PyTorch®. They created a neural network model, defined its architecture, and incorporated data preprocessing steps.

Finally, students trained the model, tested its performance on unseen data, and evaluated their solution using the pre-prepared datasets concerning accuracy, precision, recall, and other relevant metrics. Students performed this process in iterations, fine-tuning parameters to improve performance.

Step 5. Pitching.

Students pitched their solutions as potential startup idea.

Figure 65. Students work with the ICT-INOV digital learning platform in the Artificial Intelligence course, spring 2024.

8.7 Course: Final Year Project

8.7.1 Description of the course

This course is about applying theoretical knowledge acquired by students throughout their studies to a real-world project and to enhance technical skills by working on a project that involves programming, software development, or other technical aspects. Students conduct research to explore existing solutions, analyze relevant literature, and understand the state-of-the-art in the chosen problem domain. The project fosters teamwork and collaboration. Students are encouraged to work with peers, mentors, or industry partners. Students develop skills in documenting the project work, writing a comprehensive report, and effectively communicating project outcomes. They are required to develop a functional prototype or system that addresses the identified problem. Students are expected to deliver a well-documented codebase accompanied by user and technical documentation. They present the results of rigorous testing and evaluation, demonstrating the effectiveness and efficiency of the solution.

8.7.2 Description of the participants

This course is compulsory for Computer Science, Software Engineering, and Information Technology students. The course is offered in the final year of studies in the Department of Computer Science, ISRA University, Hyderabad, Pakistan. In the spring 2024 semester the course was attended by 24 students.

8.7.3 Description of gamified design thinking activities

Students were challenged in different phases of the design thinking process, including empathy, ideation, prototyping, and testing. They were asked to refine their ideas, define the ideas, convert their thought process into paper prototypes, code the solutions, and evaluate their solution.

These activities were carried out in groups. Throughout the process, students used the ICT-INOV digital learning platform for collaboration.

Step 1. Empathy and problem discovery.

Students were asked to identify a broad area of interest within their field of study. They conducted thorough research through literature reviews, industry reports, and expert consultations to understand existing solutions and potential gaps.

Next, students worked on research on user needs. They were encouraged to not only focus on technical aspects. Rather, to conduct user research through surveys, interviews, and observations to gain insights into the target audience's needs, challenges, and pain points.

Using the results of their research, students next clearly defined the specific problem that their project aimed to address. They were encouraged to try to answer questions of the type "what, why, and how@ in the context of the identified problem, for example: What is the problem? Why is the problem happening? How are they going to solve the problem?

Step 2. Ideation.

Students were asked to define their solution and answer "what, why, and how" questions again in the context of solution development, for example: What is the solution? How is the solution going to work? Why is this solution selected? The overall context of the ideation phase was to clearly define the solution and its architectural components.

Step 3. Paper prototyping.

Students were required to draw and explain the key components of their solution, the components interactions, and the interface of their applications. They defined the overall flow of the application through suitable tools.

Step 4. Data preparation, training, testing, and evaluation.

Students implemented their solution through software code, using the principles and ideas they identified in the ideation and prototyping stages. They used appropriate software libraries and frameworks.

Step 5. Pitching.

Students pitched their solutions as potential startup ideas.

Figure 66. Students use the ICT-INOV digital learning platform in the Final Project Course, spring 2024.

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9. Kathmandu University

9.1 Course COMP342: Computer Graphics

9.1.1 Description of the course

The course covers basic concepts, mathematical foundations, fundamental theory, algorithms, software techniques, hardware and system issues, and application examples of computer graphics. The main topics are modelling, rendering, and interaction. Learning is delivered through lectures and through practical hands-on activities that take place in computer labs. The practical activities encourage students to apply their theoretical knowledge to real-life problems. Upon completion of the course students are familiar with basic computer graphics techniques and their application in the field of animation.

9.1.2 Description of the participants

The course is compulsory in the 6th semester of the Bachelor in Computer Science program of the formal curriculum of the Department of Computer Science and Engineering of Kathmandu University. 59 students enrolled in the course in the 2022 – 2023 academic year.

9.1.3 Description of gamified design thinking activities

Students solved mathematical problems related to Computer Graphics in tutorial classes. The course included biweekly laboratory work, in which students implemented the algorithms taught in lectures to solve real-life problems and build games. At the end of the course, students were asked to submit a mini project based on which they applied theoretical course concepts in Computer Graphics. Students applied design thinking in project work. Examples of projects implemented by students include:

- Terrain generation using Perlin Noise.

- Sorting visualization.
- Space invaders using Pygame® and Pyopengl®.
- Visualizing 3D structure of the protein with a protein data bank file.
- Maze game.
- Black hole visualization in 2D space.
- Rotating cube in 3D space.
- Bouncing ball using OpenGL.
- Sorting algorithm visualizer.
- Stack.
- Rotating diamond.
- Smart village.
- Racing game.
- Interactive trigonometric visualization.

Students were encouraged to access the physical lab developed through the ICT-INOV project and use the digital learning platform for collaboration. They worked in groups of 1 to 2 individuals. The ICT-INOV educational platform provided instructors with flexibility in structuring the learning activities based on well-accepted design thinking steps.

Step 1: Team building.

Students were asked to form groups and select their mini-project's topic. As the class is comprised of 59 students, each group includes 1 to 2 members. After selecting the team members, students were asked to choose a team name and an identity-related activity. A total of 30 groups were formed, and each of them selected their team's name.

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Step 2: Understanding the problem and developing game plots and scenarios.

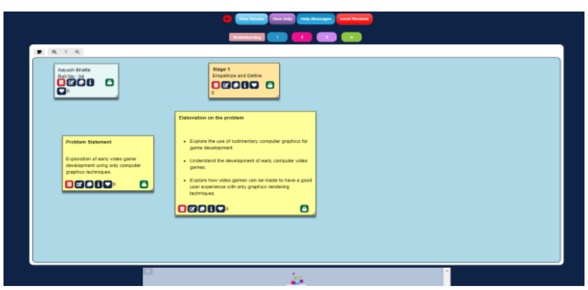
Students performed research and brainstormed towards solving the identified problem using a graphical approach. Teams that focused on game design introduced the game plots at this stage. Teams that focused on problem-solving developed a case scenario.

Step 3: Prototyping the obtained concept.

Students implemented their solutions using their chosen programming language and graphical libraries.

Step 4: Presenting the developed work.

Students presented the results of their work to faculty members.



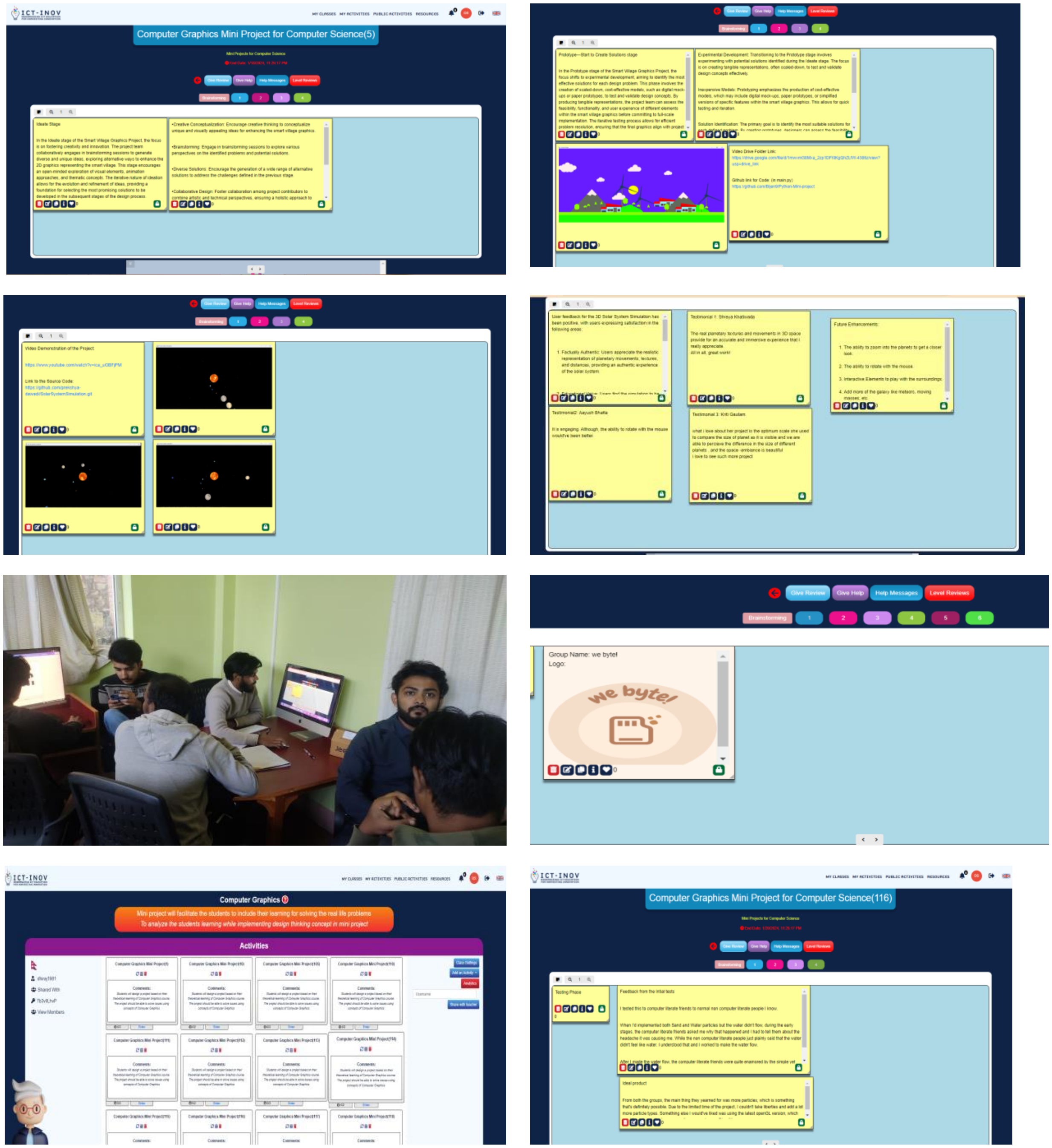


Figure 67. Students use the ICT-INOV digital learning platform in the Computer Graphics course, fall 2022.

9.2 Course COMP315: Computer Architecture and Organization

9.2.1 Description of the course

The course aims to develop knowledge of computer architecture concepts as well as computer organization and design. The course addresses designing basic computers, central processing units, control units, input and output organization, and memory organization. Prerequisites of the course are Digital logic and Microprocessors. In the context of project ICT-INOV, the course has been updated to include principles for design thinking. Students deploy design thinking to implement the internal architecture of a computer system based on group work.

9.2.2 Description of the participants

The course is mandatory in the 5th semester of undergraduate studies at the Department of Mathematics of Kathmandu University. The ICT-INOV gamified design thinking methodology was deployed in July 2022. A total of 22 undergraduate students from the Department of Mathematics engaged in the activities.

9.2.3 Description of gamified design thinking activities

A learning activity was designed for the course following the design thinking paradigm. The primary objective of integrating design thinking was to make the students work in a group to achieve a common goal. The students were asked to design a computer system based on the theoretical knowledge they had gained through lectures and practical classes. The students were encouraged to access the physical lab developed through the ICT-INOV project and use the digital learning platform for collaboration. They worked in groups of 1 to 2 individuals. The ICT-INOV educational platform provided instructors with flexibility in structuring the learning activities based on well-accepted design thinking steps.

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Step 1: Team building.

Students were asked to form groups. As the class is comprised by 22 students, each group included a maximum of 2 students, while one group included 3 students. After forming teams, students were asked to introduce a group name and to design a group logo. A total of 11 groups were formed.

Step 2: Understanding the problem and identifying the solution.

Students were asked to perform research to understand the problem in more detail. Students created lists of the issues that needed to be addressed while solving the problem and posted them on the ICT-INOV digital learning platform.

Step 3: Brainstorming for possible solutions and selecting the best solution based on consensus.

Upon developing a deeper understanding of the problem, students engaged in a brainstorming session discussing possible solutions. The outcome of this session was multiple potential solutions for addressing their identified problem. After listing the possible solutions, students engaged in rigorous discussions with their team members to identify the most promising solution, namely one that was innovative and could be implemented with available resources.

Step 4: Identifying the list of hardware components necessary for solution design.

Students identified the list of equipment needed for designing the solution.

Step 5: Prototyping the system based on the identified solutions.

Students developed a prototype system using Nand to Tetris® software or paper.

Step 6: Presenting the solution.

Students presented the results of their work to faculty members.

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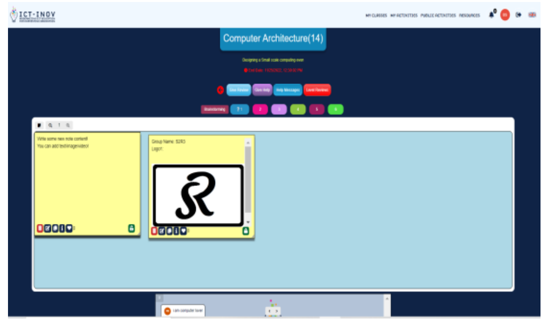
Computer Architecture and Organization
Activities

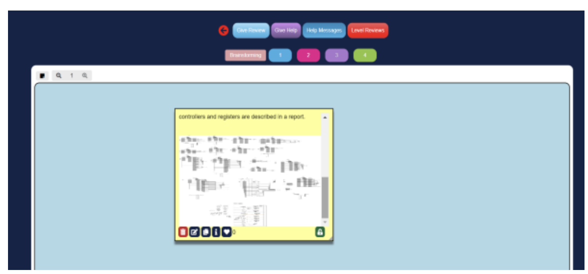

Computer Architecture(14)

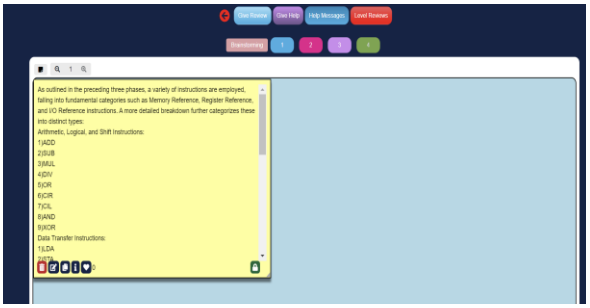

Computer Architecture Mini Project for CE(Group-4)

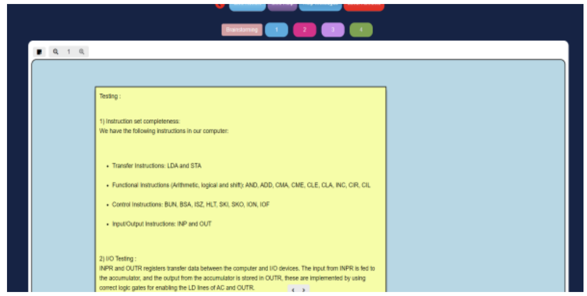

Computer Architecture Mini Project for CE(Group-11)

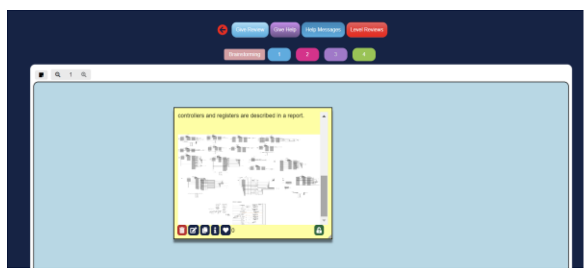

Computer Architecture Mini Project for CE(Group-4)


Computer Architecture Mini Project for CE(Group-11)









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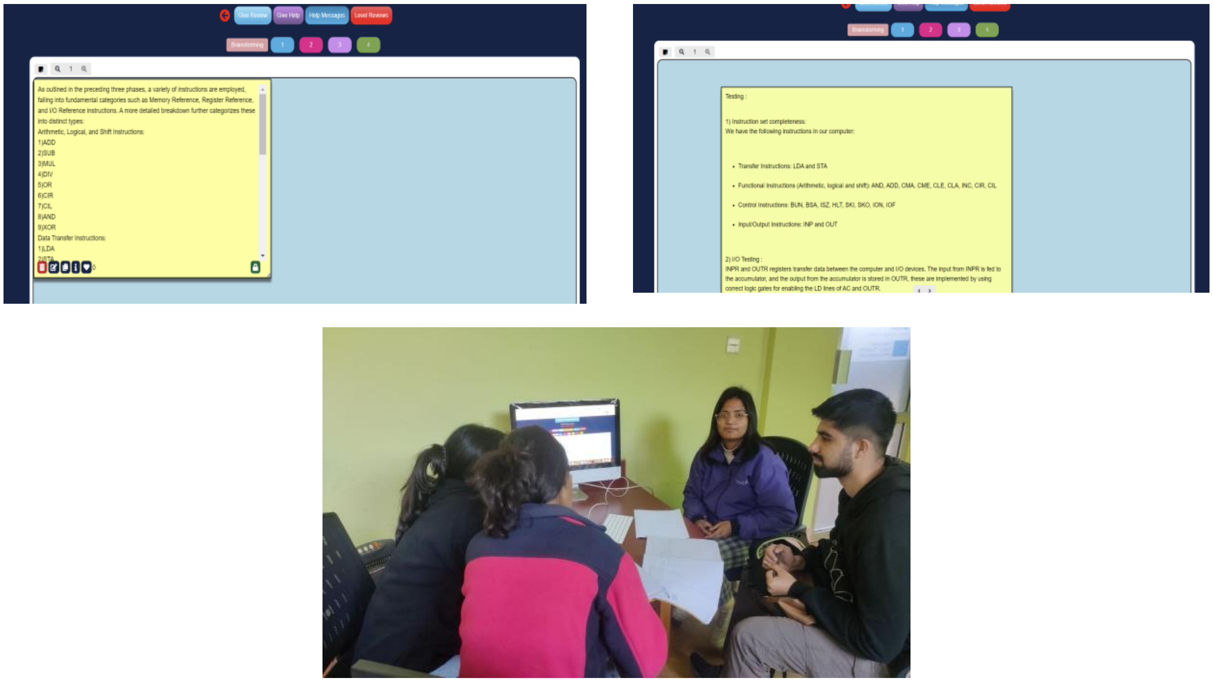

Figure 68. Students work on projects in the Computer Architecture and Organization course, July 2022.

9.3 Course COMP 307: Operating System for Computer Engineering

9.3.1 Description of the course

The course focuses on different aspects of operating systems, such as memory, file interface, and input/output interface. Students develop an understanding and knowledge of different components of operating systems. Upon completion of the course, students are able to practically apply operating systems concepts.

9.3.2 Description of the participants

The course is attended by students enrolled in the Bachelor of Engineering in Computer Engineering program. A total of 12 students participated in the course in spring 2023.

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9.3.3 Description of gamified design thinking activities

Students were divided into groups of 4 individuals. They were assigned projects related to different topics of operating systems. Project work helped students to develop, explore and implement theoretical knowledge in practice. Work was organized as follows:

Step 1. Define.

Students were challenged to introduce a problem statement accurately describing the problem in focus.

Step 2. Apply.

Students introduced ideas and synthesized a solution to the problem in focus. They developed prototypes for testing their ideas.

Step 3. Test.

Students tested their ideas in real-world conditions. They integrated the generated feedback into their solutions for better-addressing user needs.

Step 4. Present.

Students presented their ideas to the class and were evaluated on their solution design.

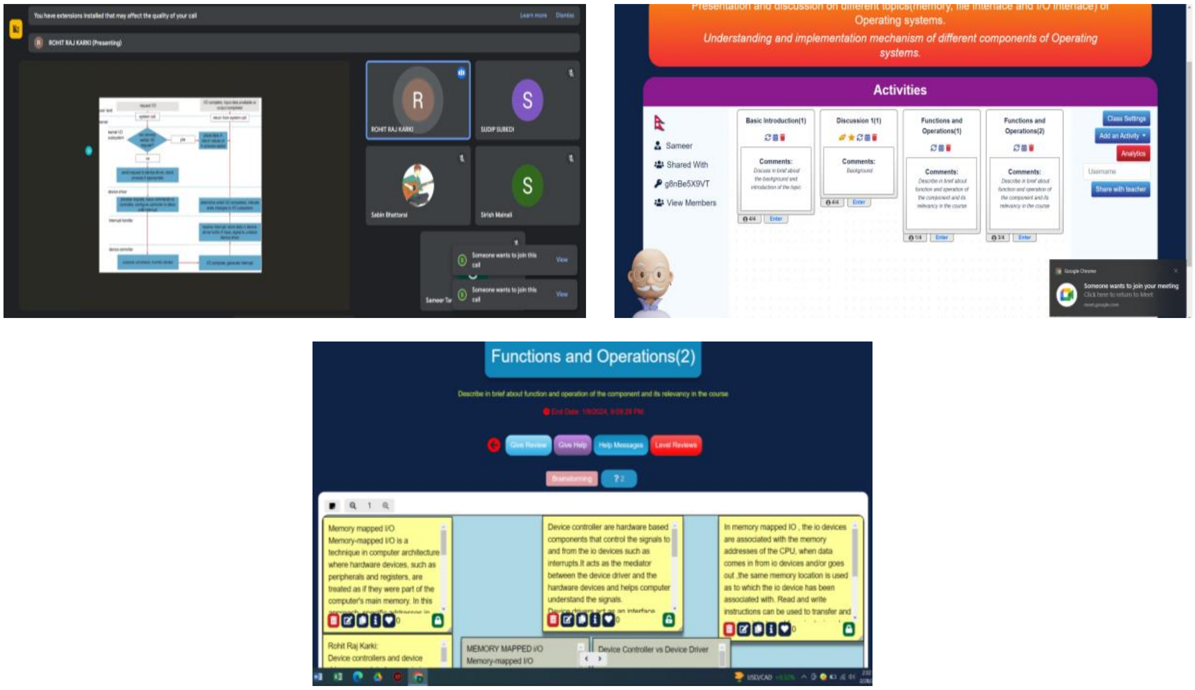

Figure 69. Student work in the Operating Systems for Computer Engineering course, spring 2023.

9.4 Course COM 211: Operating Systems

9.4.1 Description of the course

The course familiarizes students with the concepts and implementation of operating systems in computers. The course has been updated to include design thinking principles. Students are challenged to resolve operating systems challenges related to the Linux® operating system.

9.4.2 Description of participants

This is a mandatory course in the 4th semester of undergraduate studies at the Department of Management Informatics and Communication of Kathmandu University. A total of 37 undergraduate students enrolled in the Business and Information Systems program attended the course in the fall 2023 semester.

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9.4.3 Description of gamified design thinking activities

The ICT-INOV learning methodology based on design thinking was deployed in the course. Specifically, a learning activity was customized and integrated into the ICT-INOV digital learning platform. The primary objective of integrating the concept of design thinking was to challenge students to work in groups to achieve a common goal. Students were asked to troubleshoot issues related to the Linux® operating systems. They were allowed to access the design thinking platform developed in the project. Students were divided into groups of 2 to 3 individuals. Some of the troubleshooting problems assigned to students are as follows:

- The system boots up, but the screen resolution is very low, while it was previously correctly set.
- A user is unable to log-in to a system they have previously logged-in to.
- An administrator needs to make changes to the home directory for all future new users.
- The system reports that a service has failed to start.

The ICT-INOV educational platform provides instructors with flexibility in structuring the learning activities based on well-accepted design thinking steps. Project activities in the context of the course were organized as follows:

Step 1. Researching the problem.

Students were asked to identify the possible causes of operating system issues through thorough research. At this stage, students worked independently.

Step 2. Group findings.

Students discussed the findings of their research within their team, collectively identifying the root causes of operating system issues.

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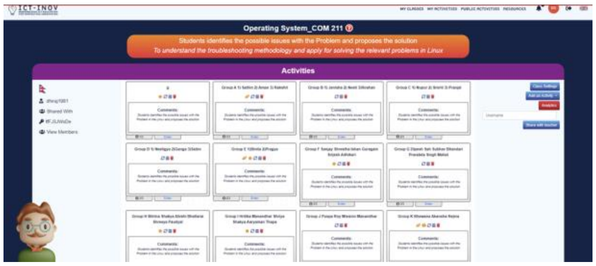
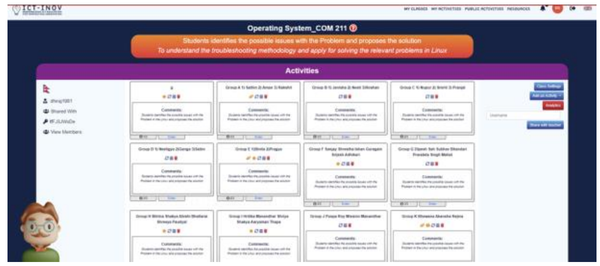
Step 3. Solution synthesis.

Students identified potential solutions to operating system issues studied.

Step 4. Presentations.

Students presented their solutions to the class.





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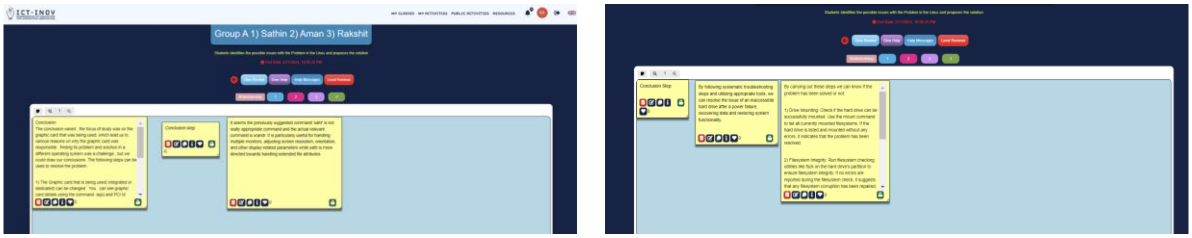

Figure 70. Student work in the Operating Systems course, fall 2023.

10. Tribhuvan University

10.1 Course: Software Engineering

10.1.1 Description of the course

This course provides a systematic approach towards planning, developing, implementing and maintaining a system. It builds the skills that students need to develop software projects. During the course, students work in groups on implementing an end-to-end project. Work involves developing a software prototype, documenting the software and deploying the result. The ICT-INOV design thinking software platform has been introduced in this course since the 2022 - 2023 academic year.

10.1.2 Description of the participants

The course is offered in the 3rd year of studies of the Bachelor in Computer Engineering program in the Department of Electronics and Computer Engineering, Pulchowk Campus, Institute of Energy, Tribhuvan University. The ICT-INOV platform was deployed in the 2022 academic year. A total of 96 undergraduate students in their 3rd year of studies in the Department of Electronics and Computer Engineering were engaged in the course. ICT-INOV will be further deployed in the following academic years.

10.1.3 Description of gamified design thinking activities

A specific activity named Software Engineering Project was developed in the ICT-INOV platform for direct use in this course, although it can also be used in other similar courses. The activity was used in the Software Engineering course. Students were divided into 26 teams of 3 – 4 individuals. Each team had its own workspace on the ICT-INOV platform.

The activity consisted of the following 3 levels.

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Step 1. Team formation and project inception.

Students were asked to form teams and to decide on a team logo. They were asked to select a project for implementation from a list pre-prepared by the instructor. Students were asked to post their team's name and project title on the ICT-INOV platform.

Step 2. Prototype development and documentation.

Students were challenged to develop a complete software prototype. They were asked to post characteristic screenshots of their work on the ICT-INOV platform. In addition, students were asked to develop documentation for their software and to share it on-line through the ICT-INOV platform.

Step 3. Deployment and testing.

Students were asked to deploy and test the developed prototype. The software was deployed on the servers or computers provided by the department or as instructed by the course instructor. Students were asked to publish the deployment details and URLs needed on the ICT-INOV platform. After the deployment, students were asked to test the outcome of their project and to post the testing details along with the list of known issues and bugs on the ICT-INOV platform.

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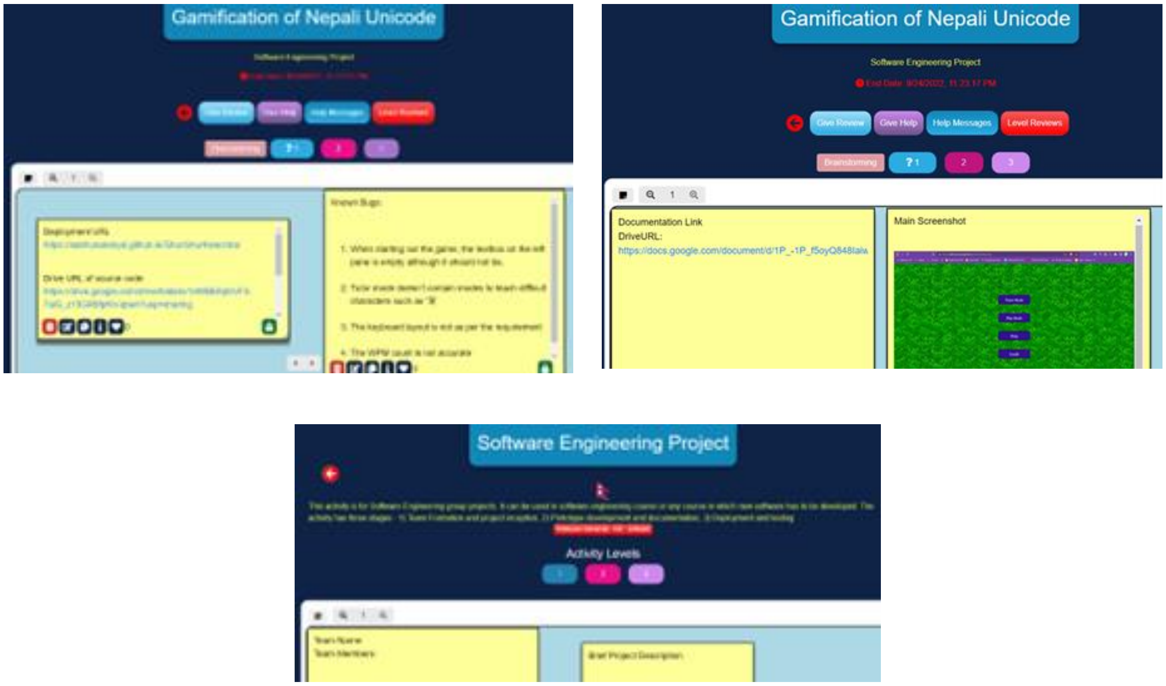


Figure 71. Screenshots of student projects, demonstrating team building steps, working groups and sharing ideas in the Software Engineering course, fall 2022.

10.2 Course: Knowledge Engineering

10.2.1 Description of the course

This course aims to familiarize students with basic concepts of knowledge engineering. It teaches the basics of knowledge acquisition methods, IR, NLP and machine learning techniques. In addition, it focuses on knowledge representation, logic and reasoning. Finally, the course introduces students to the semantic web and ontology engineering. During the course, students implement a group project in which they work on knowledge engineering concepts to build a knowledge-based system prototype, document it, and deploy it within a semester. The ICT-INOV design thinking software platform has been introduced in this course since the 2022 – 2023 academic year.

10.2.2 Description of the participants

The course is mandatory in the 1st semester of Master in Computer Systems and Knowledge Engineering graduate-level program offered by the Department of Electronics and Computer Engineering, Pulchowk Campus, Institute of Energy, Tribhuvan University. A total of 20 graduate students were engaged in the course in the fall 2022 – 2023 academic year. ICT-INOV will be further deployed in the following academic years.

10.2.3 Description of gamified design thinking activities

Students worked in 5 groups that consisted of 4 individuals each. Each team worked on an individual project. A dedicated activity was developed in the ICT-INOV platform and was organized in the following steps.

Step 1. Team formation and project background study.

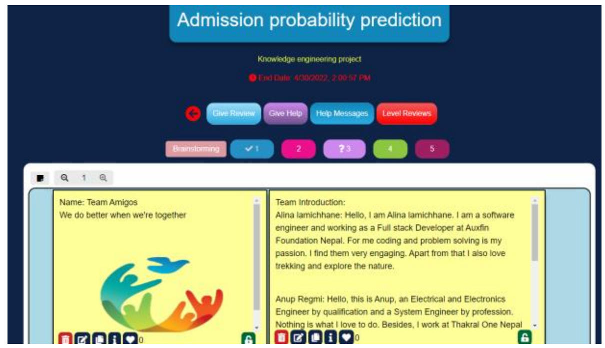
Students were asked to form a group of up to 4 individuals and choose a name and logo for the team. Subsequently, groups were asked to select a project topic from a list of projects provided by the instructor or to introduce a different topic of their choice. Students were asked to post a project description along with their team's name and group members on the ICT-INOV platform.

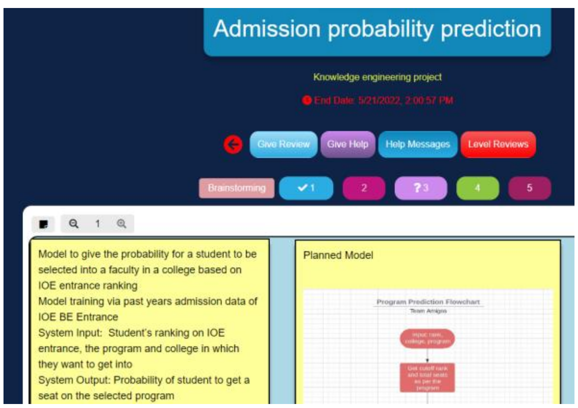
Step 2. Domain exploration and model development.

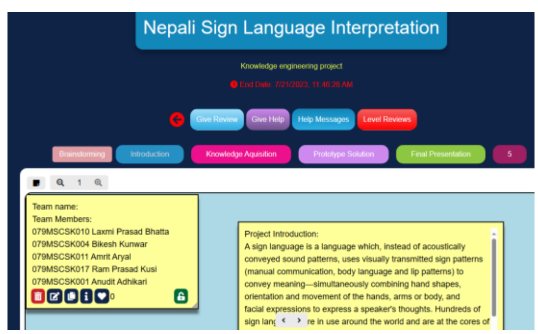
Students explored the domain of knowledge engineering and posted their findings on the ICT-INOV platform. They designed a solution to their project in the form of a model for a knowledge-based system. Students posted the model architecture, flowchart and suggested solution algorithm in the ICT-INOV platform.

Step 3. Prototype development and demo.

Students developed a software prototype knowledge-based system and demonstrated it to their peers. The prototype was based on the domain research and model of the previous steps. Students posted screenshots and descriptions of the system on the ICT-INOV platform.







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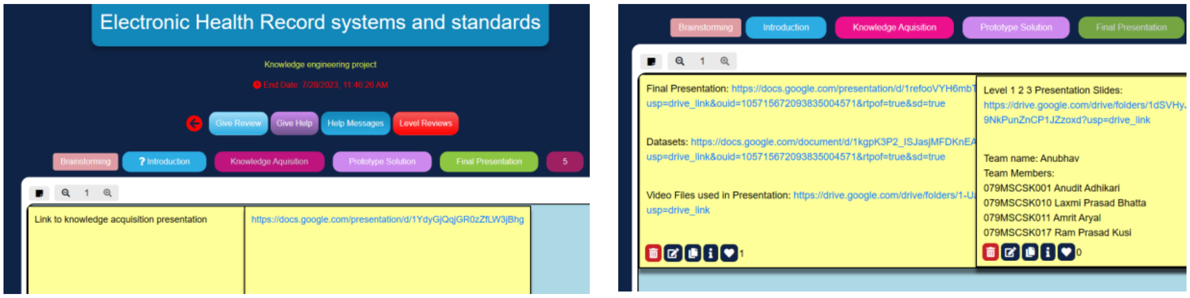


Figure 72. Screenshots of student projects, demonstrating team building, student workspaces and teamwork in the various stages of project implementation in the Knowledge Engineering course, fall 2022.

10.3 Course: Information Visualization

10.3.1 Description of the course

The objective of the course is to build knowledge on presenting information in an understandable, efficient, effective, and aesthetic manner to explain ideas and analyse data. Another objective is to build skills in designing and evaluating information visualizations and other visual presentation forms. Students become familiar with core principles and some of the field's literature. The ICT-INOV digital learning platform was introduced in this course in 2022.

10.3.2 Description of the participants

The course is mandatory in the 2nd semester of the Master's program in Computer Engineering, Specialization: Data Science and Analytics, conducted by the Department of Electronics and Computer Engineering, Pulchowk Campus, Institute of Energy, Tribhuvan University. A total of 20 graduate students in their 1st year of graduate studies were engaged in the course. ICT-INOV will be further deployed in the following academic years.

10.3.3 Description of gamified design thinking activities

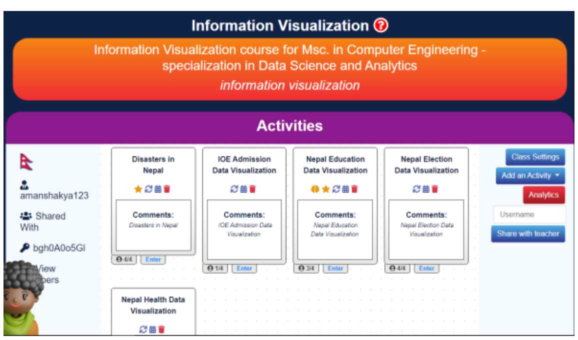
Students worked in 5 groups that consisted of 4 individuals each. Each team worked on an individual project. Students used the ICT-INOV lab to visualize information. A dedicated activity was developed in the ICT-INOV platform and was organized in the following steps.

Step 1. Team formation and project background study.

Students were asked to form groups of up to 4 individuals and choose a name and logo for the team. Subsequently, groups were asked to select a project topic from a list of projects provided by the instructor or to introduce a different topic of their choice. Students were asked to post a description of the project along with their team's name and group members on the ICT-INOV platform.

Step 2. Information visualization. Students explored the domain and developed several information visualizations using tools like Tableau®.

Step 3. Final submission of deliverables. Students submitted the final deliverables, which included the wrangled datasets, final information visualizations, source code, and presentation slides.



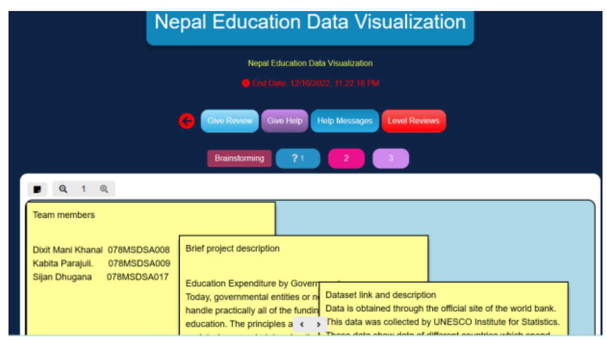


Figure 73. Screenshots of student projects, background research, and visualizations in the Information Visualization course, fall 2022. Student use of the ICT-INOV digital learning lab.

10.4 Course: Database Management Systems

10.4.1 Description of the course

The course builds knowledge of fundamental concepts, theory, and practice in the design and implementation of Database Management Systems. Students work in groups to build a database application, to document it, and to deploy it within a semester. The ICT-INOV lab has been used for this course starting in November 2022.

10.4.2 Description of the participants

The course is mandatory in the 3rd year of the Bachelor's program in Computer Engineering, conducted by the Department of Electronics and Computer Engineering, Pulchowk Campus, Institute of Energy, Tribhuvan University. A total of 96 students in their 3rd year of students were engaged in the course in the fall of 2022.

10.4.3 Description of gamified design thinking activities

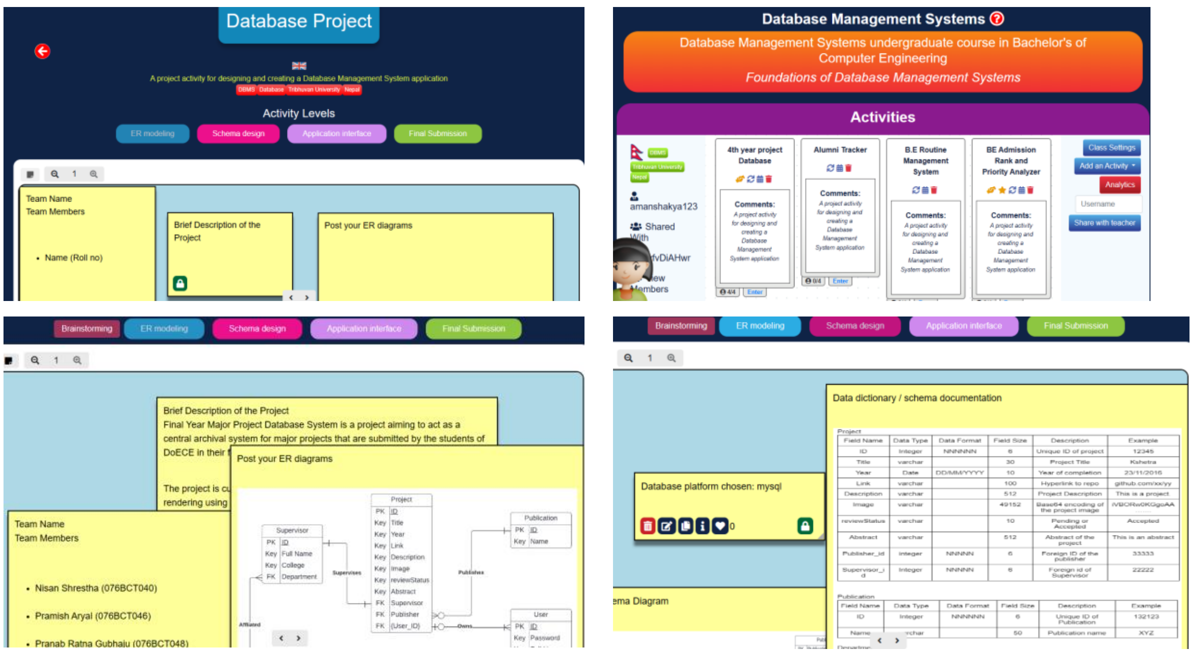
The ICT-INOV design thinking lab is used in the course for lectures and database design exercises. The interactive digital display and digital sketchpads are used to draw database design models in the class. The cameras for communication are used to record the lectures for future reference. Activities were organized in the following steps.

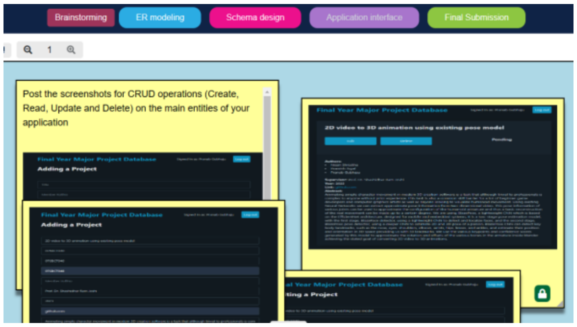
Step 1. Team building and ER modelling. Students were asked to form groups of up to 4 individuals and choose a name and logo for the team. Subsequently, groups were asked to select a project topic from a list of projects provided by the instructor or to introduce a different topic of their choice. Students were asked to post a project description along with their team's name and group members on the ICT-INOV platform. Teams also posted the database conceptual design for the project as an ER model.

Step 2. Database schema design. Students developed a detailed database schema design. They posted the database schema design and related documentation on the ICT-INOV digital learning platform.

Step 3. Application interface development. Students developed a working application prototype interface and posted screenshots on the ICT-INOV digital learning platform.

Step 4. Final submission of deliverables. Students submitted the final deliverables, which included the project code, user interface, documentation, and screenshots.





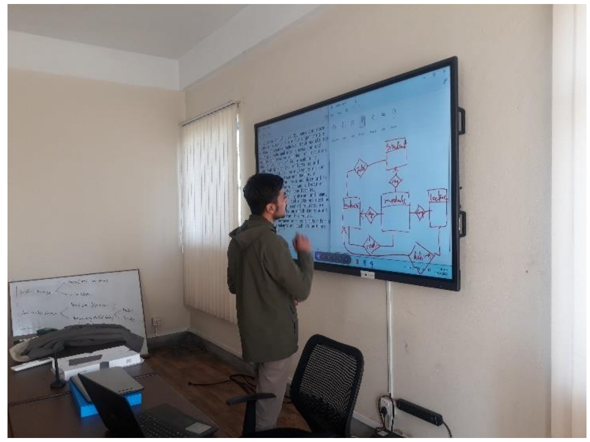


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Figure 74. Screenshots of student projects, background research, and visualizations in the Database Management Systems course, fall 2022. Student use of the ICT-INOV digital learning lab.

10.5 Course: Artificial Intelligence

10.5.1 Description of the course

The course develops knowledge of Artificial Intelligence (AI) principles and applications. Students work in groups to build an AI system and demonstrate its functionality. The course has been updated to include design thinking principles.

10.5.2 Description of the participants

This is a mandatory course in the 4th year of the Bachelor in Computer Engineering program conducted by the Department of Electronics and Computer Engineering, Pulchowk Campus, Institute of Engineering (IOC), Tribhuvan University. A total of 96 undergraduate students enrolled in the Department of Electronics and Computer Engineering were engaged in the course in the spring 2024 semester.

10.5.3 Description of gamified design thinking activities

The ICT-INOV design thinking methodology for innovation and digital learning platform was introduced in the course in the spring 2024 semester. The methodology and platform will continue to be used in the following academic years.

Specifically, an activity named “Artificial Intelligence Project” was created in the ICT-INOV platform. The activity is tailored directly to the needs of the course, although it can be used in other similar courses.

Students worked in groups of 3 – 4 individuals. The number of teams engaged in the project was 32. The activity was structured through design thinking steps as follows:

Step 1. Team building and introduction.

Students were asked to create teams and select a team name. Furthermore, they were asked to select an AI project to work on and briefly present it to the class.

Step 2. Dataset description.

Students selected a dataset to use in their project implementation.

Step 3. Prototype development.

Students developed a working prototype system. They posted characteristic screenshots or photos of their system on the ICT-INOV digital learning platform.

Step 4. Final presentation and report.

Students presented the final implementation of their project and the corresponding implementation report. They uploaded the presentations on the course-shared digital space and posted the links on the ICT-INOV digital learning platform. Furthermore, students posted links to the source code, datasets, and characteristics screenshots of their implemented project on the ICT-INOV platform.

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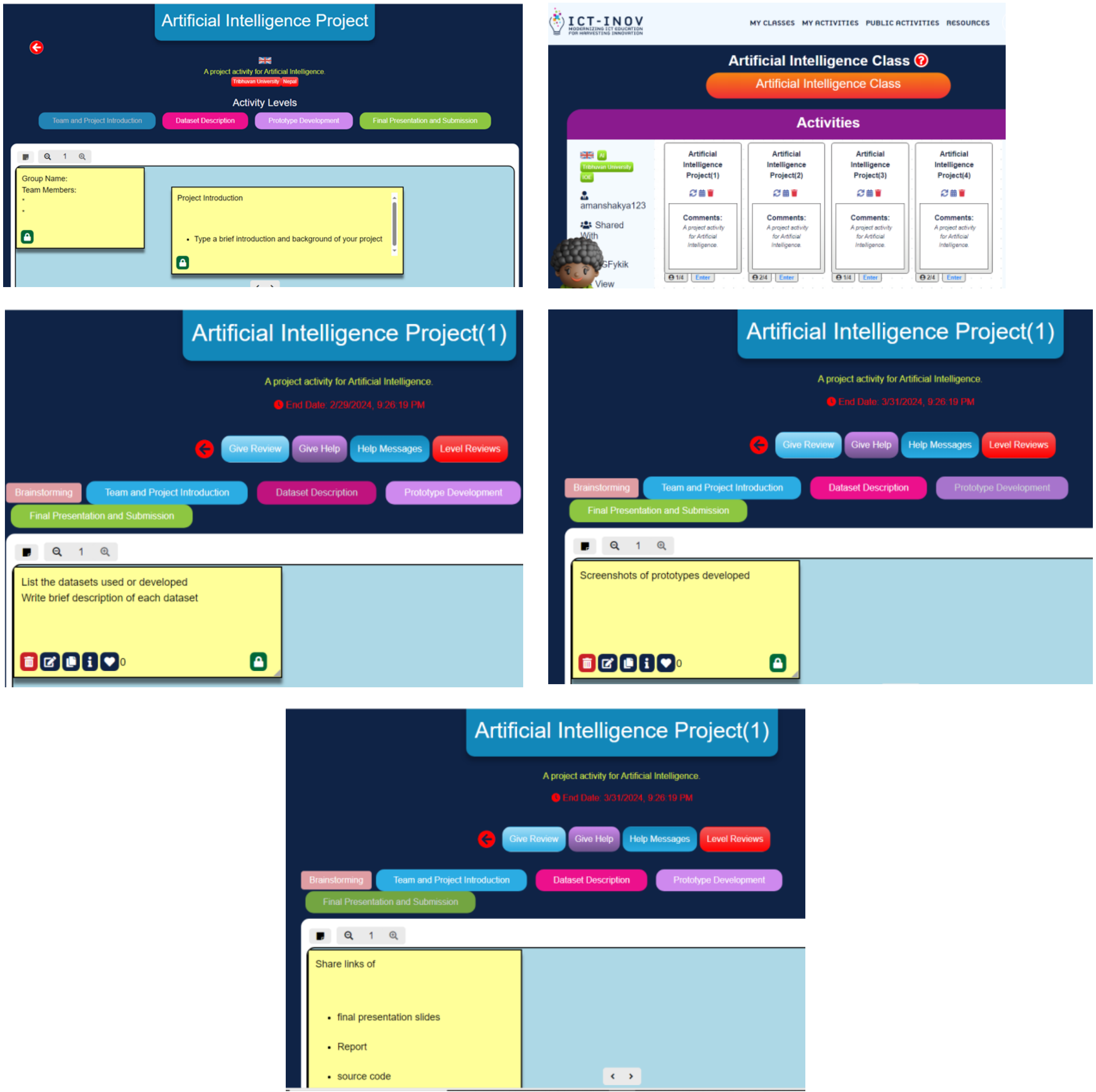

Figure 75. Student work, team spaces, and activity structure in the Artificial Intelligence course, spring 2024.

10.6 Course: Minor Project Computer

10.6.1 Description of the course

The course develops undergraduate students' knowledge and skills in designing and developing a complete project in Computer Engineering. Students work on a sizable project in which they develop a computer software system and demonstrate its functionality. The course has been updated to include design thinking principles.

10.6.2 Description of the participants

This elective course is offered in the 3rd year of the Bachelor in Computer Engineering program conducted by the Department of Electronics and Computer Engineering, Pulchowk Campus, Institute of Engineering (IOE), Tribhuvan University. A total of 96 undergraduate students engaged in the course in the spring 2024 semester.

10.6.3 Description of gamified design thinking activities

The ICT-INOV design thinking methodology for innovation and digital learning platform was introduced in the course in the spring 2023 academic year and continues to be used in the spring 2024 semester. The methodology and platform will continue to be used in the following academic years.

Specifically, an activity named "Minor Project Computer" was created in the ICT-INOV platform. The activity is tailored directly to the needs of the course, although it can be used in other similar courses.

Students worked in groups of 3 – 4 individuals. The number of teams engaged in the project was 32. The activity was structured through design thinking steps as follows:

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Step 1. Team introduction.

Students were asked to create teams and select a team name.

Step 2. Project proposal.

Students worked in their teams to select a theme for their project. They were asked to post the title and a short project description along with their team's name and group members on the ICT-INOV digital learning platform. They presented their project topic in class and uploaded links to their presentations on the platform.

Step 3. Mid-term presentation and report.

The student presented the project's mid-term progress report. They posted links to their mid-term report and presentation slides on the ICT-INOV digital learning platform. They further posted characteristic photos of the system under development as well as links to their source code and datasets.

Step 4. Final presentation and report.

Students presented the final implementation of their project and the corresponding implementation report. They uploaded the presentations on the course-shared digital space and posted the links on the ICT-INOV digital learning platform. Furthermore, students posted on the ICT-INOV platform links to the source code and datasets and characteristics screenshots of their implemented project.

Figure 76. Student work, team spaces, and activity structure in the Minor Project Computer course, spring 2024.

10.7 Course: Minor Project Electronics

10.7.1 Description of the course

This course develops undergraduate students' knowledge and skills in designing and developing a complete electronics, communication, and information engineering project. Students develop and demonstrate a hardware and software system. It has been updated to include design thinking principles.

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10.7.2 Description of the participants

This is a mandatory course in the 3rd year of the Bachelors in Electronics, Communication and Information Engineering program conducted by the Department of Electronics and Computer Engineering, Pulchowk Campus, Institute of Engineering (IOE), Tribhuvan University. A total of 48 undergraduate students engaged in the course in the spring 2024 semester.

10.7.3 Description of gamified design thinking activities

Work was organized in design thinking steps following the format described above in the “Minor Project Computer” course. The following steps were used:

Step 1. Team introduction.

Students were asked to create teams and select a team name.

Step 2. Project proposal.

Students worked in their teams to select a theme for their project. They were asked to post the title, a short project description, their team’s name, and group members on the ICT-INOV digital learning platform. They presented their project topic in class and uploaded links to their presentations on the platform.

Step 3. Mid-term presentation and report.

The student presented the project's mid-term progress report. They posted links to their mid-term report and presentation slides on the ICT-INOV digital learning platform. They further posted characteristic photos of the system under development as well as links to their source code and datasets.

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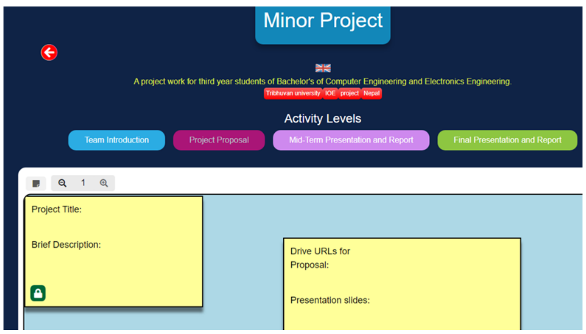
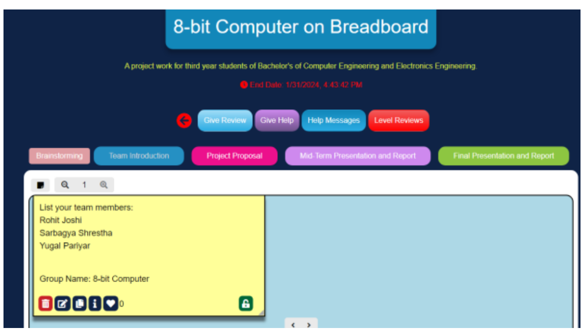
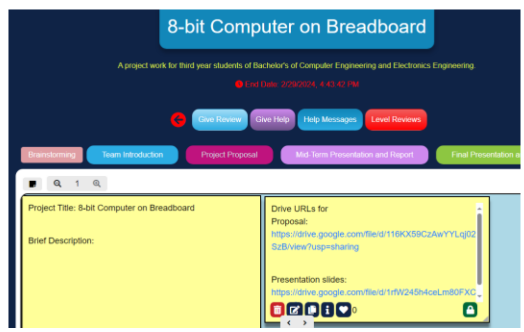
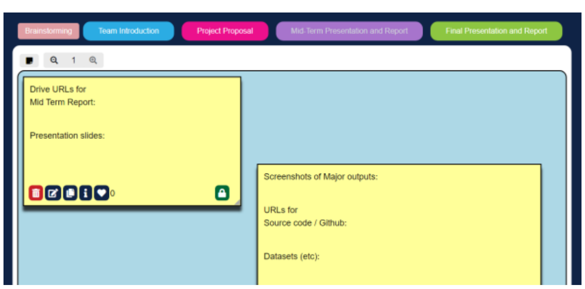
Step 4. Final presentation and report.

Students presented the final implementation of their project and the corresponding implementation report. They uploaded the presentations on the course-shared digital space and posted the links on the ICT-INOV digital learning platform. Furthermore, students posted links to the source code, datasets, and characteristics screenshots of their implemented project on the ICT-INOV platform.









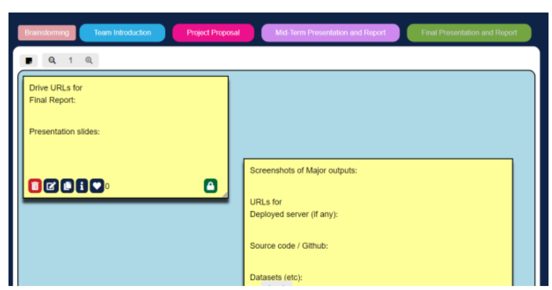


Figure 77. Student work, team spaces, and activity structure in the Minor Project Electronics course, spring 2024.

11. Von Neumann Institute

11.1 Course: IT Services Design

11.1.1 Description of the course

The course introduces a practical approach to the challenge of improving life quality by designing IT services for digital transformation in Ho Chi Minh City. Students are guided to solve the problem through design thinking. This course includes 2 parts. The 1st part introduces design thinking. The 2nd part involves project work in teams. Upon completion of the course, participants can understand and apply the basic concepts of design thinking in practice.

11.1.2 Description of the participants

This course was introduced to Vietnam National University Ho Chi Minh City's students on Aug 1st and 4th, 2022. A total of 70 students attended the 2 sessions.

11.1.3 Description of gamified design thinking activities

Activities were organized as follows:

Step 1: Team building.

Students were randomly assigned to 6 teams and engaged in team-building activities in the form of mini-games that helped break the ice. In addition, team members decided on a team name and designed a team logo.

Step 2: Understanding the problem.

Students were challenged to research how digital transformation can improve the quality of life of citizens through innovative ICT services.

Step 3: Understanding users.

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Students were encouraged to survey or interview stakeholders, namely their classmates, in order to understand user needs.

Step 4: Point of view.

Using the results of the above steps, students redefined the problem and presented it to users to ensure that they understood user needs clearly.

Step 5: Brainstorming and design with creativity techniques.

Students were asked to research and design a solution to the redefined problem. Then, each team presented and defended their solution to the entire class and received feedback.

Figure 78. Students deploying design thinking in the IT Services Design course, August 2022.

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12. Hanoi University

12.1 Course: Special Subject 01

12.1.1 Description of the course

The course offers students an opportunity to work on semester-long projects related to their curricula. Students are divided into groups. Each group develops a computerized application based on a specific topic under the guidance of a supervising educator. Examples of project themes include web design, human-computer interaction, multimedia design and more.

12.1.2 Description of the participants

This obligatory course addresses undergraduate students from the Department of Information Systems, Faculty of Information Technology, Hanoi University. Approximately 30 students in the 2nd year of studies enrolled in the course in the fall semester of the academic year 2022 - 2023.

12.1.3 Description of gamified design thinking activities

Course activities deploy the proposed gamified design thinking methodology. The key purpose of this activity is to address actual problems faced by real companies. Students were in charge of a development team hired to build a computer-based solution for the given company, namely the customers. Work is divided into the following steps.

Step 1. Problem discovery.

Students were encouraged to study the current situation in the company and discover opportunities for introducing a new system or enhancing existing practices that help the company gain a competitive advantage over their rivals.

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Step 2. Empathy.

In order to correctly understand the customer's needs and address real, as opposed to perceived, problems, students were encouraged to practice empathy by applying user-centred approaches such as conducting research to understand the customer's past, present and future needs. Students were further encouraged to join the customers in their daily business or observe them working at their site.

Step 3. Problem definition.

After establishing a list of possible enhancements at the customer site due to empathy and problem discovery, students were directed to select a specific challenge to solve. They formulated the problem definition in a "who, what, why" statement.

Step 4. Ideation.

Based on the results of the problem definition, students were encouraged to generate as many ideas as possible to help their customers address problems and gain competitive advantages. Activities related to ideation included listing all possible ideas without limitations.

Step 5. Solution synthesis, prototyping and evaluation.

Students were encouraged to select one to convert into a prototype from the pool of solution ideas generated in the ideation step. Students selected the most viable idea by creating lists of pros and cons. Criteria for evaluating ideas include the potential to achieve a competitive advantage, financial aspects, available human resources and time constraints. Students created a prototype of the selected idea and delivered it to the customer for validation. Based on customer feedback, students refined their prototype solutions to address the challenge in focus.

The following are pictures of students working on projects in the Design Thinking Lab at Hanoi University.

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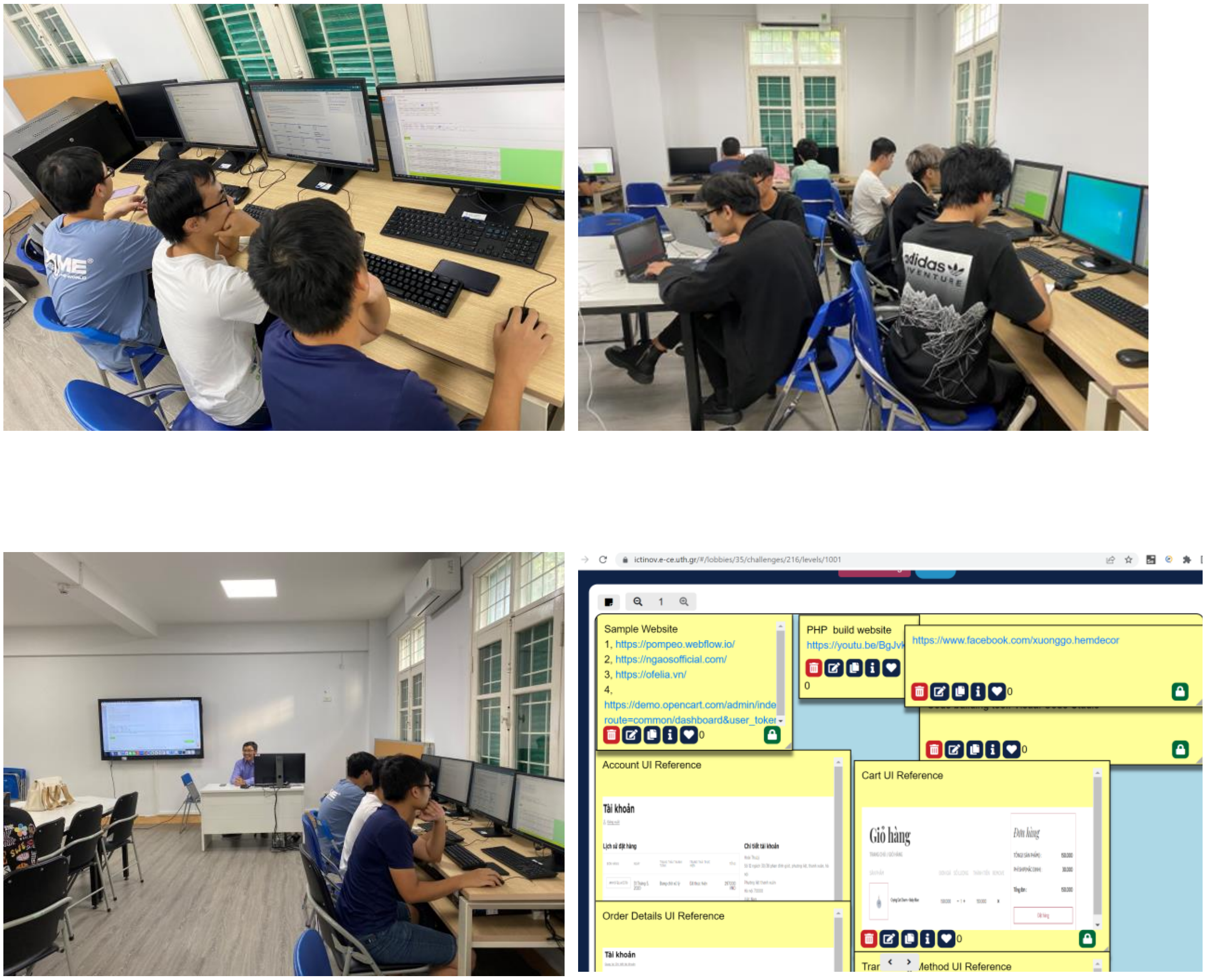

Figure 79. Students working in the Design Thinking Lab of Hanoi University, fall 2021.

12.2Course: Information Systems Design and Implementation

12.2.1 Description of the course

The course develops an understanding of how to build an information system step by step. It further addresses agile development, user requirements analysis and project management. In addition, the course develops skills in using designing tools, analyzing and designing accurately, and then applying the design to implementation. Normally, this course is delivered in person. However, due to COVID-19 restrictions, classes were conducted virtually during semester 2 of the 2021 – 2022 academic year.

12.2.2 Description of participants

This obligatory course addresses undergraduate students from the Department of Information Systems, Faculty of Information Technology, Hanoi University. Approximately 150 students in the 4th year of studies enrolled in the course in the 2nd semester of academic year 2021 - 2022.

12.2.3 Description of gamified design thinking activities

Students created accounts on the ICT-INOV design thinking platform and joined the class virtually. Upon joining a class, students had access to several available activities. They were encouraged to select the activity of their choice, provided that the maximum number of allowed participants in the activity had not been reached. Work was structured in the following steps.

Step 1. Problem discovery.

Upon joining an activity on the ICT-INOV digital learning platform, students could see a short description of the activity's theme. Subsequently, they were encouraged to research the theme and discover challenges and opportunities for improvement through information technology.

Step 2. Empathy.

In order to thoroughly understand the problem, students identified stakeholders and created a RACI matrix. The RACI matrix helped them define stakeholders' roles and responsibilities, contributing to student understanding of challenges and needs. Teams conducted research and interviews to understand users' needs. They set aside assumptions to obtain insights into the users' world by observing and engaging with users, building an understanding of users' experiences, motivations and problems.

Step 3. Problem definition.

Students defined an accurate problem statement based on the research they conducted in the previous steps. They formulated the problem definition in a “who, what, why” statement.

Step 4. Ideation.

Students were encouraged to brainstorm, introducing as many solution ideas as possible. The goal of the activity was to create a broad solution space with various ideas. Subsequently, they analyzed ideas and grouped them into categories, such as ‘’can do”, “will do”, “good to have” and “can’t do”. From the broad repository of ideas and analysis, students selected one for prototyping .

Step 5. Solution synthesis, prototyping, and evaluation.

Students created a visual prototype of their idea using AdobeXD® to benefit the customer. Students posted the prototype image and link on the ICT-INOV design thinking platform. They discussed the idea in their groups and sent the outcome to stakeholders for validation. Stakeholders provided feedback, which the development team consulted for refining their designs.

The following pictures illustrate the use of the ICT-INOV design thinking platform in this course.

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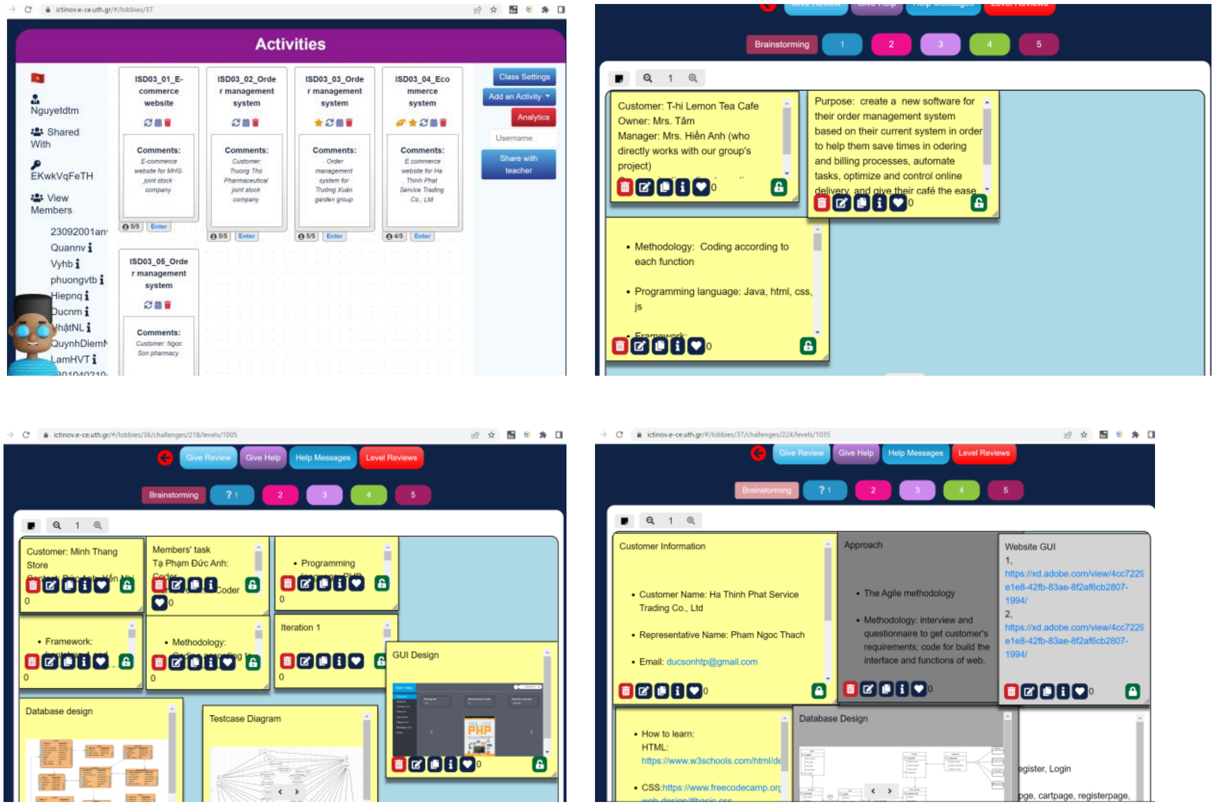

Figure 80. Screenshots of student projects in the Information System Design and Implementation course, fall 2021.

12.3 Course: System Analysis and Design

12.3.1 Description of the course

The course focuses on systems analysis and design, including topics such as software development lifecycles, UML diagram development, analysis and specification of system requirements, analysis and design of object-oriented information systems, project management aspects such as tangible and intangible costs, scheduling, culture and legal requirements, data management and user interface design.

12.3.2 Description of the participants

This is an obligatory course for students in the 4th year of studies. The course was attended by 37 students in semester 1 of the 2020 – 2021 academic year.

12.3.3 Description of gamified design thinking activities

The activity was organized in the following steps.

Step 1. Challenge assignment.

Students were assigned small tasks with increasing difficulty. This approach helped them gain knowledge and supported students in gradually engaging in more challenging and rewarding tasks, applying the knowledge developed in past activities.

Step 2. Recognition and rewards.

Students were rewarded with points upon completion of each task. At the end of the class, the highest-performing student was rewarded with a gift. This approach boosted motivation, morale and long-term engagement in the learning process.

Step 3. Feedback.

The teacher provided instant feedback when a student completed a task or quiz. This approach encouraged student engagement and allowed the educator to track student progress by completing game levels with increasing difficulty.

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Figure 81. Students work on assigned tasks in the Systems Analysis and Design course, fall 2021.

12.4 Course: Human-Computer Interaction

12.4.1 Description of the course

The course familiarizes students with the design of interactive interfaces between users and software, fundamentals of interface and application design, and analysis of development trends in the field of interactive interface design. The course includes theoretical and practical components, through which learners practice knowledge gained through specific exercises, projects, and products.

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12.4.2 Description of the participants

This is an obligatory course for students in the 3rd year of studies. The course was attended by 110 students in semester 2 of the 2021 – 2022 academic year.

12.4.3 Description of gamified design thinking activities

Activities were organized in the following steps.

Step 1. Problem definition.

Students were challenged to design a software user interface with broad accessibility.

Step 2. Empathy.

Students were encouraged to do research to understand the difficulties faced by disabled individuals when using a website. For example, how difficult is it for a colour-blind person to identify an item in the desired colour when shopping online? Students interviewed individuals with disabilities to better understand the difficulties they encounter in everyday activities.

Step 3. Ideation.

Students brainstormed and listed numerous ideas for enhancing accessibility to a software service for all.

Step 4. Prototyping.

Students used Adobe XD® or Figma® to visually present a prototype which demonstrated their ideas for enhancing accessibility for disabled individuals.

Step 5. Evaluation and refinement.

Students gave characteristic users access to the prototype, asking them to use it and provide feedback based on which they refined their design.

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The following are pictures from student projects in the ICT-INOV gamified design thinking platform.

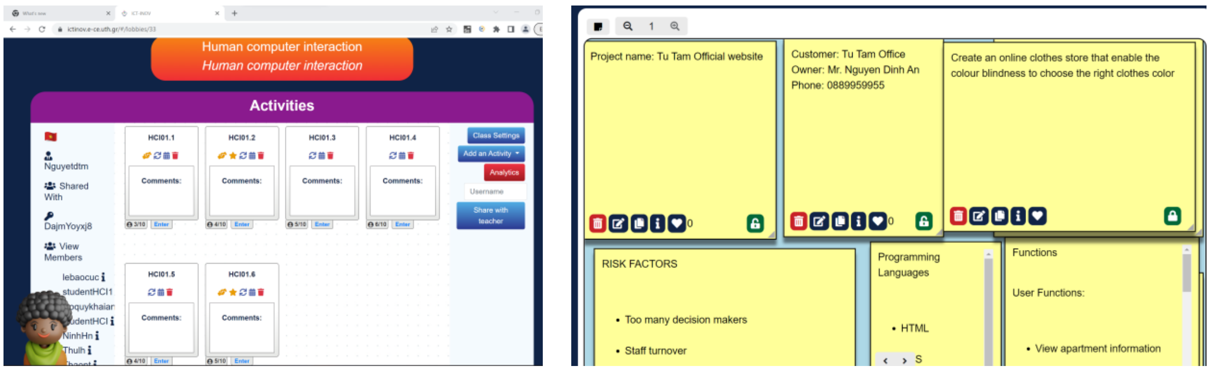


Figure 82. Screenshots of student projects in the Human-Computer Interaction course, spring 2022.

12.5 Course: Business Information Systems and Processes

12.5.1 Description of the course

The course provides students with an in-depth look at an information system and how today's business firms use information technologies and systems to achieve corporate objectives. The course emphasizes the importance of total business process reengineering to improve productivity and quality dramatically. By the end of the course, students are able to explain the importance of business process management and the role of people in information systems. This course has been updated to include design thinking principles. Students practice design thinking to bring innovative solutions that can address target customers' needs.

12.5.2 Description of the participants

This obligatory course is conducted for undergraduate students from the Department of Information Systems, Faculty of Information Technology, Hanoi University. The course was attended by 42 students in the second semester of the 2022 – 2023 academic year, all enrolled in the 3rd year of studies.

12.5.3 Description of gamified design thinking activities

Students were grouped into teams of 4 - 5 members. Each group was challenged to identify a small business running on outdated processes and to revise the existing business processes using software information systems to achieve operational excellence. Each group was encouraged to select a specific software package to support business processes and to inform the teacher for approval. Students deployed the ICT-INOV digital learning platform throughout the project to post problems, share ideas, and interact with others in the team.

Activities were organized in the following steps.

Step 1. Team building.

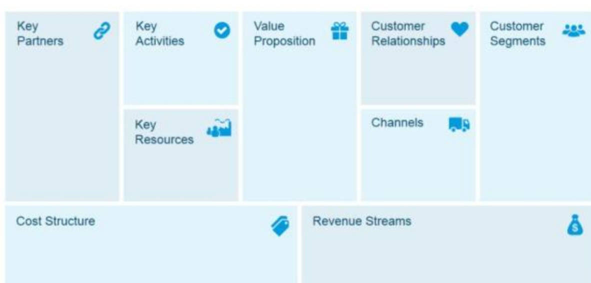
After being grouped into teams, students were allowed to work together, ask each other questions, discuss the strengths and weaknesses of each team member, and define team member roles. Subsequently, each group agreed on a team name and designed a team logo.

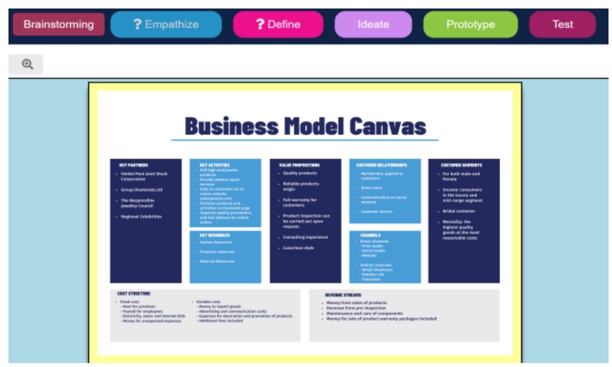
Step 2. Understanding the targeted customer and identify problems.

In order to correctly understand customer needs and the actual parameters of the given problem, students were encouraged to practice empathy by applying user-centred approaches, such as conducting research to understand customers' past, present, and future needs and aspirations. Subsequently, they drew a business model canvas to concisely describe the profile of the selected company, specifically the company's functional areas, core business processes, and cross-business processes, with detailed explanations.

Step 3. Brainstorming.

Students were encouraged to describe the information system or software they selected to manage business processes. They were asked to list key features and explain carefully how they match with company business processes. Specifically, they described the rationale for selecting the specific information system, the system's functionality, and at least 3 key features explaining how they match business processes. They were also asked to provide screenshots of the software. Some suggestions for information systems software for use in the class include ABIT®, Sapo®, KiotViet®, Hararetail®, Nhanh.vn®, CRMViet®, MShopKeeper®, Suno®, and others.





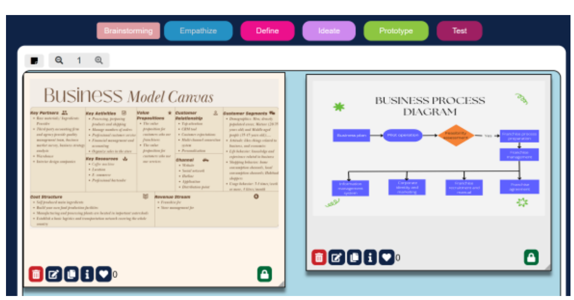


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Figure 83. Screenshots of student projects in the Business Information Systems and Processes course, spring 2023.

12.6 Course: Programming Design

12.6.1 Description of the course

The course introduces students to basic mobile design and programming concepts on MIT APP Inventor®. The application provides students with an intuitive, visual programming environment that everyone can use to build fully functional apps for Android® phones, iPhones®, and Android/iOS® tablets.

12.6.2 Description of participants

This is an elective course targeting undergraduate students enrolled in the Bachelor of Arts in Journalism and Mass Communications program at the Foreign Trade University. The course was attended by 32 in the second semester of the 2022 – 2023 academic year, and all of them are enrolled in the 2nd year of their studies.

12.6.3 Description of gamified design thinking activities

The course offers rich activities that are well-aligned with design thinking principles. For example, one of these activities challenged students to build a game named "Sky war" that, as the name suggests, simulates a war in the sky. Players engage in the game by controlling one of the objects participating in the battle. Students were encouraged to consider a meaningful game termination condition further.

The activities were organized in the following steps.

Step 1. Problem definition.

Students worked in groups to define the problem that they needed to solve.

Step 2. Game design.

Students brainstormed to introduce as many ideas as possible for game implementation. This included game characters, effects, and other elements.

Step 3. Solution selection.

After introducing several possible solutions, students evaluated the suggested ideas by analyzing the pros and cons as well as implementation difficulty. Based on this analysis, they identified one solution for prototyping.

Step 4. Game interface design.

Students worked in their teams on game design. Team members were assigned roles for game implementation, such as creating or collecting assets and resources, such as images or sound.

Step 5. Prototype game implementation.

After designing the game interface, students programmed a fully functional game.

Step 6. Game testing and evaluation of results against requirements.

Students tested the game's functionality and then deployed it for users to use on mobile phones. They received feedback from the educator and target users on game improvements.

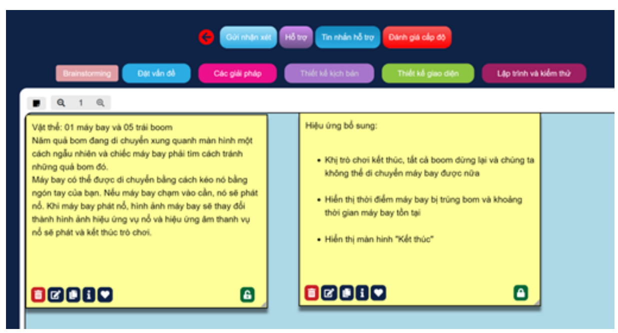

Figure 84. Screenshots of student projects in the Programming Design course, spring 2023.

12.7 Course: Project Management

12.7.1 Description of the course

The course develops the understanding of resources, goals, cost, and development environments used to implement a software project and how the whole process of a project is controlled and managed. It aims to support professionals in conducting effective project management using structured processes that follow emerging and increasingly widespread industry standards. The course addresses industry needs for wider project management training, which is directly linked to productivity and corresponds to increasingly higher corporate training budget allocations. Upon completion of the course, students are able to understand project management in IT contexts, deploy an integrated project management approach that involves scope, time, cost, quality, human resource, communications, risk, and procurement, understand core project management issues, define a scope for a medium-sized project and to use that as the basis to estimate the time and cost required for project implementation, organize a project team and to construct a project plan, monitor the quality of project implementation and introduce adaptations where necessary, and use basic project management tools.

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12.7.2 Description of participants

This obligatory course targets undergraduate students in the Department of Information Systems, Faculty of Information Technology, Hanoi University. The course was attended by 150 students in the second semester of academic year 2022 – 2023, all enrolled in the 3rd year of studies.

12.7.3 Description of gamified design thinking activities

Students were challenged to develop a strategic plan for implementing a specific project. Students were encouraged to implement design thinking for effective project management. Initially, students were exposed to basic design thinking concepts, such as principles and stages. Subsequently, they practically deployed theoretical design thinking concepts in developing an implementation strategy for their project. Design thinking supported students to create different strategies from multiple perspectives. Students were encouraged to approach a challenging project from the perspective of their users, stakeholders, or even a potential competitor. By considering a project from diverse viewpoints, students gained new insights towards designing innovative solutions that may not have been possible otherwise.

The activities were organized in the following steps.

Step 1. Identification of project goal or scenario.

Students were encouraged to work in groups to identify a project scenario inspired by real-life industry cases.

Step 2. Brainstorming on different project implementation strategies.

Students brainstormed in groups on diverse project management approaches.

Step 3. Analysis of each strategy using different criteria.

Students analyzed the proposed alternate project management approaches using diverse criteria.

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Step 4. Finalization of the project implementation strategy.

Based on the above analysis, students finalized their suggested project implementation strategy.

Figure 85. Students collaborate in the Project Management course, spring 2023.

13. Analysis of the questionnaire results

Questionnaire-based research was conducted to generate student feedback on the functionality of the ICT-INOV platform. A total of 934 students responded to the ICT-INOV evaluation questionnaire. This does not include all the students who used the project solution, but it is a significant number. Following is a presentation of the results.

Question 1: How familiar are you with design thinking?

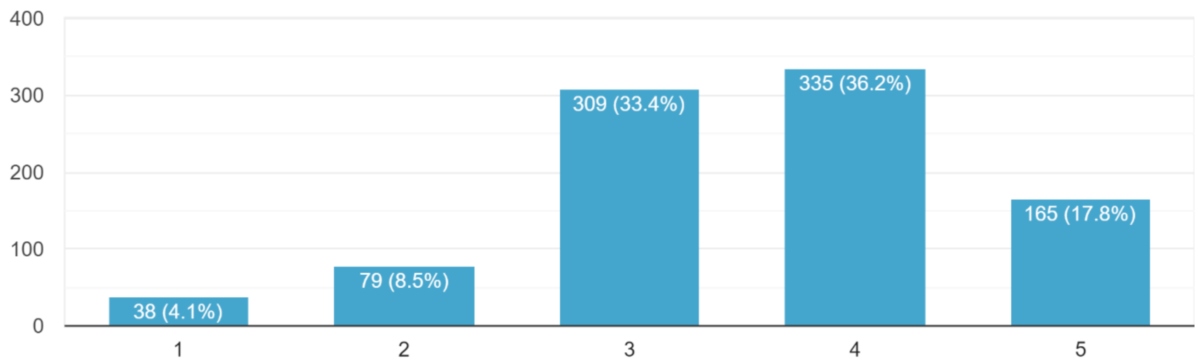

Figure 86. Responses to the question "How familiar are you with design thinking?".

The majority of students who participated in the ICT-INOV evaluation questionnaire, namely 36.2% (335 out of the total) answered that they are very familiar with the concept of design thinking, while 33.4% (309 out of the total) answered that they are moderately familiar. 17.8% (165 out of total) of respondents answered that they are extremely familiar with the concept of design thinking. In comparison, 8.5% (79 out of total) of respondents answered that they are slightly familiar and only 4.1% (38 out of total) of them answered that they are not familiar at all with design thinking.

Question 2: How familiar are you with gamification?

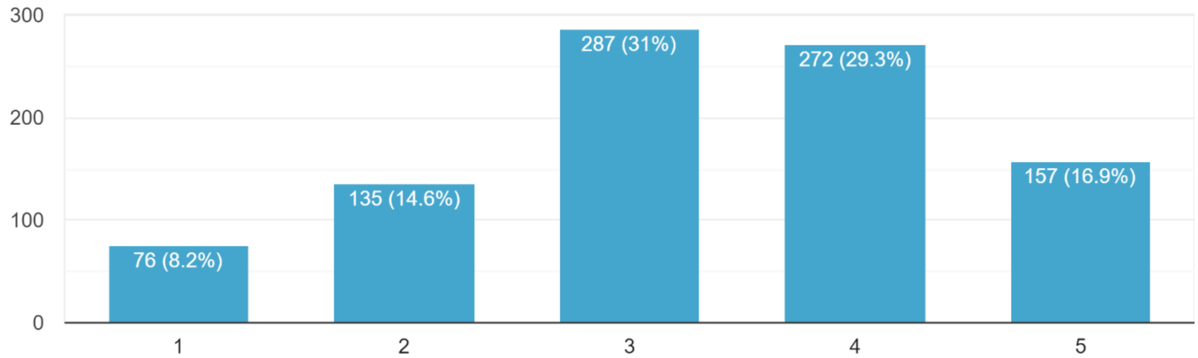

Figure 87. Responses to the question "How familiar are you with gamification?".

The majority of students who participated in the ICT-INOV evaluation questionnaire, namely 31% (287 out of the total), answered that they are moderately familiar with the concept of gamification, while 29.3% (227 out of the total) answered that they are very familiar. 16.9% (157 out of the total) of respondents answered that they are extremely familiar with the concept of gamification, while 14.6% (135 out of the total) of respondents answered that they are slightly familiar, and only 8.2% (76 out of total) of them answered that they are not familiar at all with gamification.

Question 3: Are innovation skills important in Computer Science and Engineering?

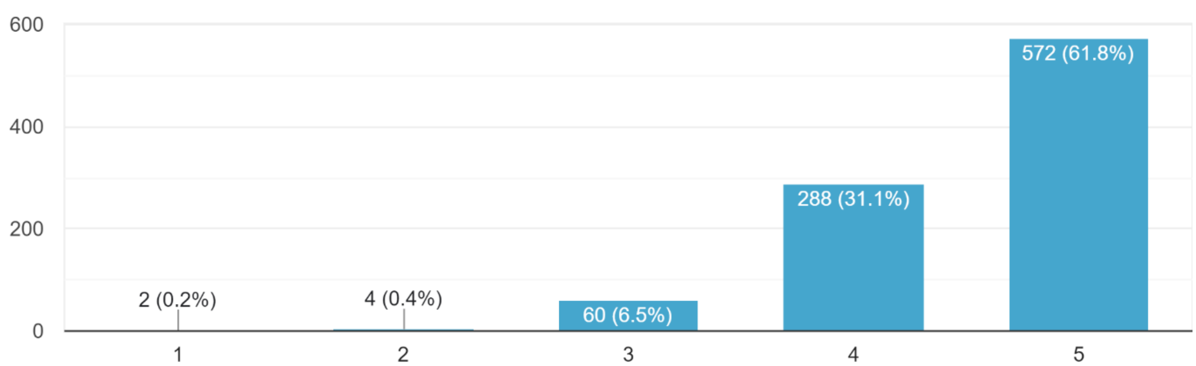

Figure 88. Responses to the question "Are innovation skills important to Computer Science and Engineering?".

The majority of students who participated in the ICT-INOV evaluation questionnaire, namely 61.8% (572 out of the total) answered that innovation skills are very important in Computer Science and Engineering, while 31.1% (288 out of the total) answered that they are important. 6.5% (60 out of total) of respondents answered that innovation skills are somewhat important in Computer Science and Engineering. In comparison, 0.4% (4 out of the total) of respondents answered that they are slightly important. Only 0.2% (2 out of the total) of them answered that innovation skills in Computer Science and Engineering are not important at all.

Students were asked to comment on their answers above.

The summary of students' perspectives gathered from the questionnaire responses underscores the vital role of innovation in Computer Science and Engineering. Students unanimously recognize the necessity of fostering creativity and innovative thinking to succeed in their academic pursuits and future careers.

Many students emphasize the importance of innovation in problem-solving and addressing societal needs. They recognize that the ability to think critically and generate novel ideas is essential for overcoming complex challenges in these fields. Design thinking and gamification are highlighted as valuable tools for fostering innovative solutions and improving user experiences.

Moreover, students express a strong belief that without continuous innovation, the fields of Computer Science and Engineering would stagnate. They recognize innovation as a driving force behind technological progress and societal advancement. Students also acknowledge that innovation is crucial for staying relevant in rapidly evolving industries and contributing to positive change.

Furthermore, students emphasize the role of creativity and innovation in shaping the future of technology. They recognize the importance of generating new ideas, designing intuitive

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interfaces, and developing cutting-edge technologies to address emerging needs and trends. Students also value the opportunity to learn about innovative concepts and methodologies, such as gamification, to enhance their understanding and skills in these fields.

Overall, students demonstrate a deep appreciation for the significance of innovation in Computer Science and Engineering. They recognize it as a fundamental aspect of their education and future careers, essential for driving progress, solving complex problems, and making a meaningful impact on society.

Question 4: Are innovation skills important for growth and employability?

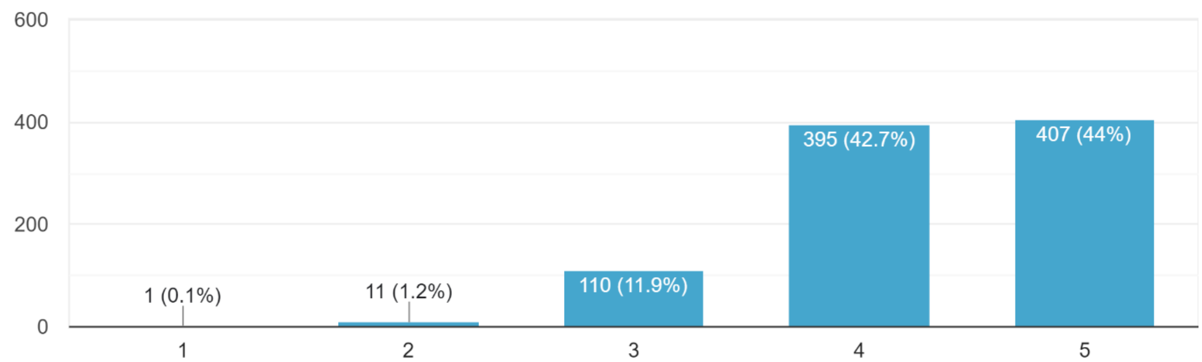

Figure 89. Responses to the question "Are innovation skills important for growth and employability?".

Most students who participated in the ICT-INOV evaluation questionnaire, namely 44% (407 out of the total), answered that innovation skills are very important for growth and employability, while 42.7% (395 out of the total) answered that they are important. 11.9% (110 out of the total) of respondents answered that innovation skills are somewhat important for growth and employability. In comparison, 1.2% (11 out of the total) of respondents answered that they are slightly important. Only 0.1% (1 out of the total) answered that innovation skills are unimportant for growth and employability.

Question 5: Can design thinking contribute to innovation skill building in ICT?

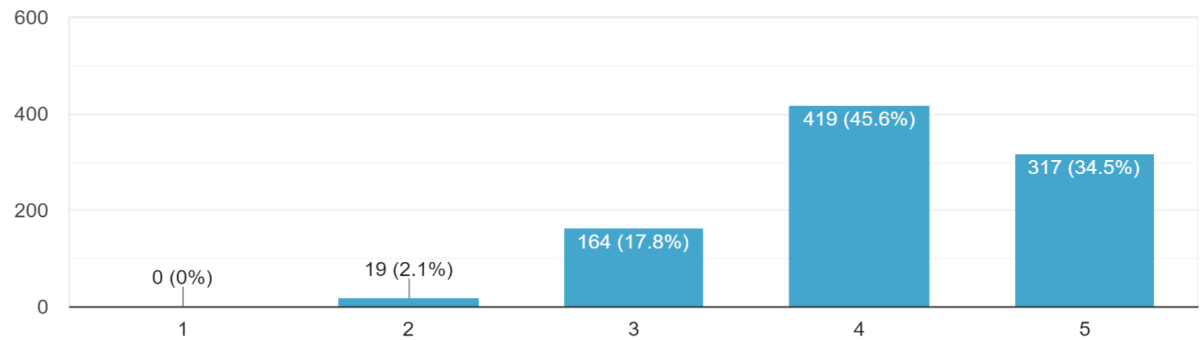

Figure 90. Responses to the question "Can design thinking contribute to innovation skill building in ICT?"

The majority of students who participated in the ICT-INOV evaluation questionnaire, namely 45.6% (419 out of the total), answered that design thinking can contribute to an extent to innovation skill building in ICT, while 34.5% (317 out of the total) strongly agreed with the statement. 17.8% (164 out of the total) of respondents answered that design thinking can contribute to innovation skill building in ICT, while 1.2% (11 out of total) of respondents slightly disagreed.

Question 6: Can gamification contribute to innovation skill building in ICT?

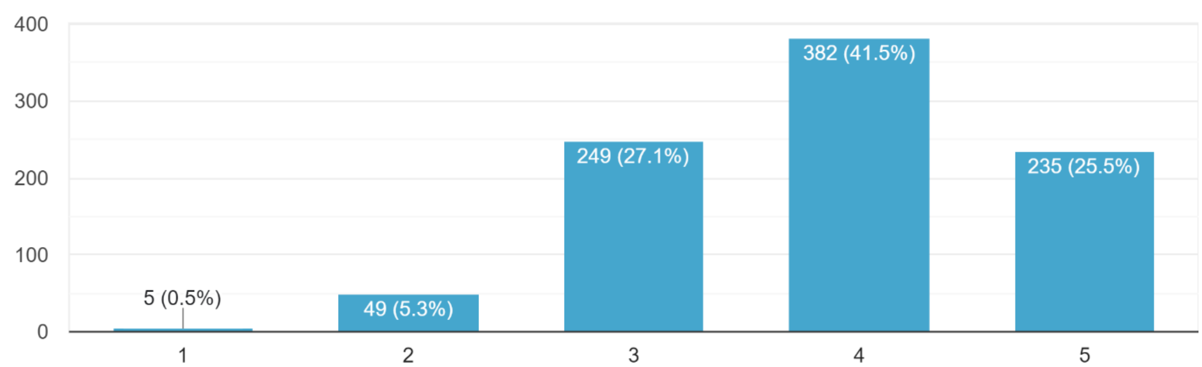

Figure 91. Responses to the question "Can gamification contribute to innovation skill building in ICT?".

The majority of students who participated in the ICT-INOV evaluation questionnaire, namely 41.5% (382 out of the total), agreed that gamification could contribute to innovation skill building in ICT, while 25.5% (235 out of the total) strongly agreed with the statement. 27.1% (249 out of the total) of respondents answered that gamification could somewhat contribute to innovation skill building in ICT. In comparison, 5.3% (49 out of the total) of respondents slightly disagreed with the statement. Only 0.5% (5 out of the total) answered that gamification cannot contribute to innovation skill building in ICT.

Students were asked to comment on their answers above.

The questionnaire responses from students overwhelmingly emphasize the importance of innovation skills in Computer Science and Engineering. Here's a comprehensive summary of the key insights gathered:

Recognition of importance: students universally recognize that innovation skills are indispensable for success in their academic endeavours and future careers. They understand that cultivating creativity and innovation is essential for addressing complex challenges and driving progress in Computer Science and Engineering.

Problem-solving and societal impact: Students widely acknowledge the pivotal role that innovation plays in problem-solving and addressing societal needs. They appreciate that the ability to think critically and generate novel ideas is vital for tackling a wide range of issues in their respective fields, from technological advancements to societal challenges.

Role in technological advancement: students highlight the crucial role of innovation skills in keeping pace with industry advancements and contributing to technological development. They understand that innovation drives progress and shapes the future of technology, making these skills indispensable for success in the rapidly evolving landscape of Computer Science and Engineering.

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Fostering creativity and innovation: Students unanimously agree that fostering creativity and innovation should be a central focus of their education. They stress the importance of developing these skills to effectively address contemporary challenges and advance the fields. Students express a strong commitment to nurturing their creativity and innovation to contribute meaningfully to technological advancement and societal progress.

Overall, the questionnaire responses reflect a deep understanding among students of the critical importance of innovation skills in Computer Science and Engineering. They emphasize the need to prioritize the development of these skills to drive progress, address challenges, and shape the future of technology in a rapidly evolving world.

Question 7: Does the ICT-INOV platform help build innovation skills?

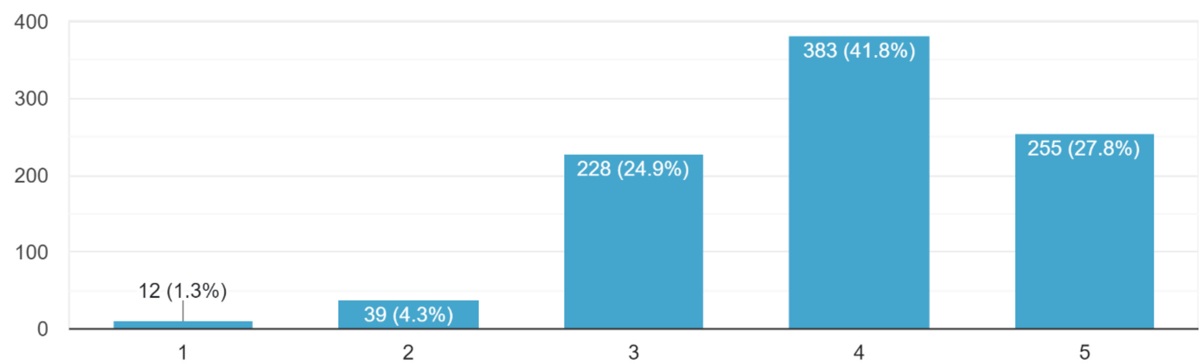

Figure 92. Responses to the question "Does the ICT-INOV platform help build innovation skills?".

The majority of students who participated in the ICT-INOV evaluation questionnaire, namely 41.8% (383 out of the total), agreed that the ICT-INOV platform helps build innovation skills, while 27.8% (255 out of the total) strongly agreed with the statement. 24.9% (228 out of the total) of respondents answered that the ICT-INOV platform somewhat helps build innovation skills, while 4.3% (39 out of the total) of respondents slightly disagreed with the statement. Only 1.3% (12 out of the total) answered that the ICT-INOV platform does not help at all build innovation skills.

Students were asked to comment on their answers above.

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The evaluation questionnaire results from students provide valuable insights into the effectiveness and usability of the ICT-INOV platform in fostering innovation skills and supporting learning in technology and engineering fields.

Students overwhelmingly appreciate the engaging features of the platform, such as interactive games and challenges, which not only make learning enjoyable but also stimulate critical thinking and logical reasoning. These elements contribute significantly to an immersive and effective learning experience, encouraging students to think creatively and approach problems from different perspectives.

Moreover, the platform's role in skill development is widely acknowledged among students. It offers diverse resources, tools, and collaborative opportunities that help enhance creativity, problem-solving abilities, and teamwork. The platform enables students to develop essential innovation skills while working collaboratively with their peers by providing a structured framework for brainstorming ideas and organising projects.

One of the key strengths highlighted by students is the platform's organization and progress-tracking capabilities. Features such as post-it notes and brainstorming sessions facilitate the structuring of thoughts and ideas, making it easier for teams to communicate effectively and track their progress on projects. This aspect of the platform significantly contributes to project management and ensures that students stay on track towards achieving their goals.

While the feedback on the ICT-INOV platform is predominantly positive, students also provide constructive suggestions for improvement. These include enhancing the user interface design for better usability, integrating industry-standard tools like GitHub and Jira for project management, and providing more diverse and challenging brainstorming exercises to stimulate critical thinking and innovation further.

Despite these areas for improvement, students unanimously agree that the platform offers flexibility and accessibility, catering to users with varying levels of experience. Its user-friendly interface makes it easy for students to navigate the platform and focus on their projects rather than grappling with complex navigation or technical issues.

In summary, the evaluation questionnaire results underscore the significant impact of the ICT-INOV platform on fostering innovation skills and supporting learning in technology and engineering fields. While there is room for improvement, particularly in terms of user interface design and the diversity of brainstorming exercises, the overall sentiment towards the platform is overwhelmingly positive. With continued refinement and enhancements, the ICT-INOV platform has the potential to further empower students and educators in their pursuit of innovation and excellence in technology and engineering education.

Question 8: Would you like to use this platform frequently?

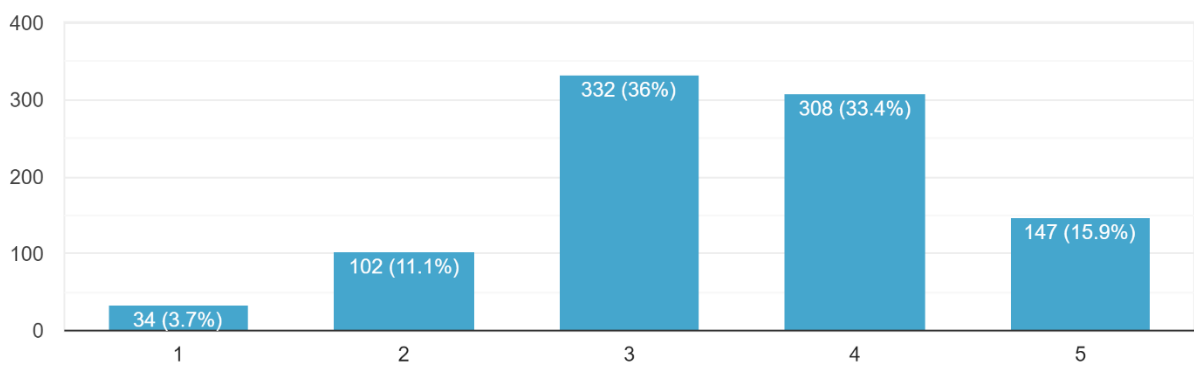

Figure 93. Responses to the questions "Would you like to use this platform frequently?".

The majority of students who participated in the ICT-INOV evaluation questionnaire, namely 36% (332 out of the total), answered that they would like to use this platform sometimes, while 33.4% (308 out of the total) answered that they would use it often. 15.9% (147 out of the total) of respondents answered that they would like to use this platform very frequently, while 11.1% (102 out of the total) of respondents slightly disagreed with the statement, and only 3.7% (34 out of the total) answered that they would never use this platform.

Question 9: Was the platform easy to use?

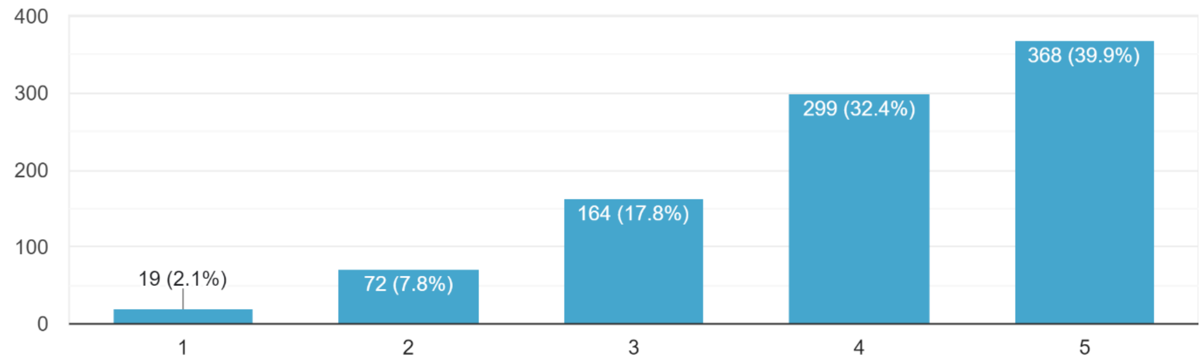

Figure 94. Responses to the question “Was the platform easy to use?@.

Most students who participated in the ICT-INOV evaluation questionnaire, namely 39.9% (368 out of the total), answered that they found the platform very easy to use, while 32.4% (299 out of the total) agreed with the statement. 17.8% (164 out of the total) of respondents answered that they found the platform somewhat easy to use, while 7.8% (72 out of the total) of respondents slightly disagreed with the statement, and only 2.1% (19 out of the total) answered that they found the platform hard to use.

Question 10: Did you need technical support to use the platform?

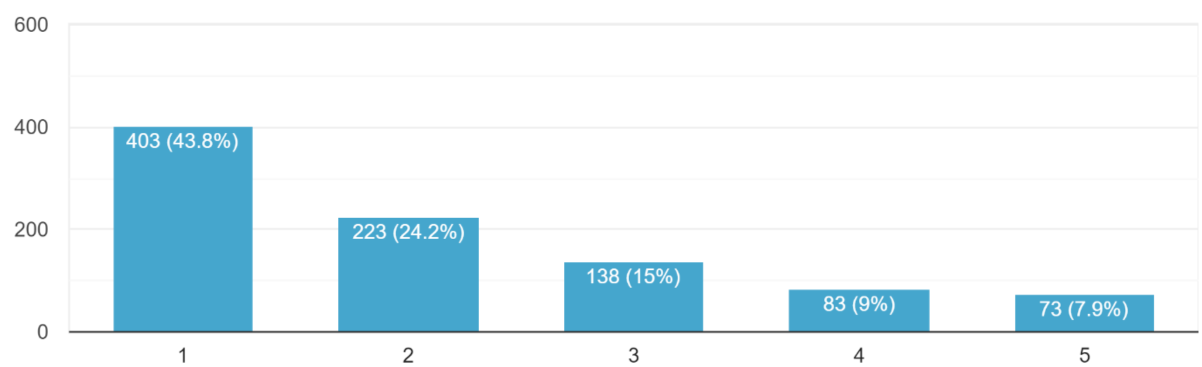

Figure 95. Responses to the question “Did you need technical support to use the platform?”.

The majority of students who participated in the ICT-INOV evaluation questionnaire, namely 43.8% (403 out of the total), answered that they do not need technical support at all to use the platform, while 24.2% (233 out of the total) disagreed with the statement. 15% (138 out of the total) of respondents answered that they sometimes need technical support to use the platform. In comparison, 9% (83 out of the total) of respondents agreed with the statement, and only 7.9% (73 out of the total) answered that they need technical support to use the platform.

Question 11: Are the various functions of the platform well integrated?

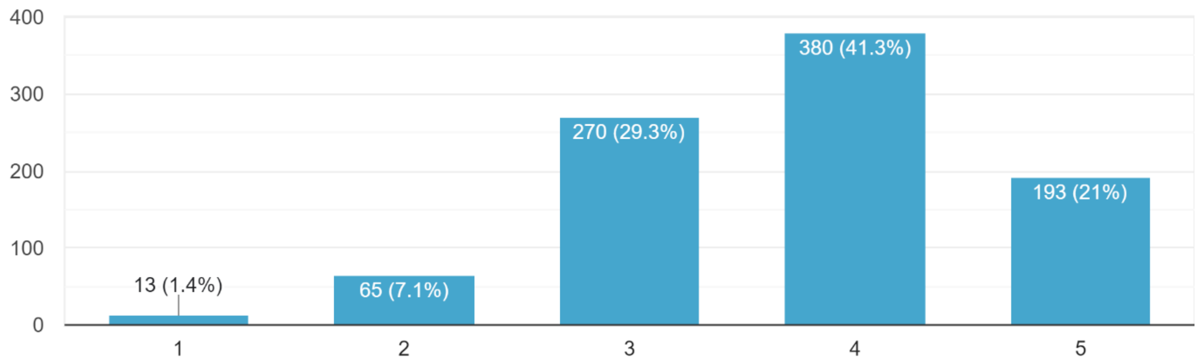

Figure 96. Responses to the question "Are the various functions of the platform well-integrated?".

The majority of students who participated in the ICT-INOV evaluation questionnaire, namely 41.3% (380 out of the total), answered that the various functions of the platform are well integrated, while 21% (193 out of the total) strongly agreed with the statement. 29.3% (270 out of the total) of respondents answered that the various functions of the platform are fairly integrated. In comparison, 7.1% (65 out of the total) of respondents slightly disagreed with the statement, and only 1.4% (13 out of the total) answered that the various functions of the platform are very poorly integrated.

Question 12: Are the learning activities interesting and meaningful?

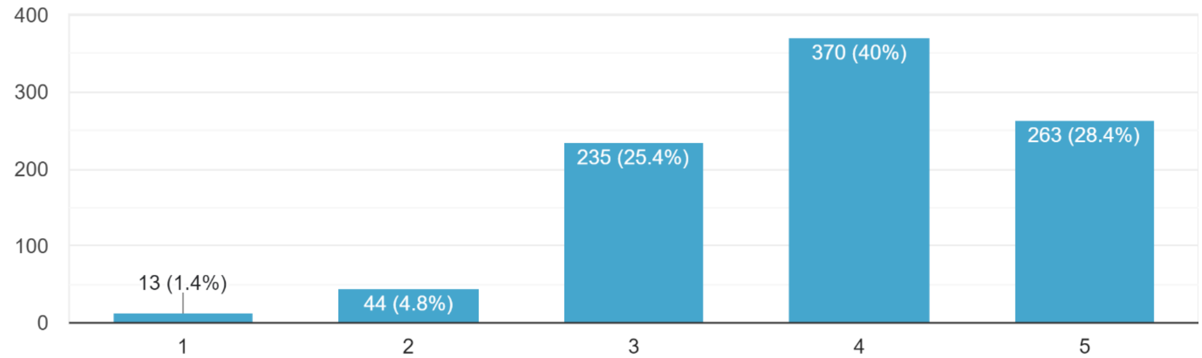

Figure 97. Responses to the question "Are the learning activities interesting and meaningful?".

The majority of students who participated in the ICT-INOV evaluation questionnaire, namely 40% (370 out of the total), answered that the activities were interesting and meaningful, while 28.4% (263 out of the total) totally agreed with the statement. 25.4% (235 out of the total) of respondents answered that the activities were somewhat interesting and meaningful. In comparison, 4.8% (44 out of the total) of respondents slightly disagreed with the statement, and only 1.4% (13 out of the total) answered that the activities were not interesting or meaningful at all.

Question 13: What suggestions would you make for improving the platform?

The evaluation questionnaire responses from students provide valuable insights into their experiences with the ICT-INOV platform, highlighting its strengths and improvement areas.

Students appreciate the platform's interactive features, such as games and challenges, which make learning engaging and enjoyable. Many acknowledge the platform's role in enhancing creativity, problem-solving, and teamwork skills through a variety of resources and tools. The structured framework is praised for facilitating effective project organization and helping students stay on track to achieve their goals. Despite some suggestions for improvement, most students find the platform easy to use and navigate.

However, students express a desire for features that enable real-time collaboration to enhance teamwork and idea generation. Some recommend improvements to the platform's interface for better readability and navigation, suggesting it can be confusing or cluttered at times. Additionally, there are requests for more tools and features to be added to the platform to expand its functionality and usefulness, catering to a wider range of needs.

Addressing server issues and technical glitches is highlighted as essential for ensuring a smoother user experience and preventing frustration. Optimizing the platform for smartphone usage is suggested to improve accessibility for students who prefer to access it on their mobile devices.

In conclusion, while students recognize the ICT-INOV platform's many strengths in promoting creativity, innovation, and collaboration, there are clear opportunities for improvement based on their feedback. By incorporating these suggestions and continually evolving to meet user needs, the platform can better serve as an effective tool for learning and skill development in the technology and engineering fields.

Conclusions

This report presented the piloting activities and findings from using the ICT-INOV digital learning intervention at all partner sites. Piloting engaged students and educators at 12 educational organizations in 8 countries. Of these organizations, 8 were located in Asia and 4 in Europe. Piloting activities followed the same format across partner sites. The goal was to deploy the ICT-INOV digital learning intervention engaging at least 100 students at each partner organization, for a total of 1,200 students consortium-wide, to ensure a wide impact. However, student and educator engagement far exceeded these expectations, with over 4,200 students reached. This report presented piloting activities at the partner and course levels. The descriptions show how the proposed digital learning intervention for innovation was used in practice to update existing courses in formal curricula and promote capacity building for innovation. Finally, the report presented results from a wide questionnaire-based research in which students responded to their perception of the added value of the ICT-INOV digital learning intervention. While initially, the plan was to collect 25 responses at each partner site, the total number of responses was 938, which far exceeded expectations. Students' overall reaction to project outcomes is favourable, highlighting the positive impact of project ICT-INOV on learning experiences and the modernization of participating educational organizations in Asia and Europe.

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