D3.5 Report on piloting in courses

Mid-project progress summary

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Content

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Executive summary

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

The ICT-INOV learning intervention has been implementing 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 presents a mid-project summary of ICT-INOV piloting activities, which have taken place at all partner sites. The report discusses how the proposed ICT-INOV has been deployed for developing innovation skills and capacity among students and instructors in ICT higher education. Early piloting activities focused on the ICT-INOV gamified design thinking methodological learning framework. Later activities also included the use of the ICT-INOV digital learning platform and/or the labs as these services were gradually completed.

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, the activities that were designed for engaging students, and the positive impact on participants.

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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 on 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 more effectively the needs of target users.

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.

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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, to promote mobile learning, to foster programming skills, to develop critical thinking, or other. The activity is directly in line with course objectives, which are 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 provides instructors with flexibility on 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 a 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 document 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 develop an understanding of 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 further encouraged to post as many ideas as possible towards the solution. Students collaborated with their team members to design and post on the ICT-INOV platform their proposed solutions.

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

Students deployed the ICT-INOV educational platform for posting their projects before they presented their solutions to the entire class. Some of the ideas that 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 of additional levels, personalization of content, and open access.
- **Supporting students with attention deficit**. Design an on-line platform through users will fill-in a questionnaire on their needs and stay in touch with experts that support them in the learning process through personalized training sessions.
- **Supporting individuals that 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.

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- **Designing an application that helps students identify valid information as opposed to fake news**. The application will help students to organize their knowledge, saving time, and maximizing the impact of their efforts.
- **Supporting all individuals to learn sign language**. The application will help individuals that are hearing impaired to 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 the elderly**. Design an application that allows elderly individuals that may feel isolated to stay connected and active as well as develop knowledge on subjects of their 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 it encourages students to work on projects in groups. Furthermore, support individuals with learning difficulties. Promote a game-based learning approach with activities that are short in duration and can be used by individuals with busy schedules.

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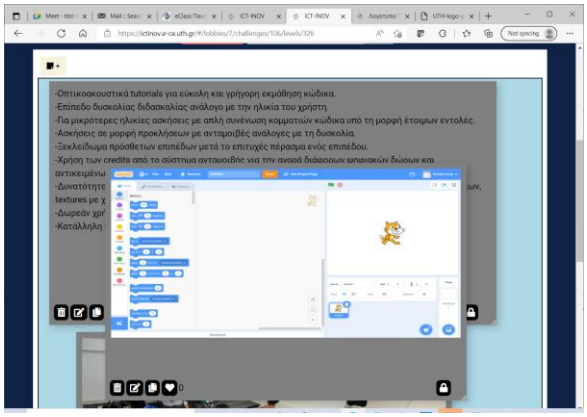

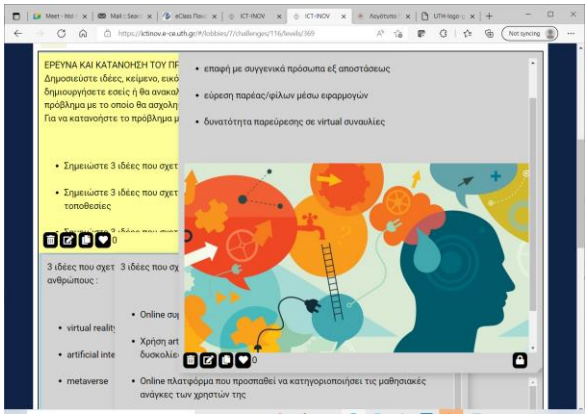

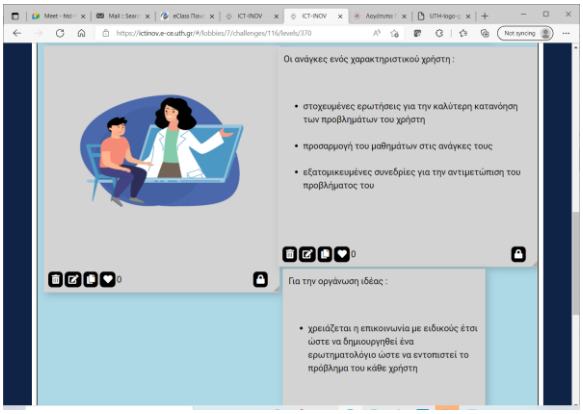

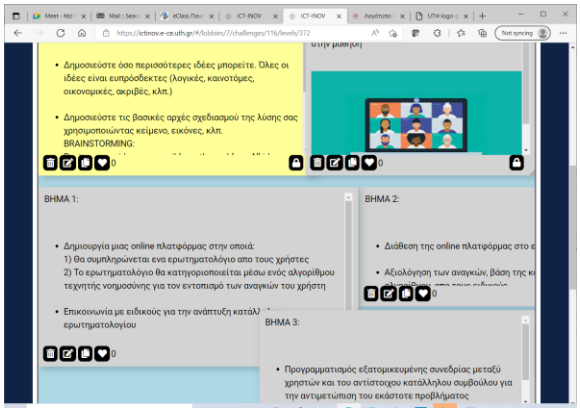

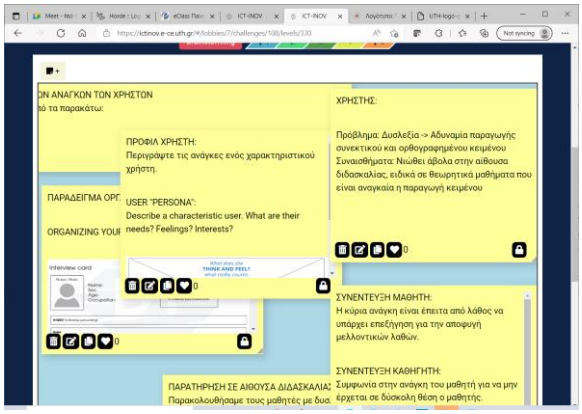

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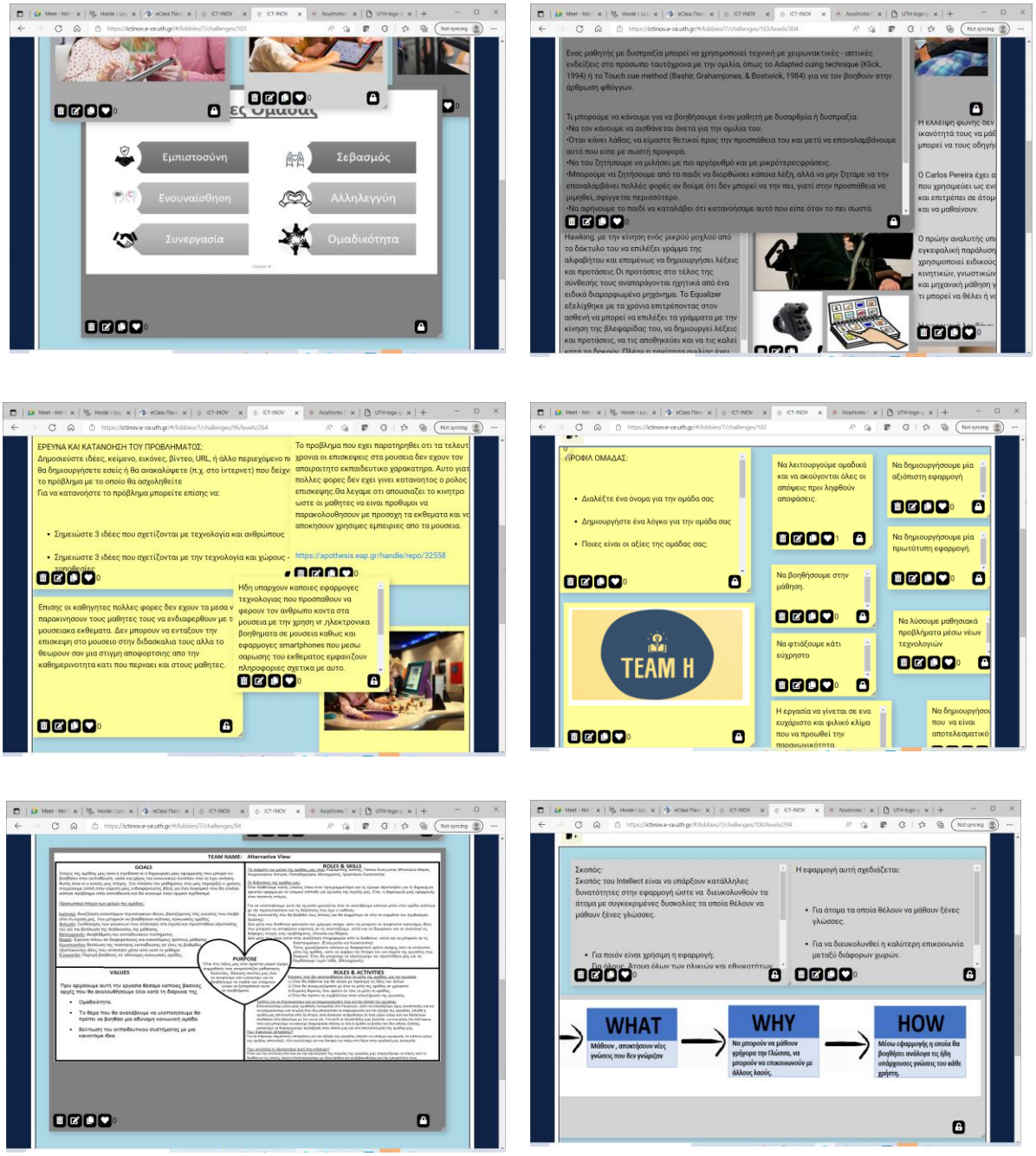

Figure 2. Screenshots of student projects in the Technology in Education course, fall 2021.

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1.2 Course MDE602: Advanced Software Engineering

1.1.1 Description of the course

The course focuses on software engineering principles, namely good practices on the design, implementation, and validation of 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, 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 towards the design and implementation of a full software services by following sound software engineering principles.

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 for the implementation of their projects.

1.2.1 Description of the participants

This is an elective course in the Master's in Computer Science program of the Department of Electrical and Computer Engineering of the University of Thessaly. The program targets students that 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 the completion of their studies may attend the course along with graduate students.

In the 2021 – 2022 academic year, the course was attended by 85 students, of which 8 were graduate students enrolled in the Master's in Computer Science program and 77 were

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undergraduate students in the Department of Electrical and Computer Engineering of the University of Thessaly.

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 aims at encouraging 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 quality of life. The exercise helped students build insight on various topics, towards selecting a specific challenge to solve.

Step 2: Empathy.

Students were encouraged to “put themselves in the shoes of the user”. They were encouraged to structure and conduct interviews with characteristic users and to document their findings into interview cards. Based on the collected information, students were asked to create a user

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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 for addressing which needs and through what means.

Step 4: Ideation.

Students were encouraged to publish as many ideas as possible towards synthesizing a solution to the problem of their choice. The objective at this stage of the process 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 possibly, with the objective of facilitating software development. In addition, students implemented their solution in 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 Advanced Software Engineering course, fall 2021.

Throughout the process, students used the ICT-INOV platform for publishing their ideas at each stage of the design thinking process. Some of the projects that students worked on include:

- **Piano practicing**. A software tool was prepared that helps 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 the fast access of individuals into 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 that are willing to support them and accompany them in excursions as well as everyday activities.
- **Fake news**. An application was developed for analyzing the probability that an article is fake news.

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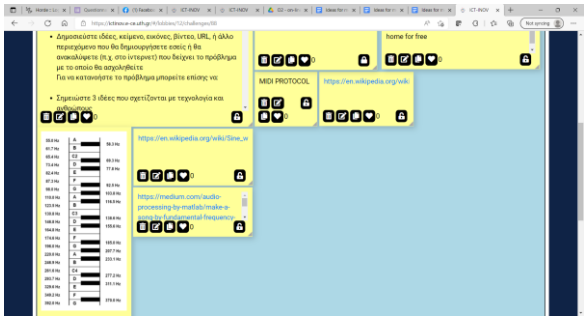
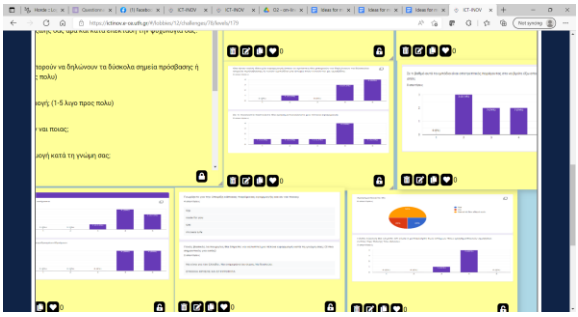
- **High blood sugar detection device**. A software tool was developed for identifying individuals at risk of high blood sugar related disease by considering medical data. The tool deploys machine learning techniques.
- **Make my way**. A software application was developed that aims to help individuals with moving disabilities to 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 for recommending movies for viewing to individuals based on their preferences.

Following are some screenshots of student project work in the ICT-INOV platform.





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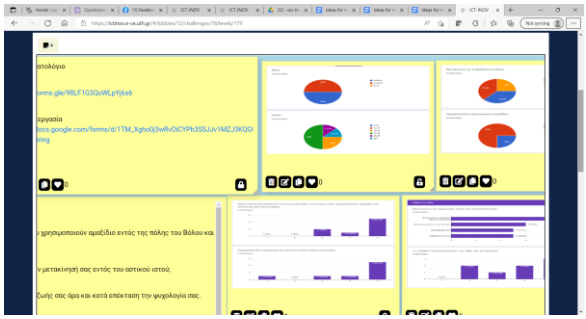

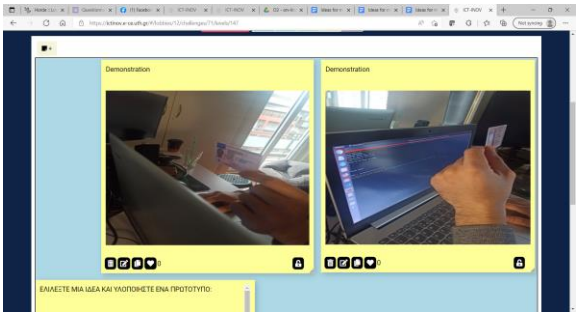

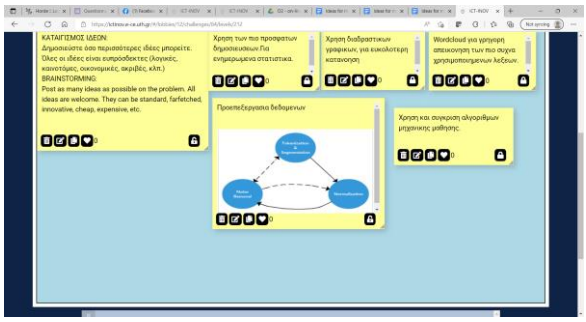

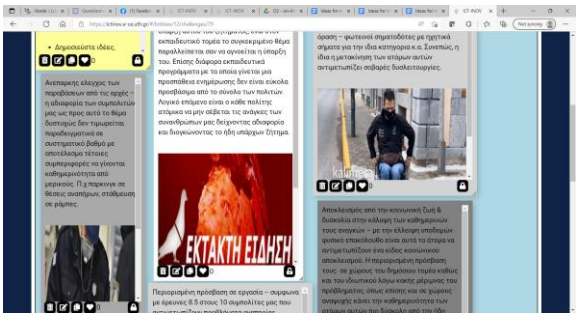

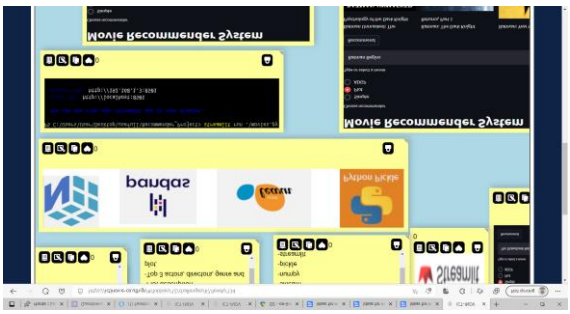

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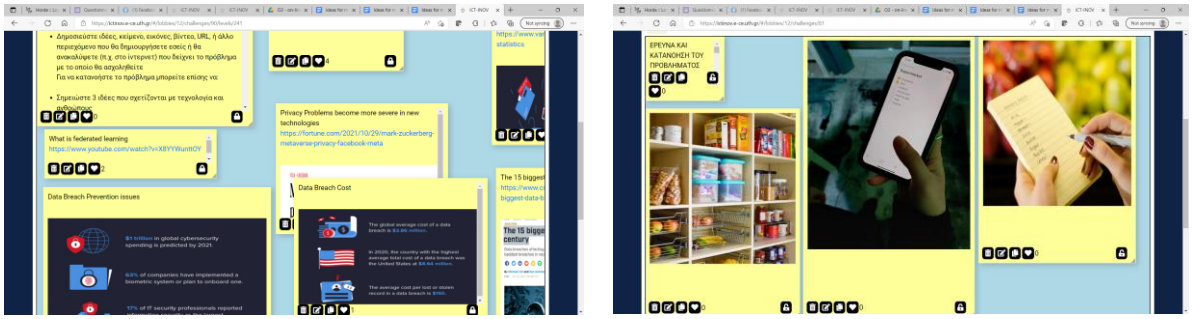

Figure 4. Screenshots of student projects in the ICT-INOV platform in the Advanced Software Engineering course, fall 2021.

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 address both theory and practice. Students design and implement in the UNITY® game development environment an actual game based by considering 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 have a good understanding of game design principles and are able to apply them in practice for developing actual games.

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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, who are close to the completion of their studies.

In the 2021 – 2022 academic year, the course was attended by 124 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 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 other. Students further had freedom on 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.

Students worked in 20 groups of up to 6 individuals. The activity was structured as follows:

Step 1: Game concept.

Students were encouraged design a game concept addressing the following aspects: game objectives, user experience, 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

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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.

Steo 7: Game balancing.

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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 for publishing their ideas and collaborating through every step of the game design process. The platform encouraged students to build on each other's ideas and allow them to collaborate from home in between class sessions.

Some examples of projects that students developed include:

- **A game on raising awareness on 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 that ponders on her past experiences for discovering her strength and building confidence.
- **A game on 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 building early math knowledge in a playful manner.
- **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 subjects of primary and secondary education curricula.
- **A game on geography**. A world trivia game challenges players to answer questions related to different continents, gaining badges and travelling the globe.

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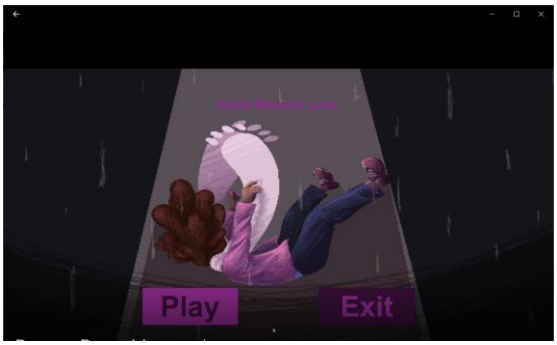

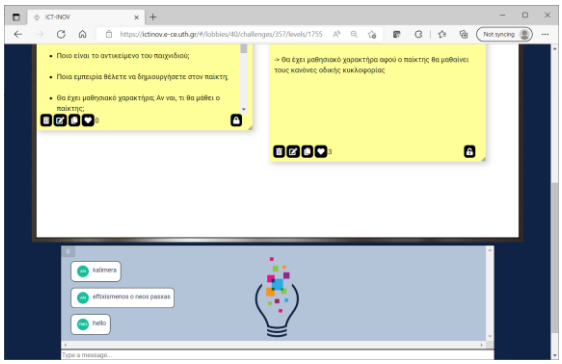

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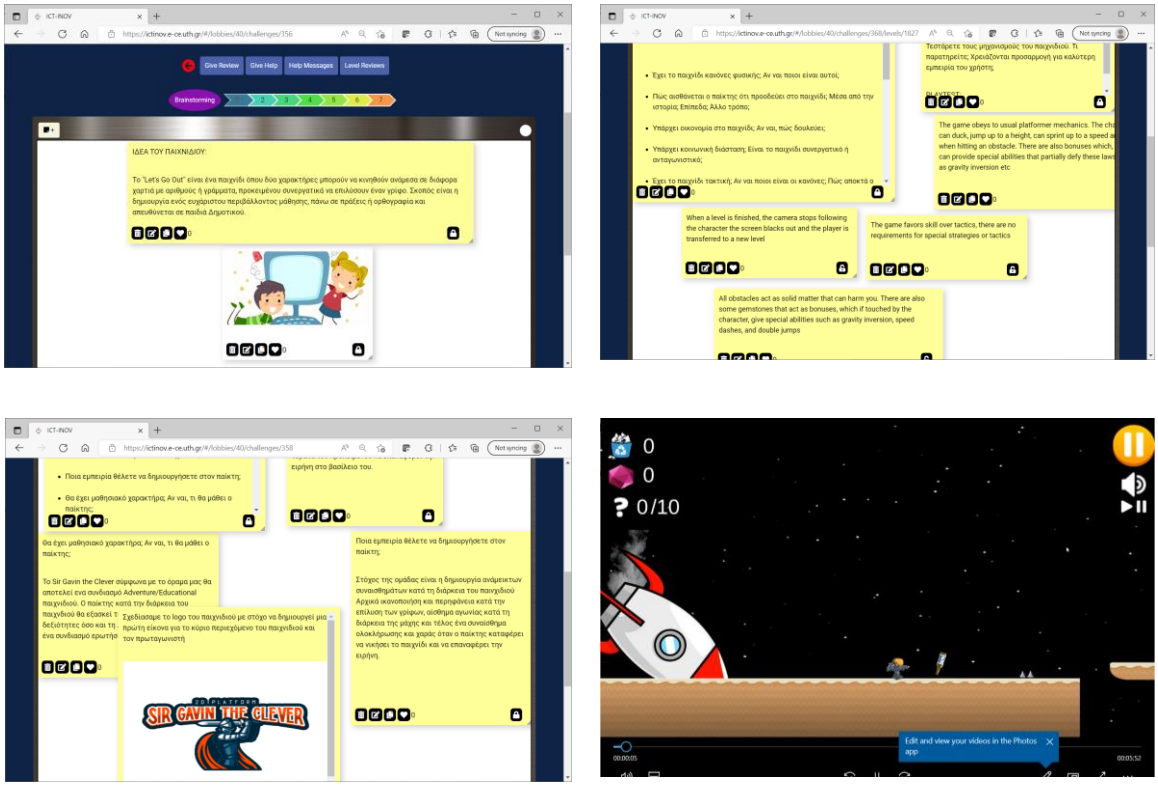

Figure 5. Student projects, presentations, and use of the ICT-INOV platform in the Games Design and Implementation course, spring 2022.

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

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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 have the option of developing a digital prototype of their game using popular platforms, such as UNITY® and Scratch® or a board game designed with paper.

1.4.2 Description of the participants

The course is an elective in the Master's program on Applied Informatics. The program targets professionals that wish to obtain a degree related to Computer Science. 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 to implement a prototype, either digital or physical. 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 other. 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.

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Students were encouraged 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 story follows the hero in the ordinary world, his exposure to the challenge,

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refusal of the hero to face the challenge, 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: 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 project 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 rules of arcade games.
- **A history game**. An arcade game that exposes the player to history questions.

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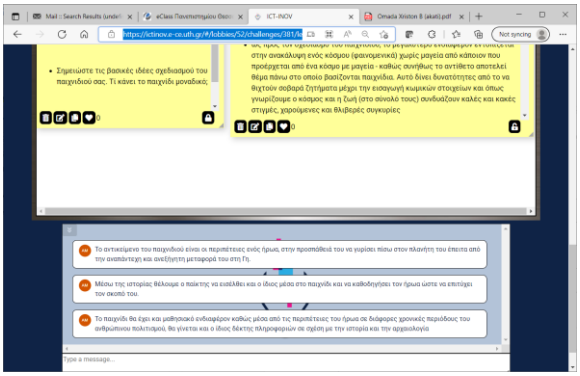

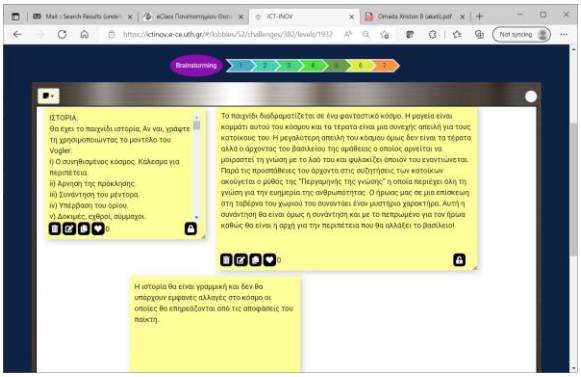

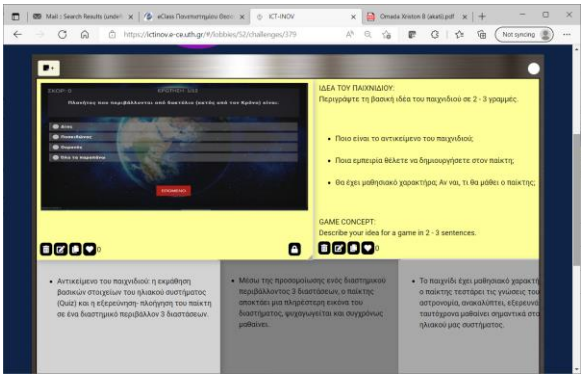

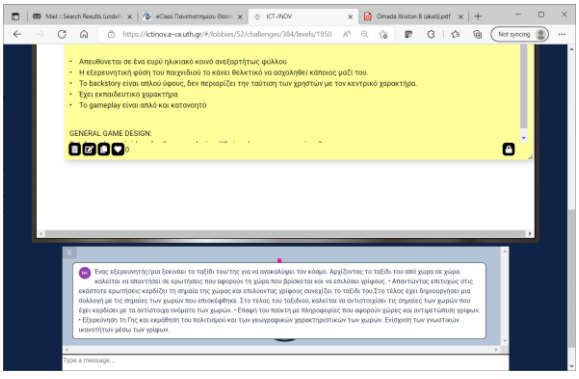

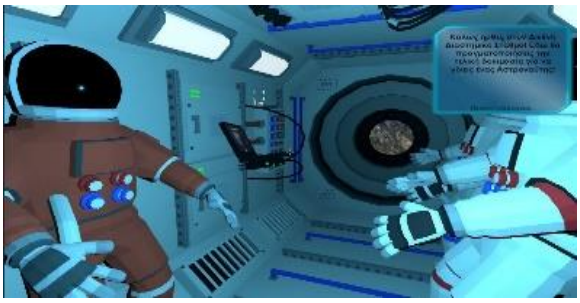

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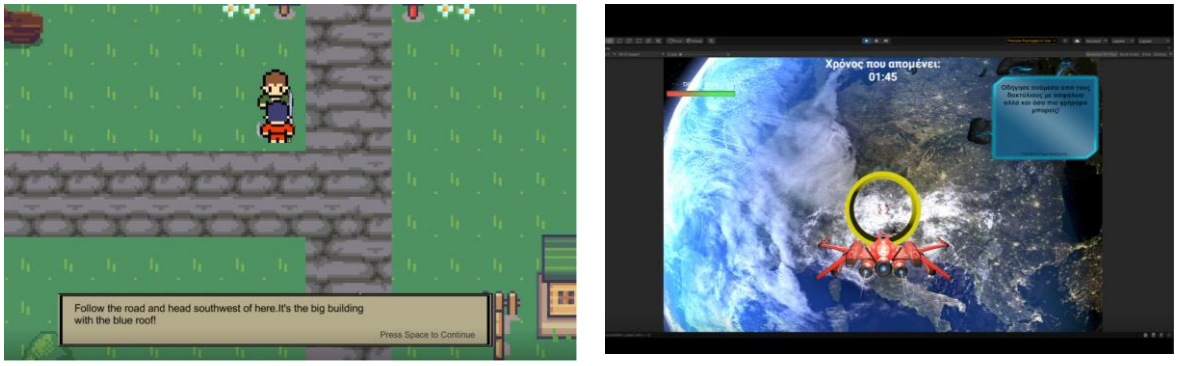

Figure 6. Screenshots of student projects and team collaboration in the ICT-INOV platform in the Serious Games course, spring 2022.

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.

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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: Introduce a solution to the Tower of Hanoi problem.

This is a classic Computer Science problem that 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 place 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: Count 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: Describe 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

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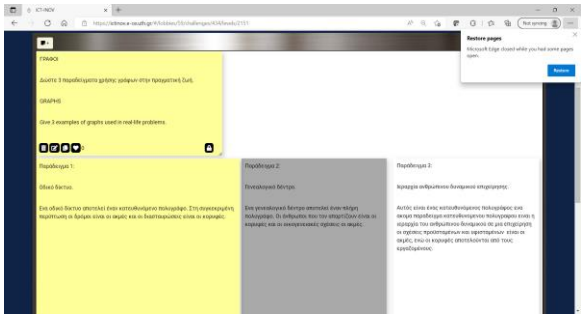
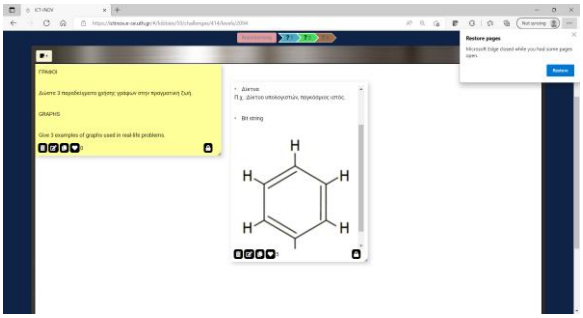
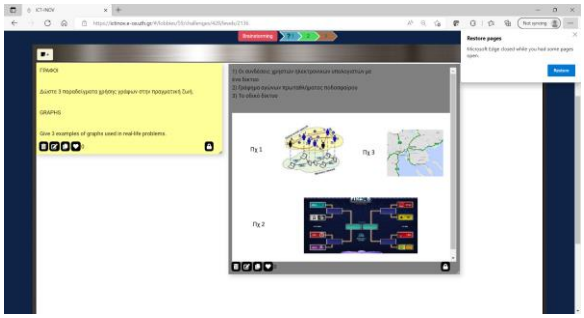
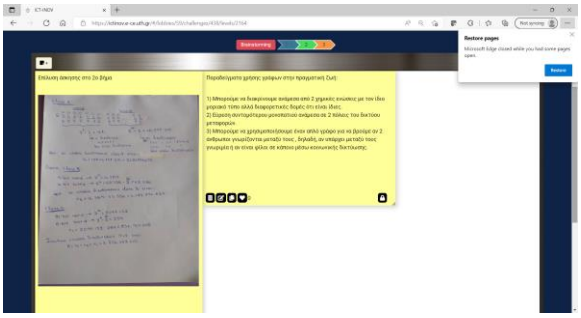
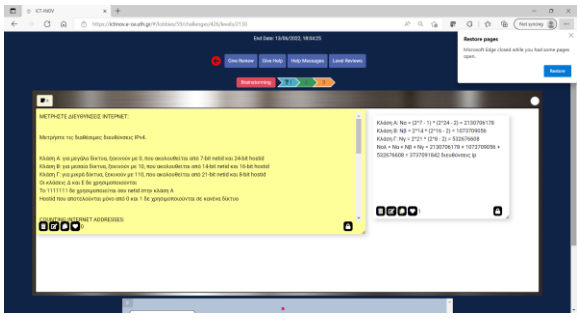
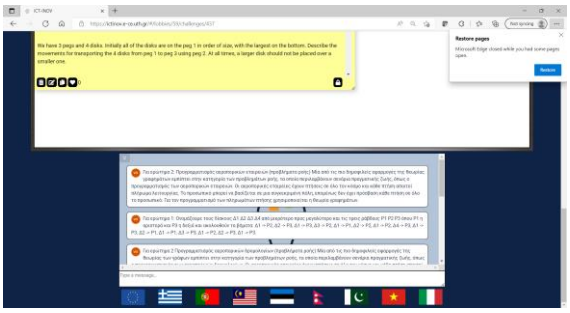
embedded in real-life. It further encouraged them to be creative in identifying links between theory and practice of networks.

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 through the publication of text, images, and even scanned handwritten solutions.

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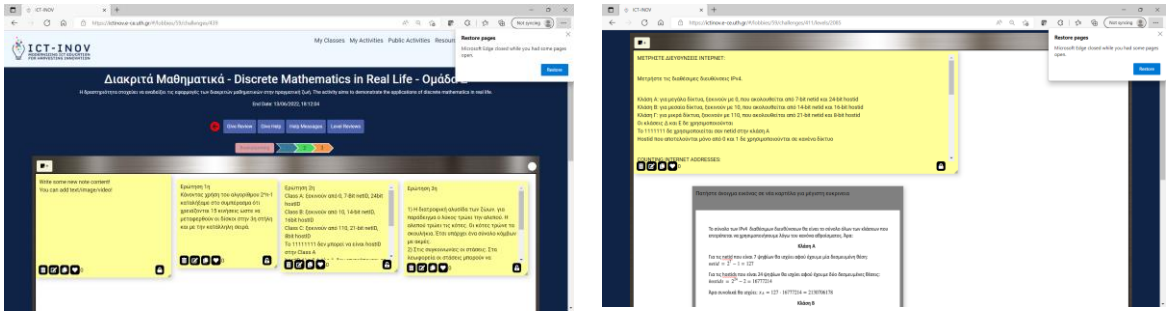

Figure 7. Student projects in the Discrete Mathematics course, spring 2022.

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 techniques of statistical machine learning, categorization and regression for business analytics and sentiment analysis and opinion mining. More specifically, the courses focuses 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 labeled and problem solving is based on regression and classification techniques, unsupervised learning, in which datasets are not labeled and problem solving is based on dimensionality reduction and clustering, and reinforcement learning, in which a model learns from its every action. The course applies machine learning in diverse fields, such as finance and business, government, health, bioinformatics, IoT, and more, through specific case studies.

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1.6.2 Description of the participants

This is an optional course in the 4th year of studies in the Department of Electrical and Computer Engineering of 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 take place in the computer lab of the Department of Electrical and Computer Engineering.

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 to describe a characteristic user through an empathy map that demonstrates how a user thinks and feels, what the user sees and hears, what is the problem the user faces, and what are the potential gains from a good solution.

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 this information with their own newly developed understanding of the problem.

Step 3. Ideation.

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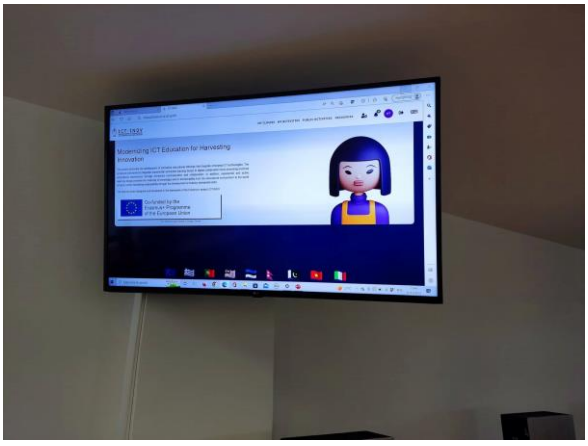
Students were challenged to introduce as many ideas as possible towards a solution. They were asked to consider solutions that require a significant budget for implementation, a small budget, and technology. From this pool of ideas, students were asked to select one for prototyping. Students evaluated ideas by categorizing them in 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 is 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 applies machine learning principles, linking theory to practical applications.



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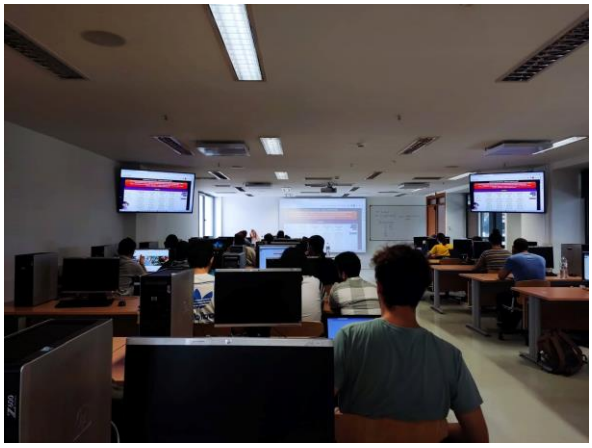

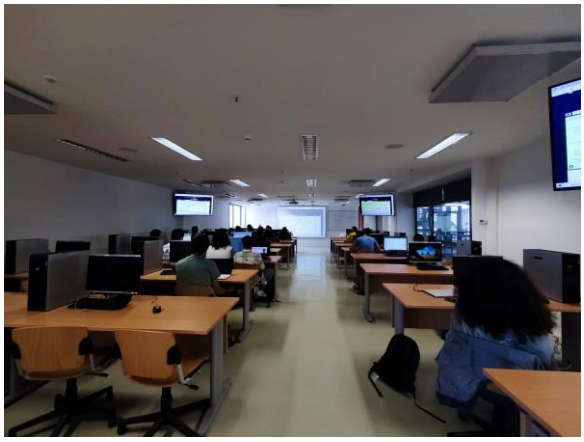


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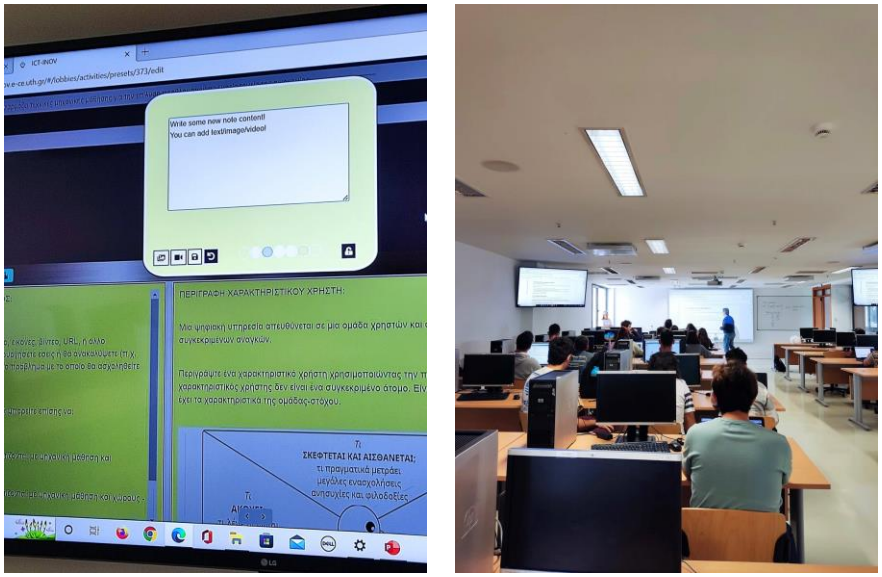

Figure 8. Students are exposed to the ICT-INOV digital learning platform in the context of the Machine Learning course, fall 2022.

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 topics related to straight and curvilinear motion, Newton's laws and applications, forces, kinetic energy, dynamic energy, conservation of energy, 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, can apply these concepts towards solving real-world problems, and have enriched critical thinking and collaboration skills.

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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 the course was attended by 180 students.

1.7.3 Description of gamified design thinking activities

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

The purpose of the project 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 to document areas for improvement for example in terms of cost, pollution, and safety.

Step 2. Ideation.

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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.

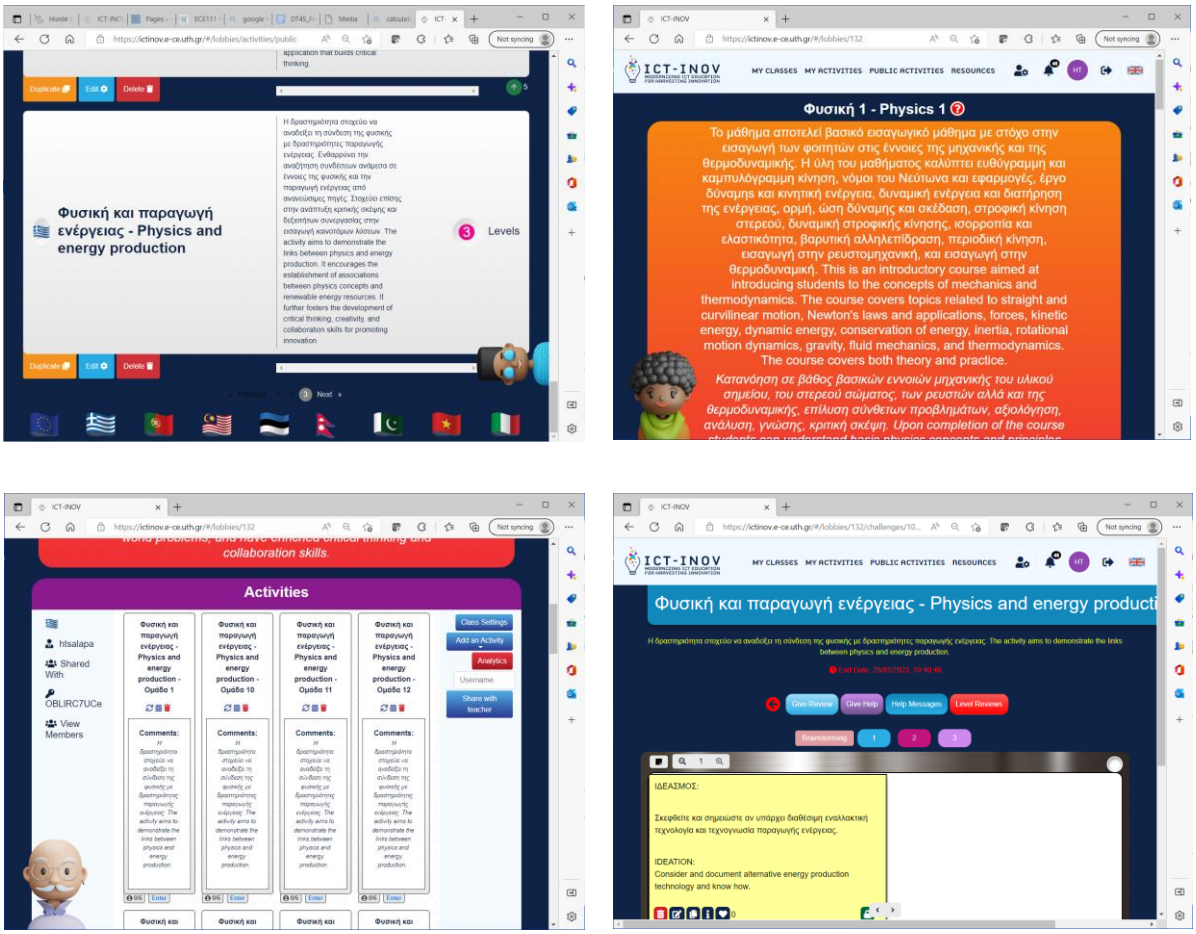

Figure 9. Activities designed for the Physics 1 course, fall 2022.

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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 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 in solving 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 be helpful in simplifying or automating 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 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 is directly in line with course objectives, which are integrate emerging pedagogies with state-of-the-art ICT for better addressing specific educational goals in broad learning contexts.

On 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 solution of the problem were also discussed in group. Students then worked in groups of up to 2 individuals to propose a programmatic solution. The ICT-INOV educational platform provides instructors with flexibility on structuring 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 those solutions could be created by the students. 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.

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

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. Prototype and test.

Students were challenged to solve the problem and deploy the solutions on the ICT-INOV educational platform for posting their projects before they presented their solutions to the entire class.

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

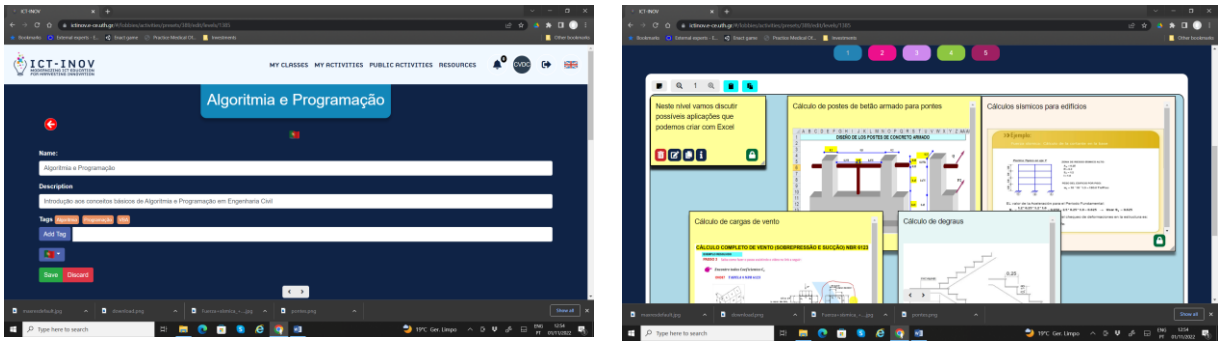

Figure 10. Screenshots of student projects in the Algorithms and Programming course, fall 2022.

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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, branch of Graphical Systems. It focuses on the understanding of the most common applications and the business models of multimedia technologies, effectively applying a project methodology in multimedia design and development of a new product, understanding how to produce a business plan of a new product or service to a set of investors. This course provides the integration of these concepts in the development of 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, adopting 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 is supporting that methodology.

2.2.2 Description of the participants

The course is part of the 2nd year of studies at the Master's in Computer Engineering of the Porto Polytechnic, 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.

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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 had to discuss and find problems related to creating games for handicapped players, and 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.

On 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 in 2 groups and each group proposed a programmatic solution. The ICT-INOV educational platform provides instructors with flexibility on 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 those solutions could be created by the students.

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 in two teams. Individual roles in the team were assigned by the peers.

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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. Prototype and test.

Students were challenged to solve the problem and deploy the solutions on the ICT-INOV educational platform for posting their projects before they presented their solutions to the entire class.

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

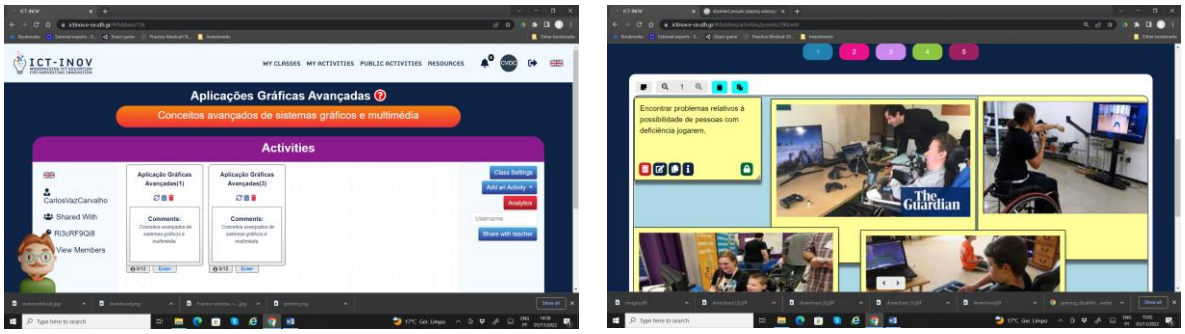

Figure 11. Screenshots of student projects in the Advanced Graphics Applications course, fall 2022.

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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 competences 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, consisting 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.

Participation in the LIFE course is supported by workshops and seminars. More detailed information about the course is available at http://elu.tlu.ee.

Upon completing the course students can make connections and can 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, has developed collaboration competences, 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 in 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 off-line, namely without the use of 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 for breaking 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 what are the main problems faced by society. They were encouraged to share their findings within their teams through the ICT-INOV digital learning platform.

Step 3: Problem definition

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Students were encouraged to have a discussion 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.

Step 4: Brainstorming and ideation

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

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 for posting 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 do a Tik-Tok 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.

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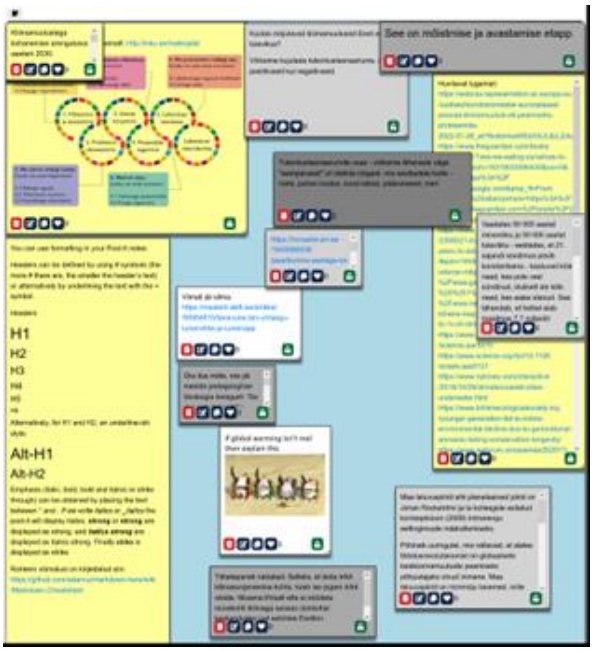
- **Video 3.** Group 3 developed a video in which kindergarten students present their thoughts on climate change. The video is accessible at the address https://www.youtube.com/watch?v=6sdbtIEOChU&list=PLTUT0jPPotgHCsLNVQq_89OXY6yfSfJd0.



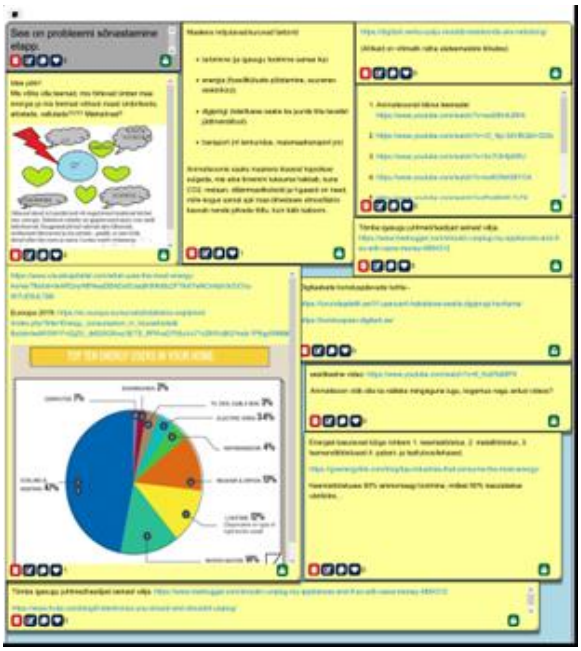


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Figure 12. Screenshots of student projects in the LIFE course, spring 2022.

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 competences towards resolving interdisciplinary problems in tertiary education.

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

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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 on 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 prior to 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 that they identified over the duration of the week leading up to the workshop to the ICT-INOV digital learning platform. They subsequently had a discussion with their peers through which they selected a joint problem to be addressed by the entire team. They accurately defined the problem and posted it on the platform.

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Step 4. Research

Students were encouraged research on-line information that helps describe the problem in focus through text, images, and videos. They described a characteristic individual that faces the problem, the problem 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 on the ICT-INOV digital learning platform platform their proposed solutions. 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 for posting 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 design to encourage further recycling.
- **Reducing light pollution**. Saving energy and promoting safety for all living beings.

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- **Pedestrian areas**. Designing a new Tallinn city center in which central streets are closed for motor vehicles. At the same time creating enticing pedestrian areas.
- **Greener Tallinn**. Making the city center more environmentally friendly by building green/living bus stops.

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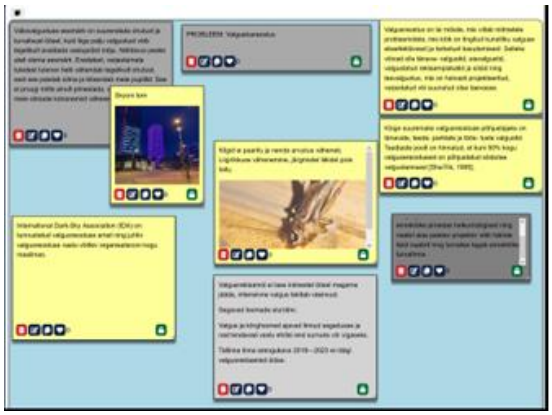

Figure 13. Screenshots of student work at project day in Kadrioru Saksa Gümnaasium, spring 2022.

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4. EUTrack

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 reflection redesign for achieving better results. Through well-planned educational robotics activities students learn not only to build a robot to solve a problem, but 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, and development of an application idea and working through the set of critical points for the application chosen.

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-solution perspective. In this context, the main distinctive feature of the course is the integration of 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 to synthesize innovative solutions while bringing a new perspective and a solid contribution to strengthening STEM education and increasing scientific literacy.

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Rightfully defined as standing at the heart of maker education, design thinking elements are implicitly present in the EduRobot curriculum. The method's full-fledged and systematic adoption is a natural extension of existing learning practices given its accent on creative and out-of-box thinking and problem-solving.

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 level. 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

The objective of course activities was to expose students to design and engineering issues in a balanced manner. Students designed and constructed a robotic arm through the use of 3D printing technology. Underlying concepts related to working with 3D objects and electronics were conveyed early in 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 product, namely robotic arm, users, which was controlled by diverse mechanisms selected in accordance with the expected use.

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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 do research related to the topic in focus to understand better 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, visons, environments, and fears.

Step 3: Problem definition.

Students were invited to be specific in the definition of the problem 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.

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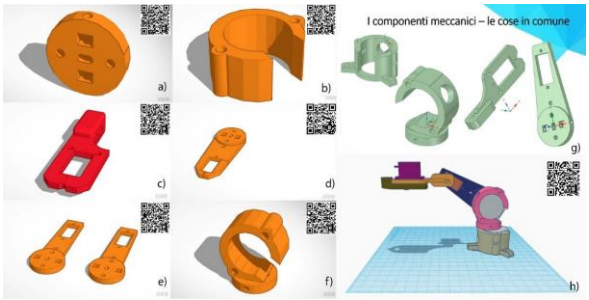
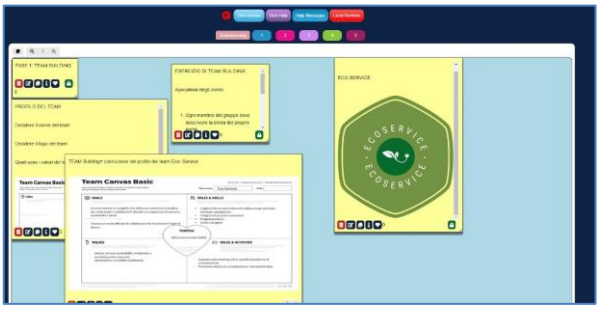
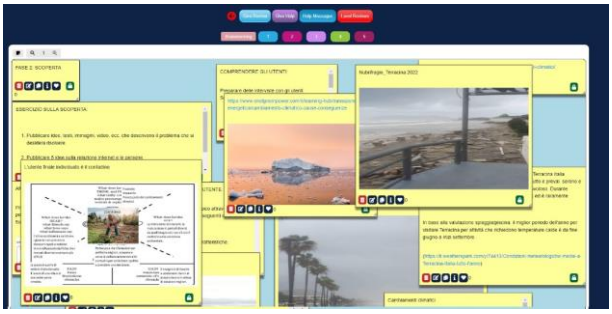
Students designed a prototype using the TinkerCad® environment. Subsequently, they implemented the prototype's mechanical elements by using a 3D printer and coded its behavior through Arduino® IDE.

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.







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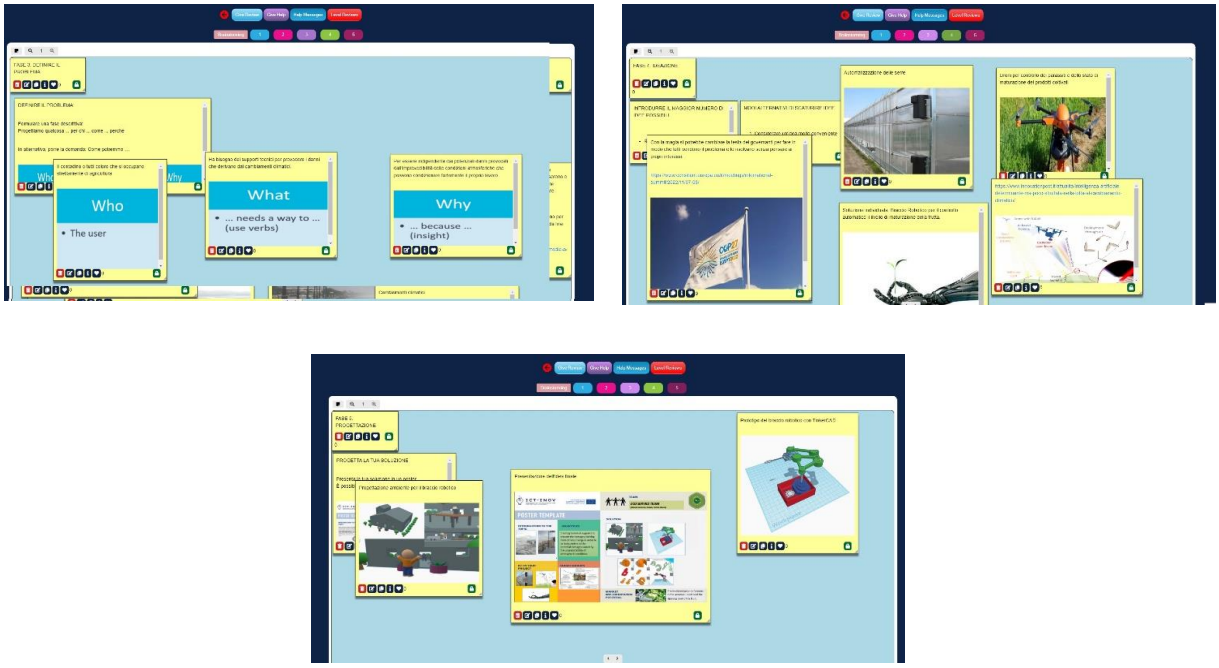

Figure 14. Images of student projects in the EduRobot course, fall 2021.

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 problems 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,

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motivated, collaborative, and innovative, capable of engaging in their own inquiries and thriving in a world of constant change.

The course aims at theoretical and practical deepening. The course aims at building student skills on 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.

For this training, the ICT-INOV methodology was deployed in the 2021 – 2022 academic year. Students aged between 22-30 years old were engaged in the course managed by the research center, 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

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attitudes, behavior, and latent needs. The purpose of design thinking deployment was to achieve a more effective needs analysis. Activities were organized in the following steps.

Step 1: Team building.

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

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.

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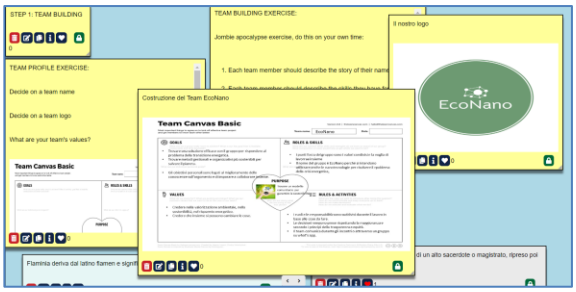
Through this method, students gained deep insights and better understanding of the researched topic and the context in which they operate through a holistic approach belonging to the ICT-INOV methodology implementation.

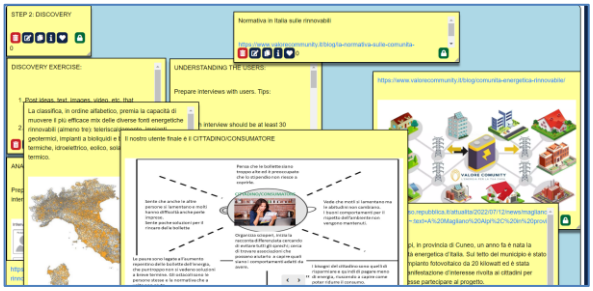
Step 4: Brainstorming and ideate.

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: Prototype and design.

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





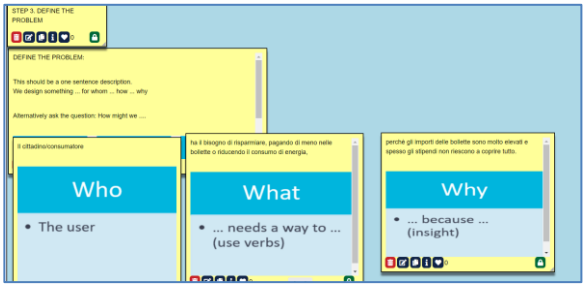


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Figure 15. Student projects in the Research-Based Approach course, fall 2021.

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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 be 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, which is a hands-on activity that further facilitates the understanding of concepts. Students from different areas of studies are asked to present problems related to their area. Using the skills and concepts learned, they are required to come up with 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 does not require any prior knowledge in programming or Computer Science. It aims to demonstrate that computational thinking is used by everyone whether they are aware of it or not, rather than guide them to use 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.

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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 ideation, prototyping, and evaluation phases of the methodology.

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 area of study. In addition, the class project aimed at building student 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 output every week. At the end of the week, students went through an interview on 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.

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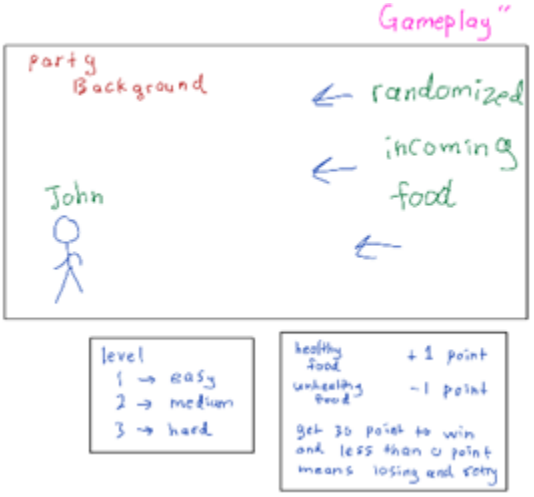
Students brainstormed towards introducing ideas for game creation. The ideation outcomes were documented through a storyboard on initial game design. The results were delivered at the end of week 2 of the activity.

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 were delivered at the end of week 4 on the activity.



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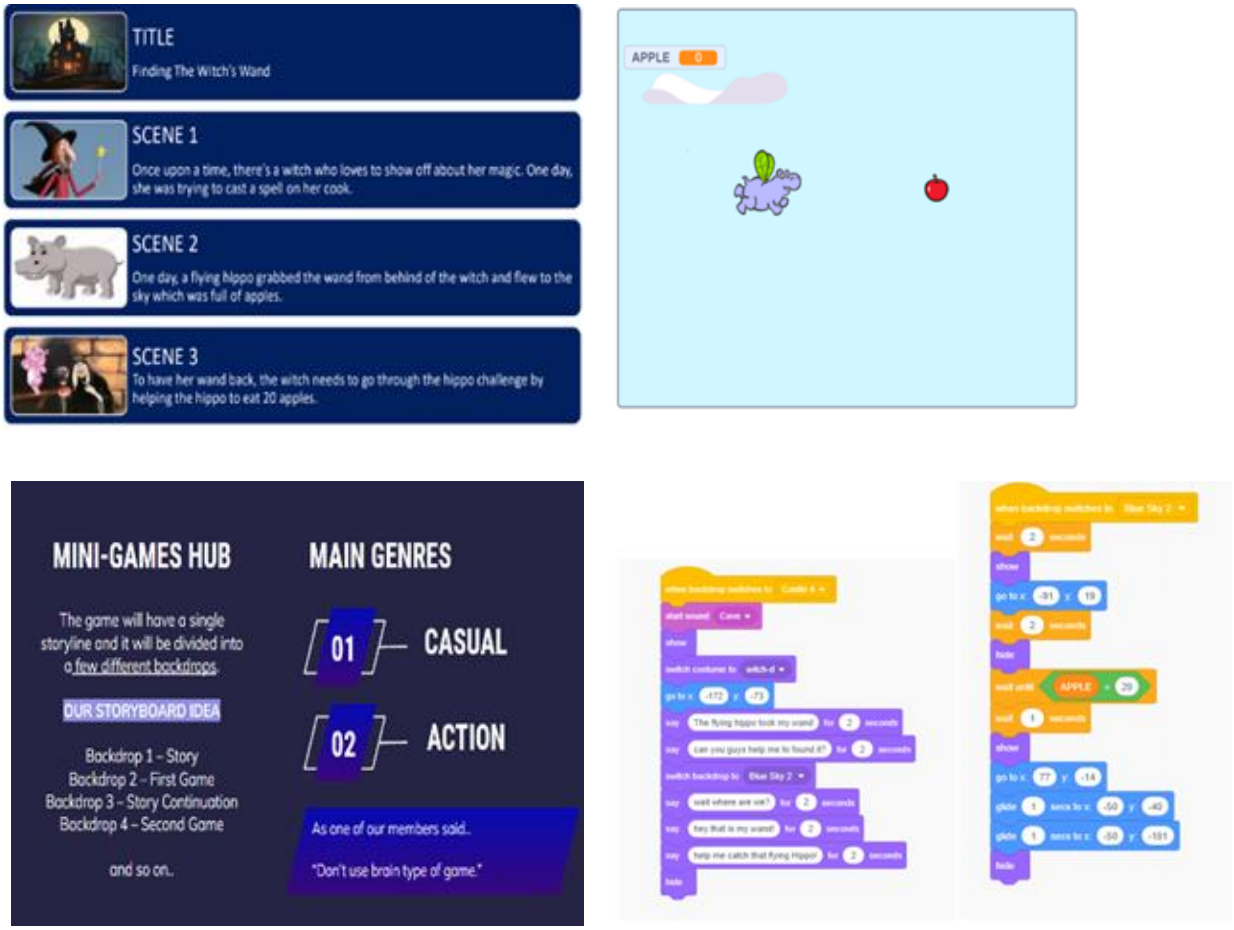

Figure 16. Screenshots of student projects in the Computational Thinking course, fall 2021.

5.2 Course WIF3005: Software Maintenance and Evolution

5.2.1 Description of the course

The Software Maintenance and Evolution course mainly covers software maintenance fundamentals, key issues in maintenance, maintenance process, techniques for maintenance, and evolution in maintenance activities. The course takes place virtually.

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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 years 20 students attended the course.

5.2.3 Description of gamified design thinking activities

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

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 faced by the elderly, such as health issues including 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 life of the elderly.

Students worked in teams of 5 individuals. They were instructed to design a mobile app that helps address a specific challenge faced by elderly individuals. 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 performed research on the selected topic and described the problem through photos, drawings, notes, and article links that they posted on the ICT-INOV digital learning platform. In addition, students observed the behavior of the targeted group, namely elderly individuals and recorded their findings. They engaged in conversation with at least 6 individuals facing the problem and recorded what they thought and felt. 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 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 were instructed to not 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. For each feature, they defined user and system requirements, both functional and non-functional, including quality requirements and constraints.

Step 5. Lessons learned.

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

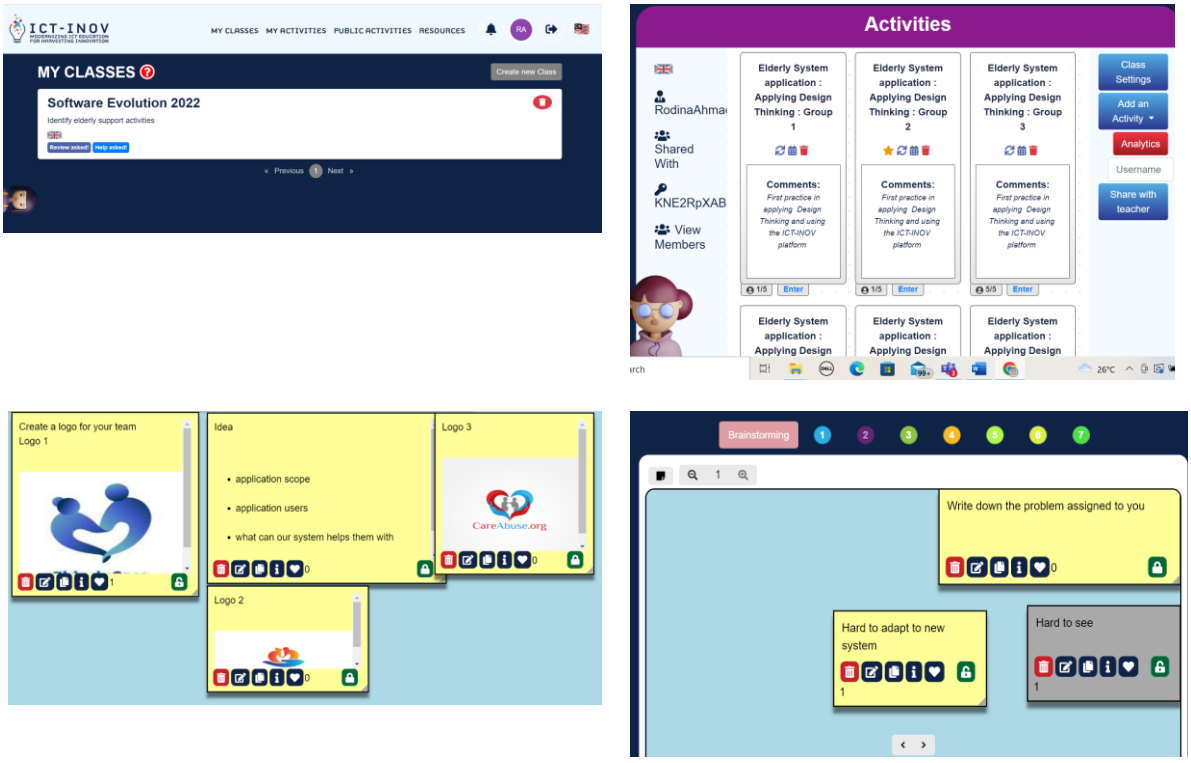

Figure 17. Screenshots of student projects in the Software Maintenance and Evolution course, spring 2022.

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, advance data structures and their implementation in modern programming environment. The course takes place virtually.

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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 years 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 the implementation of the class project, in which students were required to introduce a solution on 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 by 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: Brainstorm and analyze.

In this phase, students analyzed the parameters of the assigned problem and brainstormed on potential solution ideas.

Step 2: Design and code.

Students designed a solution and coded a computer program using Python®. They used Padlet®, Google® Docs and any other necessary collaborative tools to document the brainstorming and ideation activity before focusing on software coding. This step was implemented over weeks 7 – 12 of the course.

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Step 3: Presentation and demo.

Students delivered in groups a 20 – 30min 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.

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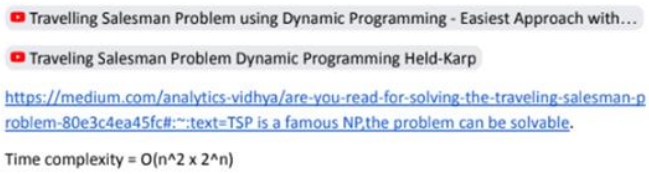

Figure 18. Screenshots of student projects in the Algorithm Design and Analysis course, spring 2022.

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 years 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 the implementation of the class project, in which students were required to introduce a solution on a specific problem.

The pedagogical approach applied in the course was project-based learning. The objective of the project-based class activity was to empower students to solve problems related to real-time issues in communication networks with an emphasis on feature-sand capabilities for supporting

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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 by 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 in their solutions control components and autonomous behavior.

Activities were organized in the following design thinking steps:

Step 1: Brainstorm.

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

Step 2. Analyze, design, and prototype.

Students analyzed potential solutions and developed a software prototype using Python® that address the problem in focus. Students had consultations 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 – 15min presentation in which the presented their work and demonstrated their prototype solution.

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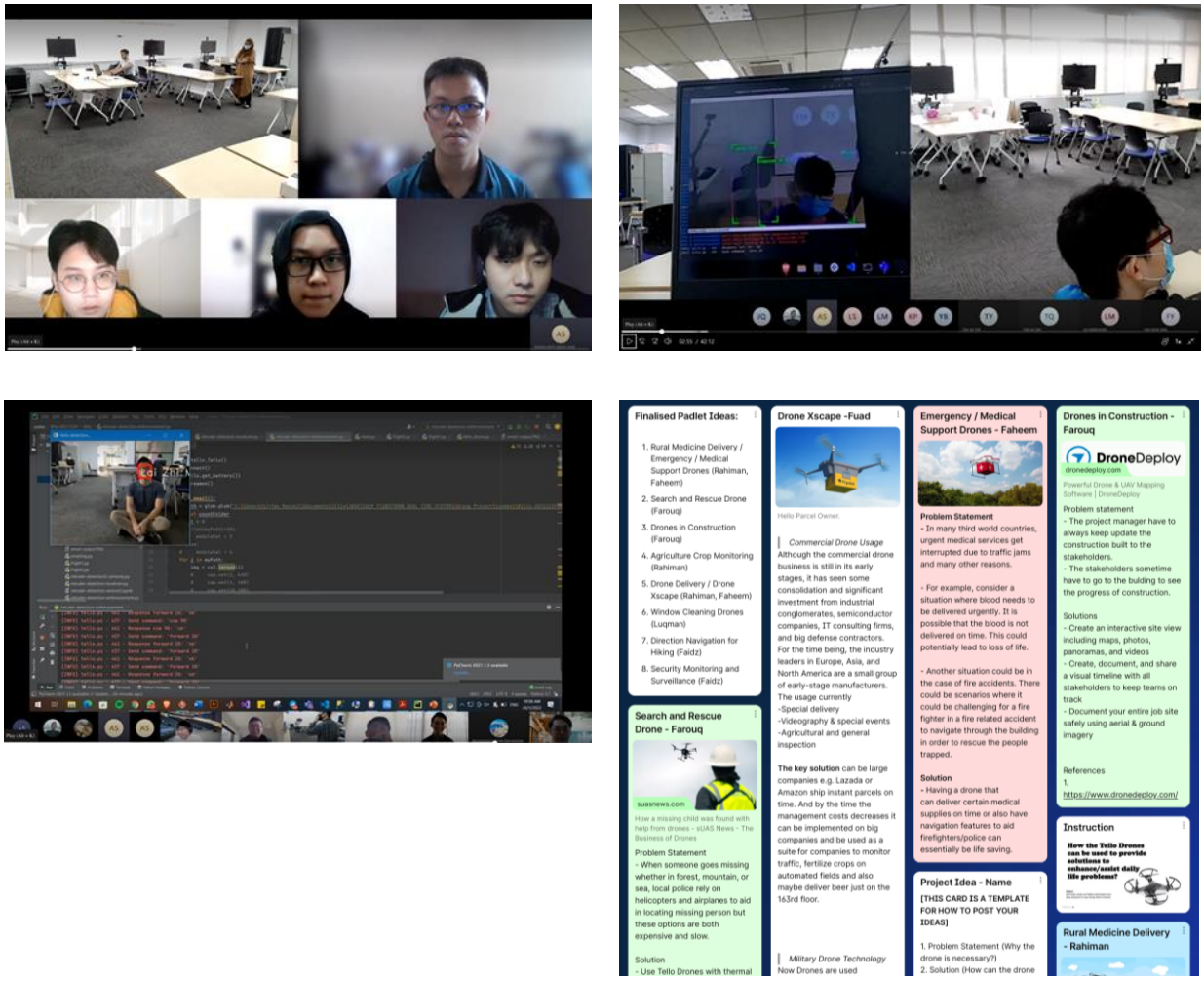

Figure 19. Screenshots of student projects in the Real-Time Systems course, fall 2021.

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.

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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 years 80 students attended the course.

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 the development of innovation skills took place. The goal of the study was 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 objective of the project-based class activity was to introducer students to requirements artefacts based on established standards and to apply appropriate techniques and methods to elicit and analyze software requirements.

Students engaged in the following activities:

Step 1. Problem research.

Students selected a web site or mobile app or both that they would like to improve on. An example of a selected project is focusing on challenges faced by elderly individuals, such as fear of mobility or being a burden. This particular activity was performed by all 80 students in the class.

Upon selecting a topic to focus on, students engaged in problem research through various means. They observed the target users to document behavior and recorded findings. They further web-based research for effectively describing the problem through photos, drawings, notes, and article links that they posted on the ICT-INOV digital learning platform. They engaged

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in conversation with at least 6 individuals facing the problem and recorded what they thought and felt. 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. For each feature, they defined user and system requirements, both 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 the main system components and documented them as activity and sequence diagrams.

Step 5. Lessons learned.

Students analyzed their own 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.

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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 on 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 years 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 student 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 text 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 for facilitating 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 presentation of the topic 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 on 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. The 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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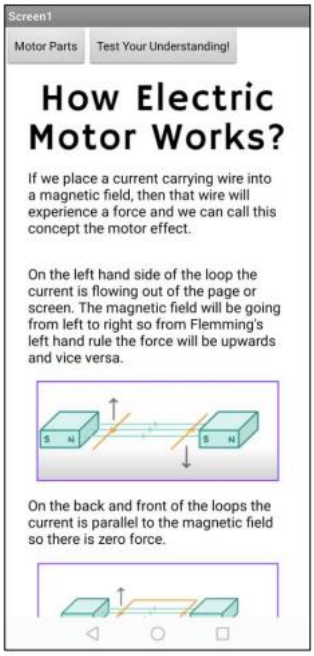

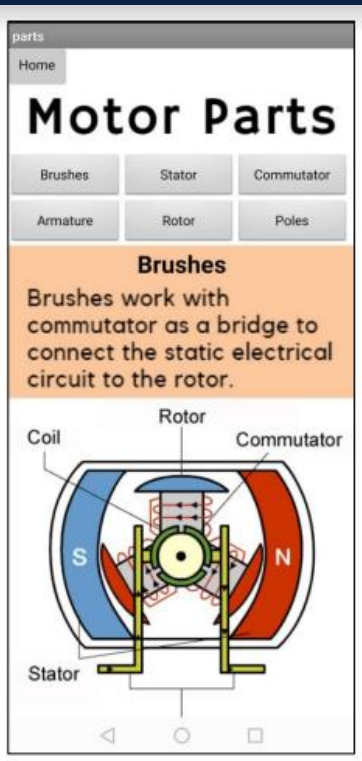

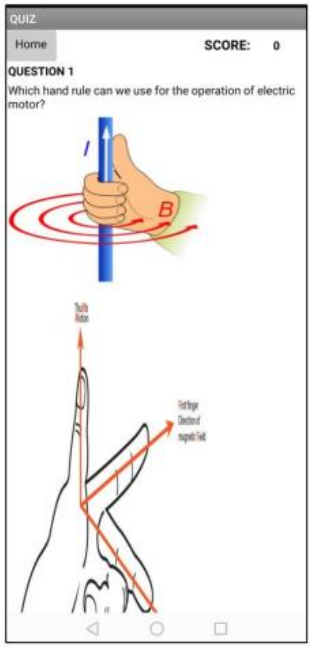

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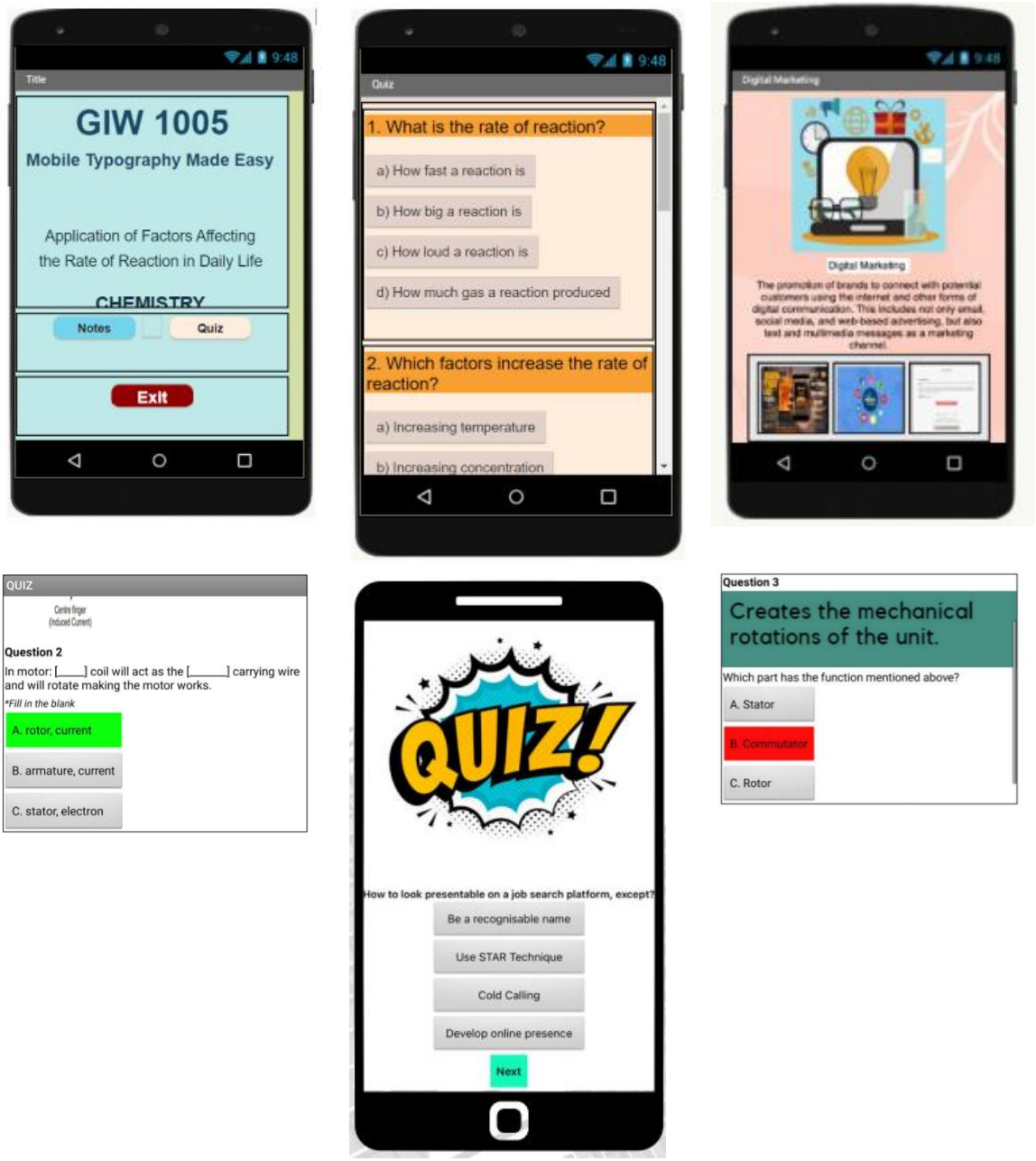

Figure 20. Screenshots of student projects in the Mobile Typography Made Easy course, spring 2022.

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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 that are 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's of Data Science program. In semester 2 of the 2021 – 2022 academic years 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 originating from China, Egypt, Bangladesh, Pakistan, Saudi Arabia, Indonesia and Malaysia. Most of the students were in their final year of studies, undertaking their 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. Through the project, students learned 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, those factors would eaten by the shark. 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 the state of the art on 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, which contributed to their understanding of network security and to the improvement

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of their communication skills. Students were given instructions in tutorial sessions in 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-attack 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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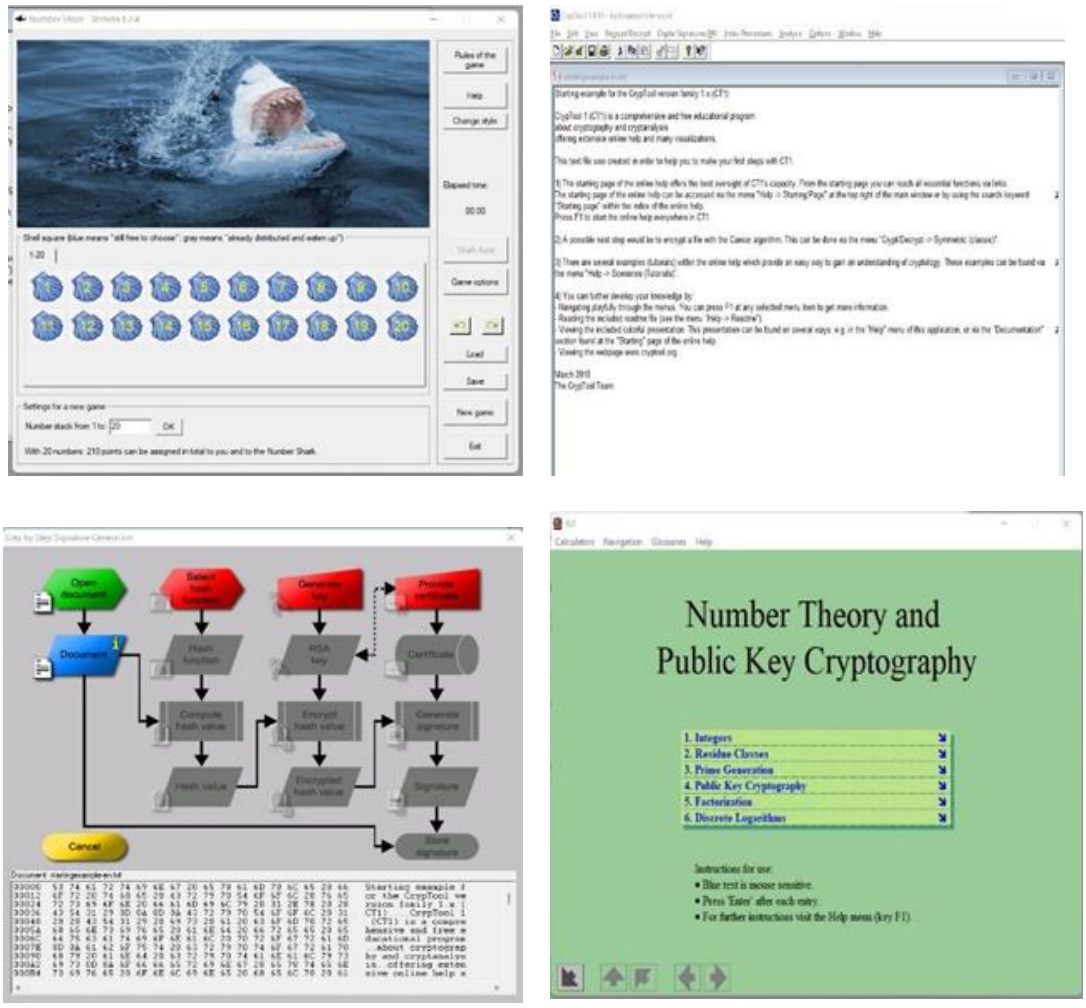

Figure 21. Interactive games in the context of the Mobile Cryptography Made Easy course, spring 2022.

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 barriers to communication. In terms of barriers for communication, topics include techniques for clarifying, analyzing and evaluating arguments

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and logical fallacies, problem solving and decision making. The course further focuses on methods for finding, evaluating and using information sources effectively. 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 years 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. A total of 392 students enrolled in the course in Semester 1 of 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 originating 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 towards providing students the opportunity to contribute knowledge, skills and competencies in their field towards solving problems or issues within communities. It is one of the initiatives of higher education in Malaysia aimed towards producing graduates who are holistic and balanced and possess an entrepreneurial mindset. The service-learning project is also one of the elements that characterizes 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

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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 own homes using their own workstation or laptop connected to the internet to participate in weekly group discussions. They used the MSTeams® platform for communication and sharing of 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 had a duration of 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, namely in what ways can we support a community for better quality of life post COVID-19 across different domains, such as education, tourism, health, business and others. They were allowed to further specialize 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 endemic COVID-19.

Step 1: Finding a collaborator and problem discovery.

The objective of the activity 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 setup a virtual meeting with their collaborator of choice. During the meeting, team members conducted an interview in an informal setting, such as a chat. The goal of this meeting was to understand what matters were important to the collaborator with respect to the topic in focus. Prior to the

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team's meeting 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 shoes of the end user in order 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 their observations gathered in previous steps. Students created a wall of ides 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 into a single problem statement that was the result of 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

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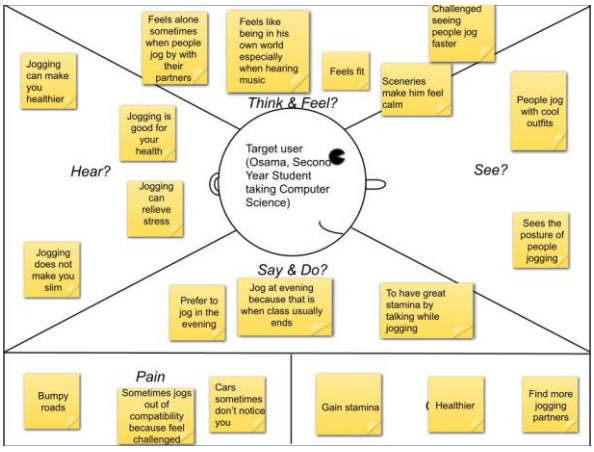
were instructed to build on the ideas of others, to stay on topic, to defer judgement and to welcome wild ideas.

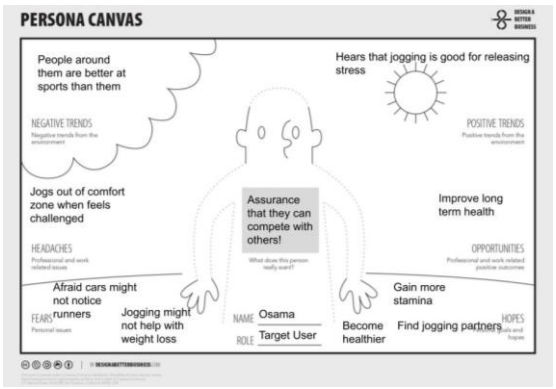
Step 5: Prototyping. How innovative can one get?

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, for example services or products. Some examples of potential media for prototyping include sketches and diagrams, paper interface, 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 a suitable medium for prototyping based on the type of solution their decided to develop.

- **For services**, the facilitator recommended as potential types of prototypes role playing, video, storyline and flyer.
- **For products**, 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.





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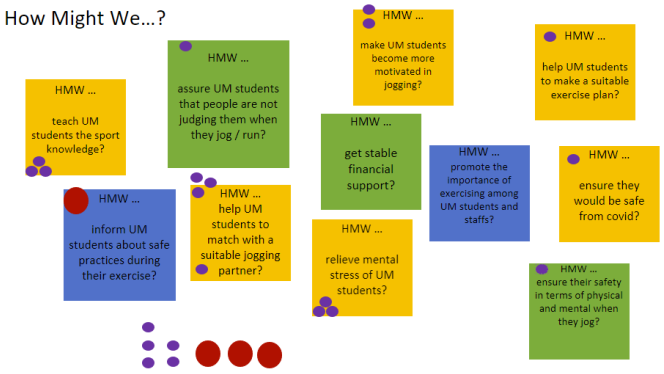
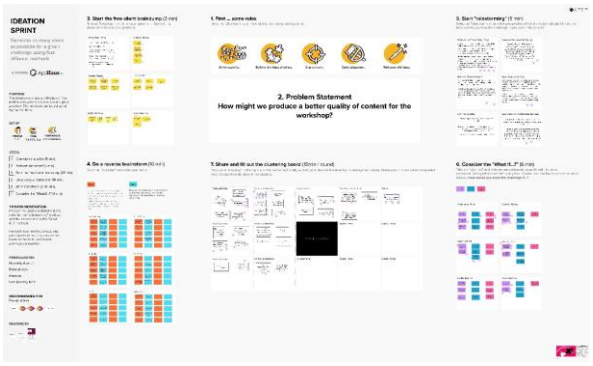




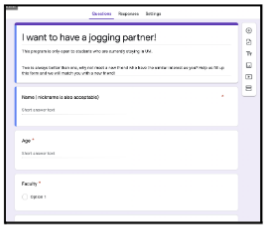
Audience Outreach

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.



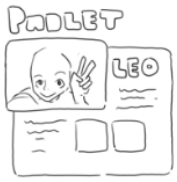
Introduction to Padlet

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 preferences 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

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Figure 22.Empathy map, user persona, problem statement definition, ideation and prototyping of a vertical farming solution in the Thinking and Communication course, fall 2021.

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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 course structure is designed by the Computer Science faculty. The course introduces social research perspectives on the use of ICT and their 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 in the use of social networks. The course is conducted virtually. It deploys a 100% continuous assessment to evaluate students' understanding and knowledge. Upon completion of the course students are able to apply selected approaches in understanding various dimensions and implications of social informatics and ICT

5.9.2 Description of the participants

Students that attended this course were enrolled in a University Malaya undergraduate program in multiple majors. 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 the Business and Economics, the Faculty of Art, and Faculty of Science. The majority of 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

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used to systematically monitor student progress in pre-defined activities within designated weeks. 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 objective of the project 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 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 via different types of techniques mainly using storyboarding. Students were encouraged to explore any technology-related design tools, such as video, editing, and analytic concept 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 the objectives of their innovative solution, to identify the technology needed for implementation, and to define the target users.

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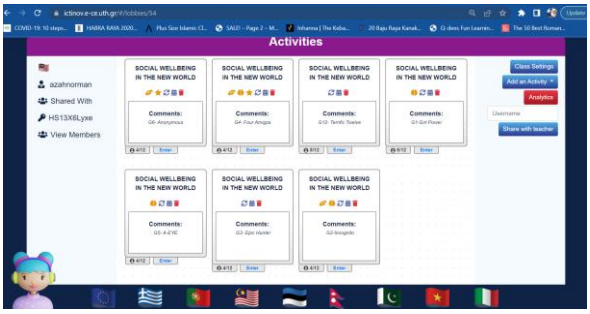
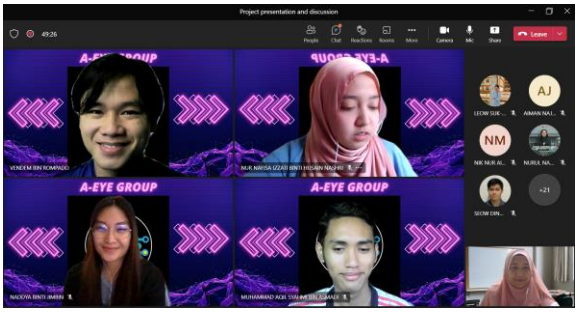
Step 3. Solution design.

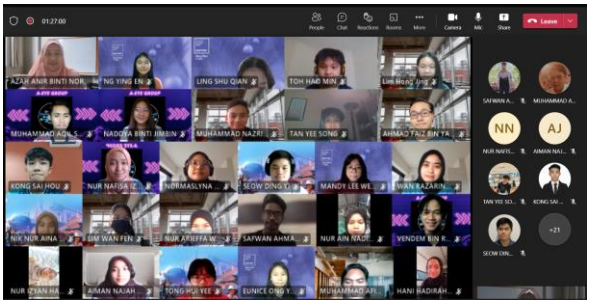
Students were asked to introduce innovative solutions to the problem in focus.

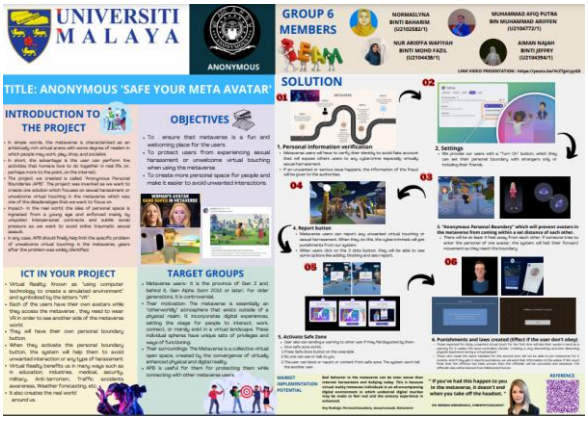
Step 4. Presentation.

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









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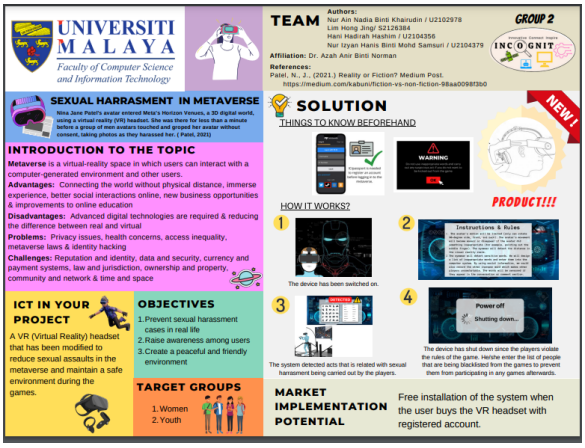

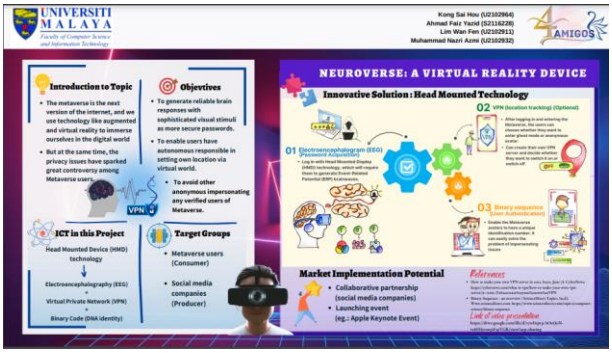

Figure 23. Students work on innovative solutions in the Social Informatics course, spring 2021.

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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 principles of software design, 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 software industry, addressing software quality assurance processes, activities, and challenges. Topics include quality control, quality assurance, quality management system, process and product quality, software configuration management, standardization, and audit.

The course includes a project assignment, which emphasizes 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 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. A total of 62

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students attended the course, 48 in the 2nd semester of the academic year and 14 in a special offering of the course 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 learning activity was to challenge students to design solutions for real software quality problems related, for example, to 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 issues related to software quality assurance implementation and perform the assigned tasks effectively in a team practicing software quality assurance activities. Students worked in groups of up to 6 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.

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 in on-line mode.

Step 2: Understanding the context.

Students were asked to perform research on software quality and the importance of ensuring quality in the developed software, as well as the consequences of low-quality software, which is the general theme of the proposed activities. They were also asked to post ideas and lessons

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learnt on the importance of quality software from the articles that they read or video that they watched.

Step 3: Problem definition.

Team members were asked to look around and identify software that they have been using, or they have seen others using, which they believed had quality problems. Each team member was required to post on the platform a description of the software and the quality problem that was identified. Through this description, students had an opportunity to present to the other team members their findings. Teams were encouraged to engage in discussions and to agree on the software that 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, namely describing a characteristic user by considering what the user thinks and 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 develop an understanding of 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 to the identified quality problem. They were encouraged to the root-cause analysis, namely a fish bone diagram, in order to categorize the causes and their respective sub-causes. They were then asked to select one cause that they want to provide the solution for. Students

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collaborated with their team members to design and post their proposed solutions on the ICT-INOV platform.

Students performed all activities and submitted their proposed solutions to the ICT-INOV educational platform before they presented their solutions to the entire 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: Search function does not return 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

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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 30-day tailored theoretical course, 30-day on-the-job training with actual software, and 30-day involvement with the real scenarios.

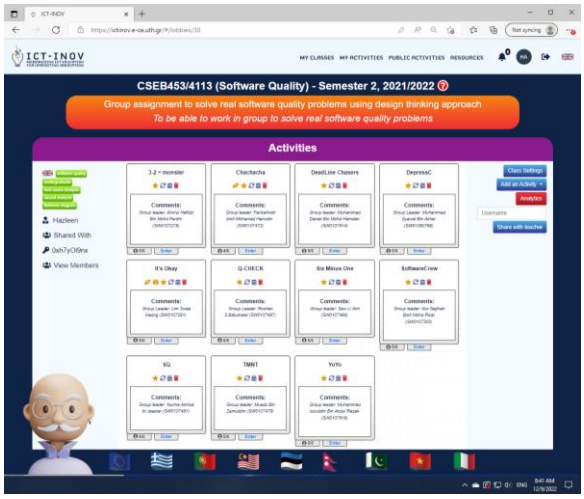
- **Software name:** ICT-INOV Platform

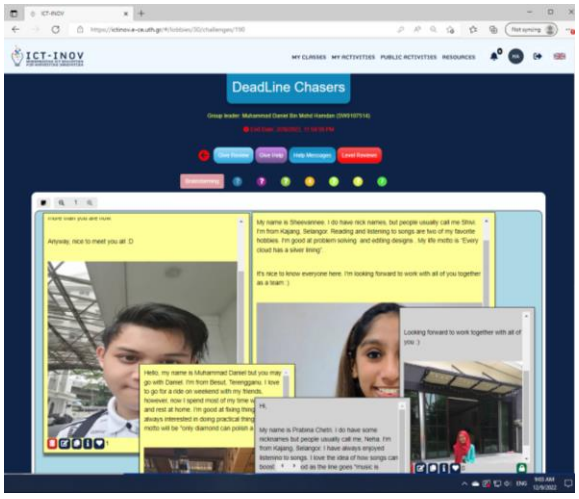
  Problem: Further enriching the user interface

  Chosen cause: Perfecting the user interface

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

  Proposed solution: Two additional features are 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 involves displaying frequently asked questions (FAQs) where users can quickly refer to when they have problems that may have already been encountered and addressed before. This will overall improve user experience





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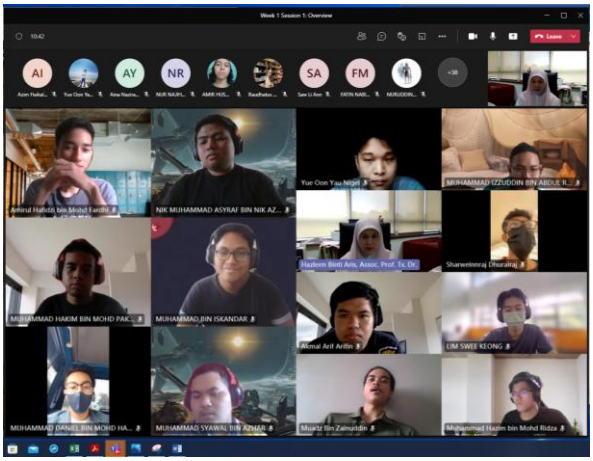

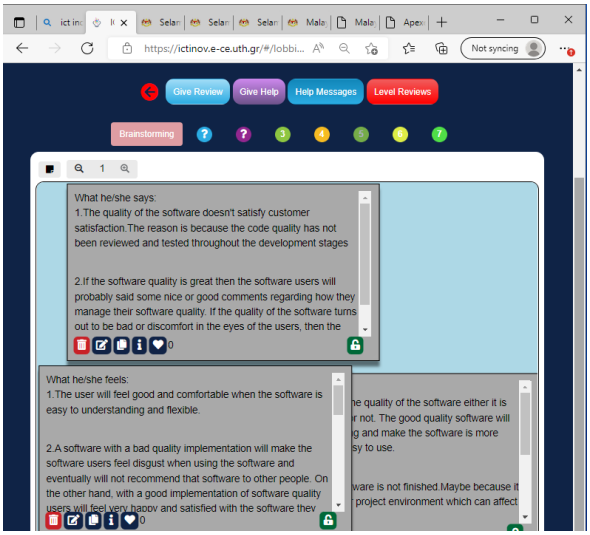

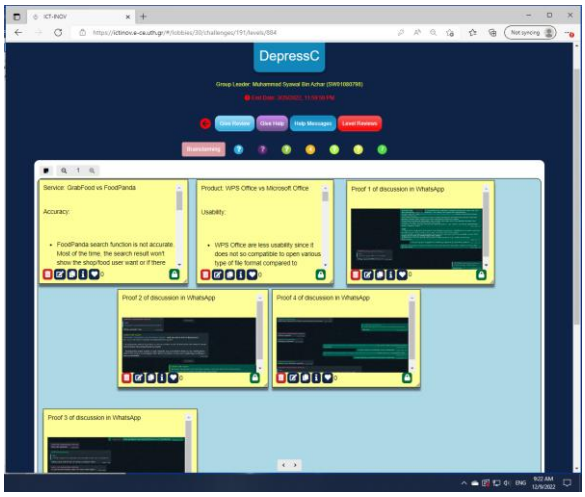

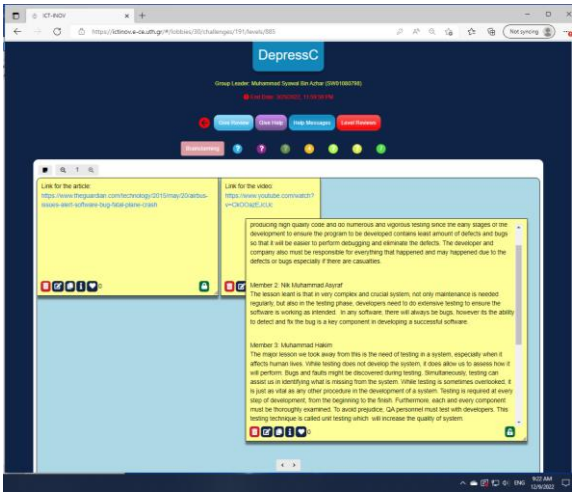

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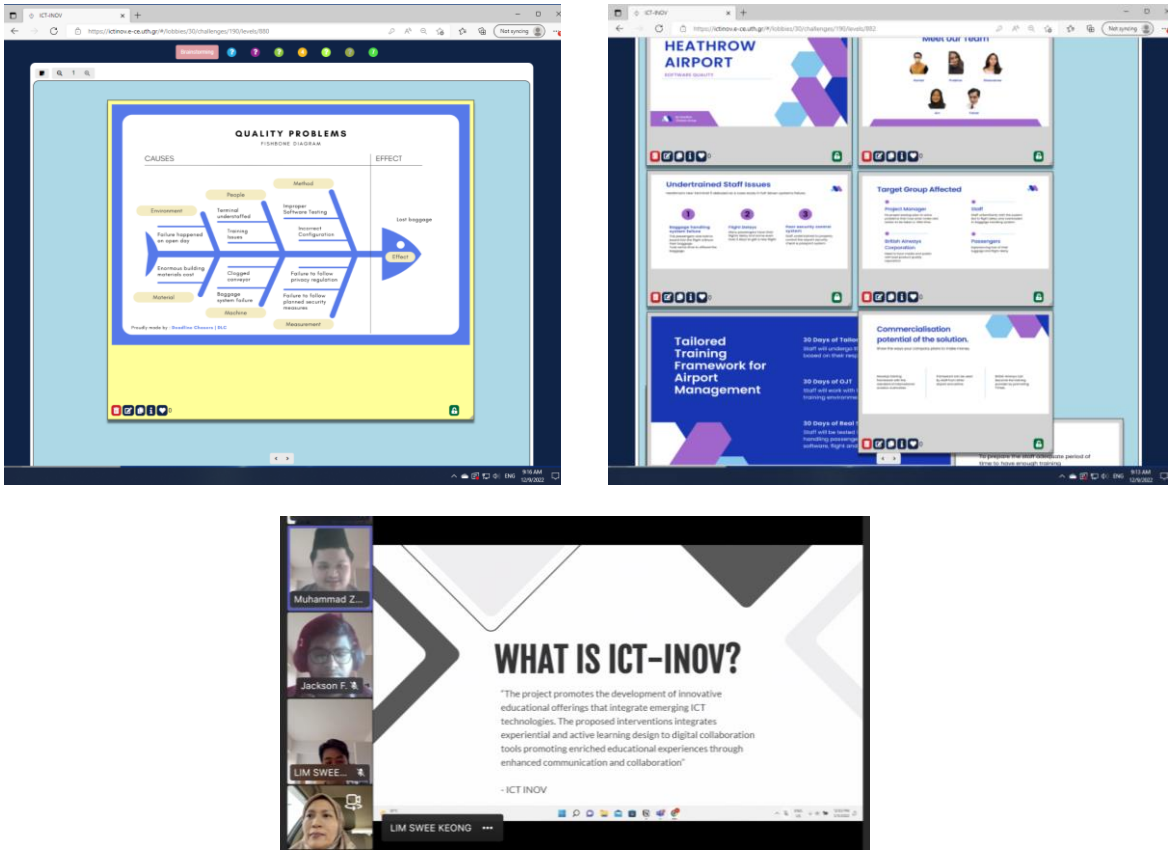

Figure 24. Screenshots of student projects in the Software Quality course, spring 2022.

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 that are involved in creating and maintaining digital business solutions. At the end of this course, students are able to demonstrate the meaning, scope, and requirements of

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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 examination. The design thinking methodology is applied in the class project that takes place from week 2 until week 15 of the semester. The class project contributes 30% to the overall course assessment.

6.4.2 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 at 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, work was divided into 4 project activities.

Step 1: Empathizing.

Work was further divided into 2 tasks. In the 1st task each student was 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 for promoting their business to their target market. As a result of this work, 6 business ideas were identified and assigned to the 6 student groups.

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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 that 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 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 and particularly how the company could create business value and make a 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. Worked focused on how to design the proposed business solution and make 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 prototype of a product or service prototype using software or apps, such as Wix.com®. They were encouraged to explore. Subsequently, students presented

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their prototype, described the customer journey, and recorded the pain and gain that are 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.

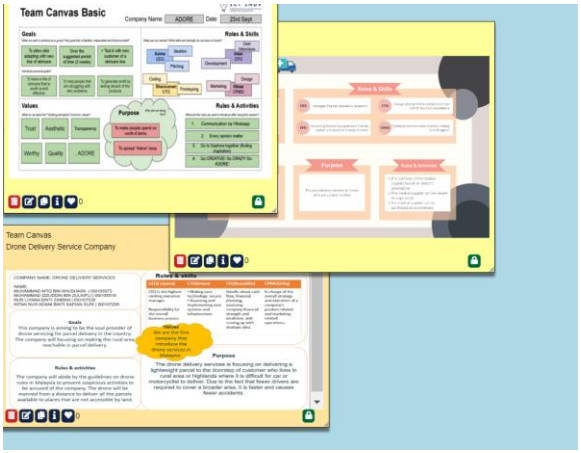

Figure 25. Students develop a team canvas and brainstorm in the Digital Business course, fall 2022.

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6.3 Course CSEB3123: Software Engineering Principles

6.3.1 Description of the course

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

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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 introduce into the course. The activity was divided into the following steps.

Step 1: Identifying problems and proposing solution.

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 in order 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 they presented their solutions to the entire class.

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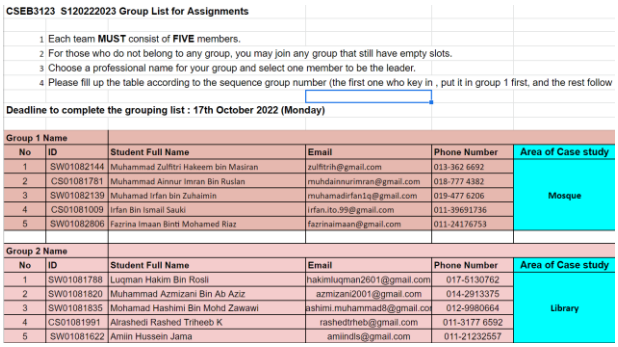

CSEB3123 S120222023 Group List for Assignments

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 Trheeb K	rashedtrheb@gmail.com	011-3177 6592	
5	SW01081622	Amiin Hussein Jama	amiindls@gmail.com	011-21232557	

Figure 26. 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 a real problem software development project. 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, UNITEN. Based on the program structure, the students are expected to take this course during the first

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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-centered system design. The focus of the project was COVID-19 innovation. Students analyzed user needs, use cases, and use context. Based on findings, students were encouraged to envision what the actual system design should look like, based on the experiences of real people, real tasks, and real needs. Activities enabled students to understand that user centered system design is not an academic process where some cookbook formula can be applied. Nor is it an intuitive process where a programmer can sit in their office and think they know what the user and their tasks are. 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 process of continuous evaluation and refactoring.

More specifically, students worked on their iterative designs of a particular system using task-centered system design methods and low fidelity prototyping. The immediate purpose of this exercise was to build student skills on articulating clear task descriptions, using the task descriptions to decide upon system requirements, and brainstorming on low fidelity prototypes based upon 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.

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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 comprised 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 sketch of a user interface, and wrote a concise proposal for each.

Task 3 : Ethnography.

Students were encouraged to observe the target users of the proposed system going about 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 (“artifacts”) 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 focused on include registration processes, form filling, information browsing, giving directions, and appointment scheduling.

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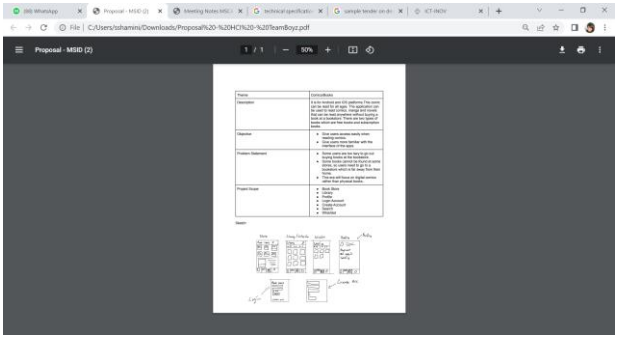
Students submitted a report that consisted of a one-paragraph justification on why they selected a particular activity to focus on followed by an overview of the activity, the end users they engaged with, and the artefacts involved, such as paper, pencil, mobile phone, or machine. In addition, the reports 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.

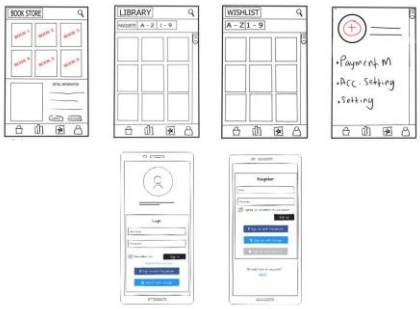
Step 4: Design.

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

Task 5 : Prototyping.

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





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Summary of the project

During covid-19 pandemic, people had to stay in their homes and could not go out to protect themselves. When this happens, they gradually become restless and day by day they don't know what they need to do to fill their free time. Therefore, we plan to produce an application where people can access their favourite books just by using a smartphone and the application "Bookstore". Based on our observation, people are more inclined to this online application because they do not leave the house on the orders of the government that implements the movement control order (MCO). After that we created a bookstore application design that is equipped with various facilities such as online banking and so on. The bookstore application also has a user-friendly interface that can make it easier for users to browse the application. Then we implement our system to be used and follow up by doing user evaluation of our system. Finally, we will finalize our application for general use.

Figure 27. Results of team building, brainstorming, ethnography, design, and prototyping in the Human-Computer Interaction and Multimedia Interface Design courses, fall 2022.

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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-centered design, conceptual models, metaphors, software design and game design. The above are applied in simple formal experiments for evaluating usability hypotheses. Upon completion of the course students are able to design usable systems that can be seamlessly integrated in everyday life, providing 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 to cognitive aspects of design and evaluate applications using multiple methods, including user testing.

7.1.2 Description of the participants

The course targets students enrolled in the Bachelor of Science in Software Engineering program. 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 more effectively address user interests. The activity was implemented as a

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semester project. Students were briefed about design thinking through a workshop that took place 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. The workshop was coordinated by a supervisor and researcher. Students worked in teams. Two separate sessions took place over the course of the week, each with a duration 1 hour 15 minutes. At the end of each session students submitted reports on assigned research questions. 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, in which 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 out of the box to create something useful with given shapes, such as a car, stick person, broom, hospital, etc. Finally, students documented in a map the activities that 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 area of land available for food production with rapidly increasing world population results in 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

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design problem by identifying the most significant data. Each team selected a single problem and briefly described it.

Step 3. Problem discovery.

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

Students performed a number of **problem discovery exercises**, the objective of which was to help them understand that looking at a problem from different perspectives can contribute to the design of an effective solution. Exercises included the neighborhood watch, in which students walked around their neighborhood alone and accompanied by specialists, such as an engineer, gardener or other documenting each time what they see. 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 experience, events that surprised them and information they discovered. In the establishing associations exercise, students documented 3 ideas related to each of the problem, the problem and people, the problem and places and the problem and feelings. They created a problem map, in which they color-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 describing 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.

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Based on the results of the problem discovery phase 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, a solution that could be implemented if resources were unlimited, a solution that could be implemented with very limited of resources, namely 100 rupee, an solution that makes someone uncomfortable and a solution that can be implemented with magic, a code name for 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, which had different sections that represent the entire design thinking process along with the problem statement and its solution.

Step 6. Reflection.

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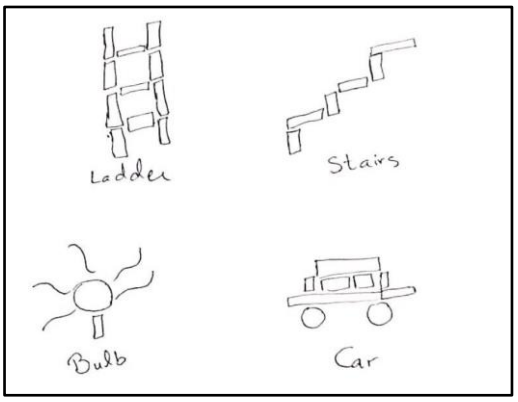
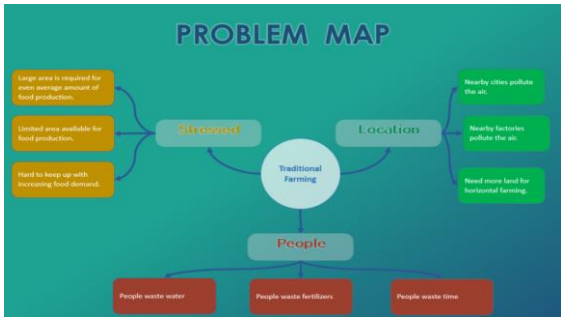
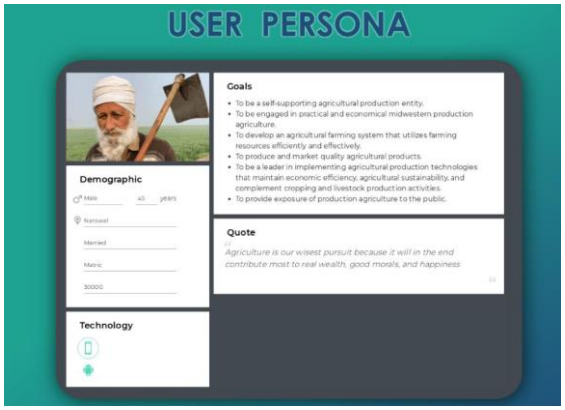
Students reflected on their workshop engagement including the most memorable experiences, the biggest surprise and their discoveries that enhanced their learning.







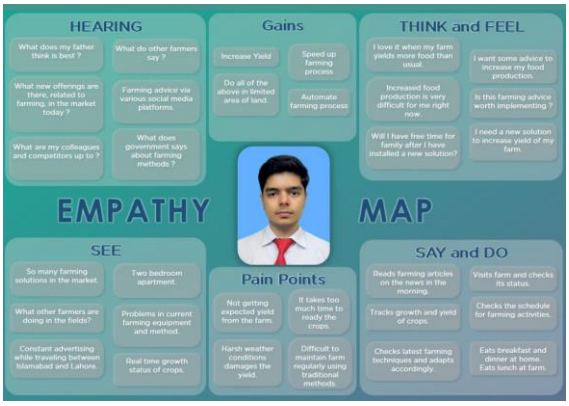


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Figure 28.Logo creation, team canvas, problem map, interview preparation, user persona, empathy map, problem definition and solution poster of a project in the Human Computer Interaction course, spring 2022.

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 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 the 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-centered 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

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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 in 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 crowd in cafeteria in 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 background, professional background, user environment, physical, social, and technological, and

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psychographics, such as attitudes, interests, motivations, and pain points), and user objectives in using their solution.

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

Upon completion of 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, if interviews highlighted the fact that the user is a technically savvy student but is facing issues in synchronizing reminders on her different calendars for different events, 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 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, if the problem in focus is that users cannot separate degradable from non-degradable waste then 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.

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Students were challenged to create rough prototypes for their solutions. The prototypes would be accepted, improved, and re-examined, or rejected based on the users' experiences. Students used Figma® or Justinmind® for prototyping the user experience. They were instructed to keep in mind interaction design principles, design rules, cognitive aspects, and multimodal interaction for all kinds of users. For example, to ensure that 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 29. Student ideas documenting through brainwriting in the User Experience Design course, spring 2021.

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- Create prototypes

➔ T

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For D3-Prototyping

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All the updated prototypes

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For the Final Report you must document as:

1. Introduction of your project [2-3 lines]
2. Personas
3. 3 scenarios [relating to each persona if you have more than one]
4. 3 of the structured specs
5. All Prototypes
6. Evaluation
    a. Experiment
    b. Usability review questionnaire

Follow the same for presentations. Front end will be examined in demos

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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 Operating Systems concepts. The course develops understanding on design and implementation issues of operating systems. Students develop knowledge on 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 is a compulsory course for Software Engineering, Computer Science and Information Technology students. 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 the course is attended by 39 students.

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 to select an activity for implementation in the area of operating systems management. For example, one group

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opted to work on concurrency in C++ programs; students were challenged to discover whether there was any possibility to execute 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 operating system process, 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 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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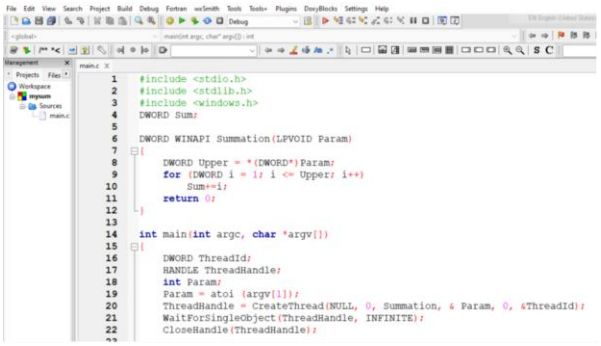

```
#include <stdio.h>
#include <stdlib.h>
#include <windows.h>
DWORD Sum;

DWORD WINAPI Summation(LPVOID Param)
{
    DWORD Upper = *(DWORD*)Param;
    for (DWORD i = 1; i <= Upper; i++)
        Sum+=1;
    return 0;
}

int main(int argc, char *argv[])
{
    DWORD ThreadId;
    HANDLE ThreadHandle;
    int Param;
    Param = atoi (argv[1]);
    ThreadHandle = CreateThread(NULL, 0, Summation, & Param, 0, &ThreadId);
    WaitForSingleObject(ThreadHandle, INFINITE);
    CloseHandle(ThreadHandle);
```

```
#include <stdio.h>
#include <stdlib.h>
#include <windows.h>
void func() {
}

int main() {
    std::thread t1(func);
    std::thread t2(func);
    std::cout << "Main Thread ID is " << std::this_thread::get_id() << std::endl;
    std::cout << "First Thread ID is " << t1.get_id() << std::endl;
    std::cout << "Second Thread ID is " << t2.get_id() << std::endl;

    t1.join();
    t2.join();

    return 0;
}
```

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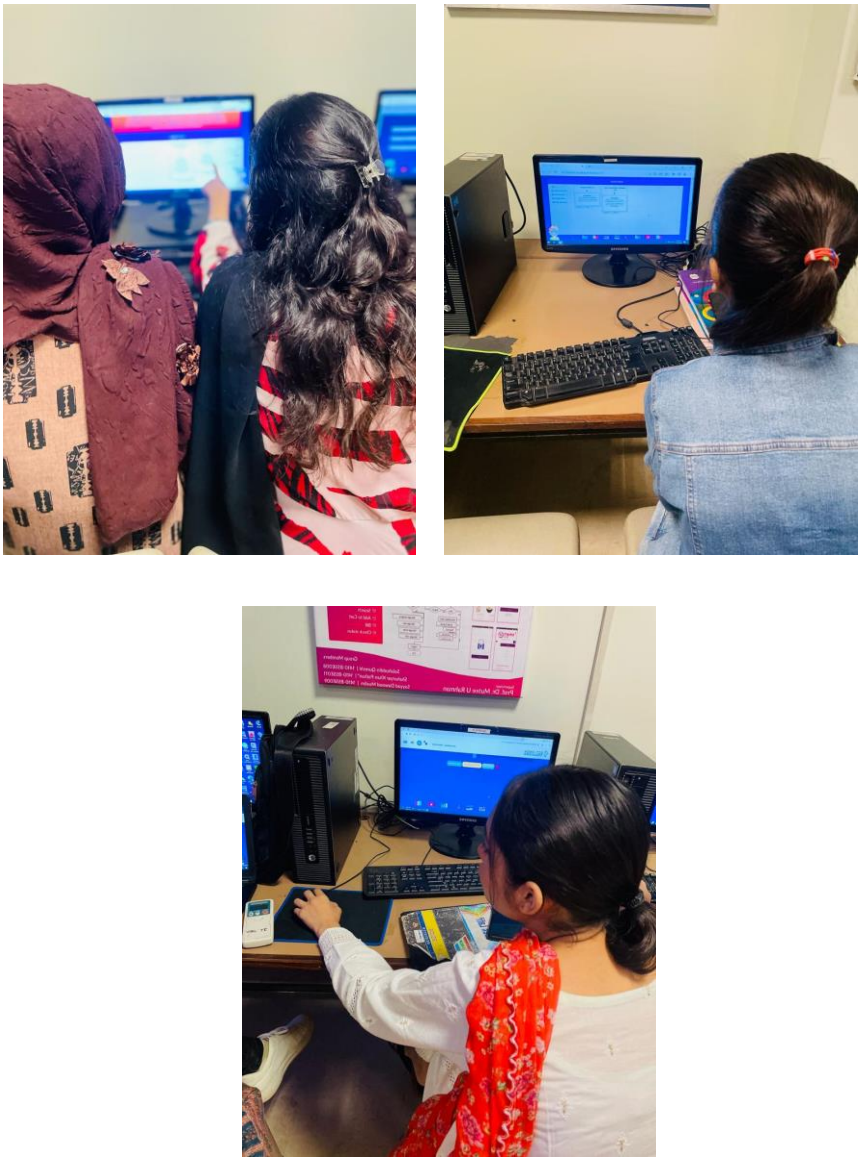

Figure 30. Screenshots of student projects in the Operating Systems course, July 2022.

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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 understanding on how formal methods help produce high quality software. The course further addresses formal modeling 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. 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 the course was attended by 35 students.

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, to overcome problems in instances and to revisit models for integrating 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.

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Students were challenged to reflect on how a simple perfect looking static model can be erroneous. They were asked to design a simple relational model to represent 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 the models they designed.

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 re-define their model with formal specifications 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 in different ways, 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 developed a model prototype by defining it with facts representing constraints in the Alloy® Analyzer environment. They developed formal model definition scripts. Prototype models were static representations of data structures or types in specific software engineering solutions.

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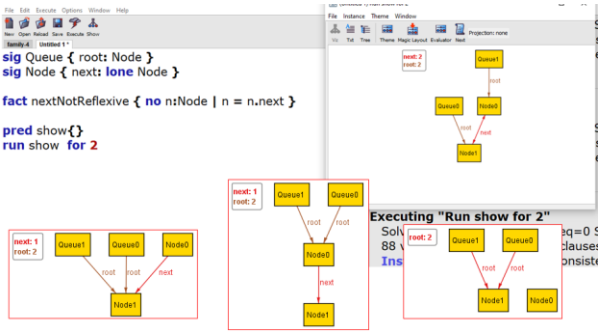

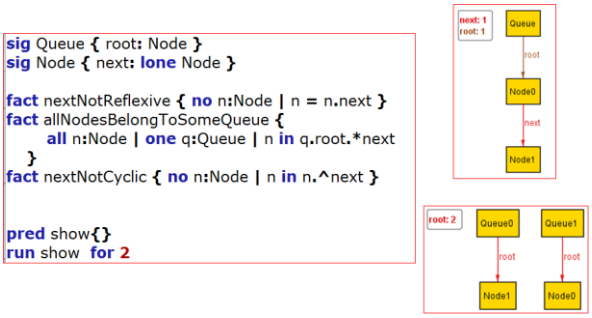

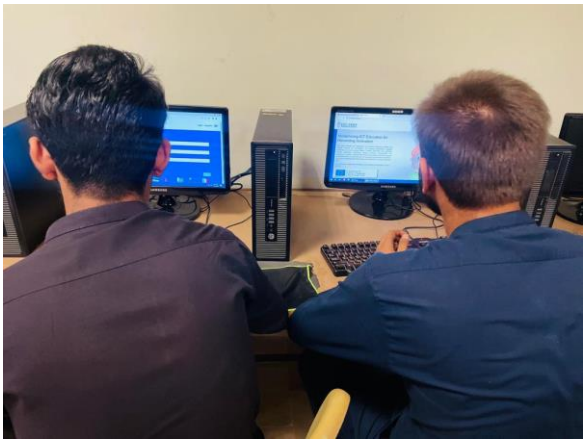

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Figure 31. Screenshots of student projects in the Formal Methods in Software Engineering course, July 2022.

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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 modeling, 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 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. A total of 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 further included biweekly laboratory work, in which students implemented the algorithms taught in lectures towards solving real-life problems and building games. At the end of the course, students were asked to submit a mini project based, in which they applied theoretical course concepts in Computer Graphics. Students applied design thinking in project work. Examples of projects implemented by students include:

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- Terrain generation using Perlin Noise
- Sorting visualization
- Space invader using Pygame® and Pyopengl®
- Visualizing 3D structure of protein with protein data bank file
- Maze game
- Black hole visualization in 2D space
- Rotating cube in 3D space

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.

Step 1: Team building.

Students were asked to form groups and to select the topic of their mini project. As the class is comprised of 59 students, each group includes 1 to 2 members. After selecting the team members students were asked to select a team name, an activity related to identity. A total of 30 groups were formed and each of them selected their team's name.

Step 2: Understanding the problem, 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 at this stage the game plots. Teams that focused on problem-solving developed a case scenario.

Step 3: Prototyping the obtained concept.

Students implemented their solutions using the programming language and graphical libraries of their choice.

Step 4: Presenting the developed work.

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Students presented the result of their work to faculty members.

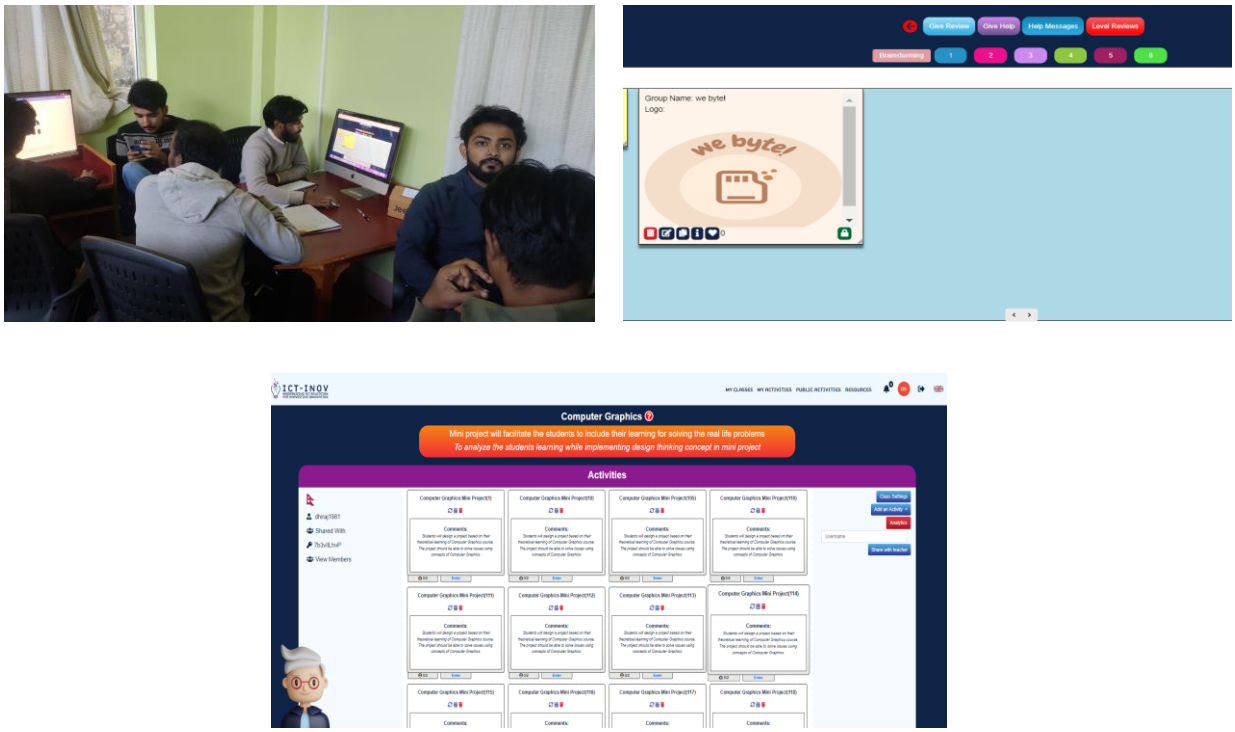

Figure 32. Students use the ICT-INOV digital learning platform in the Computer Graphics course, fall 2022.

9.2 Course COMP315: Computer Architecture and Organization

9.2.1 Description of the course

The course aims to develop knowledge of concepts of Computer Architecture 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 design thinking principles. Students deploy design thinking to implement the internal architecture of a computer system based on group work.

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9.2.2 Description of the participants

The course is mandatory in the 3rd year 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 Gamified design thinking activities for COMP 315

A learning activity was designed for the course following the paradigm of design thinking. 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 that 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.

Step 1: Team building.

Students were asked to form groups. As the class is comprised by 22 students, each group included of maximum 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 towards understanding 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.

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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 result of their work to faculty members.

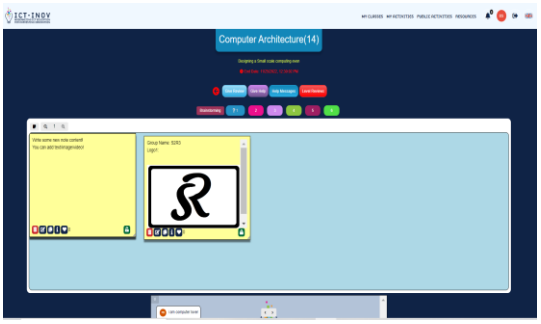

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Figure 33. Students work on projects in the Computer Architecture and Organization course, July 2022.

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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 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 in 26 teams of 3 – 4 individuals. Each team had its own workspace on the ICT-INOV platform.

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The activity consisted of the following 3 levels.

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 on the ICT-INOV platform their team's name and project title.

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 final 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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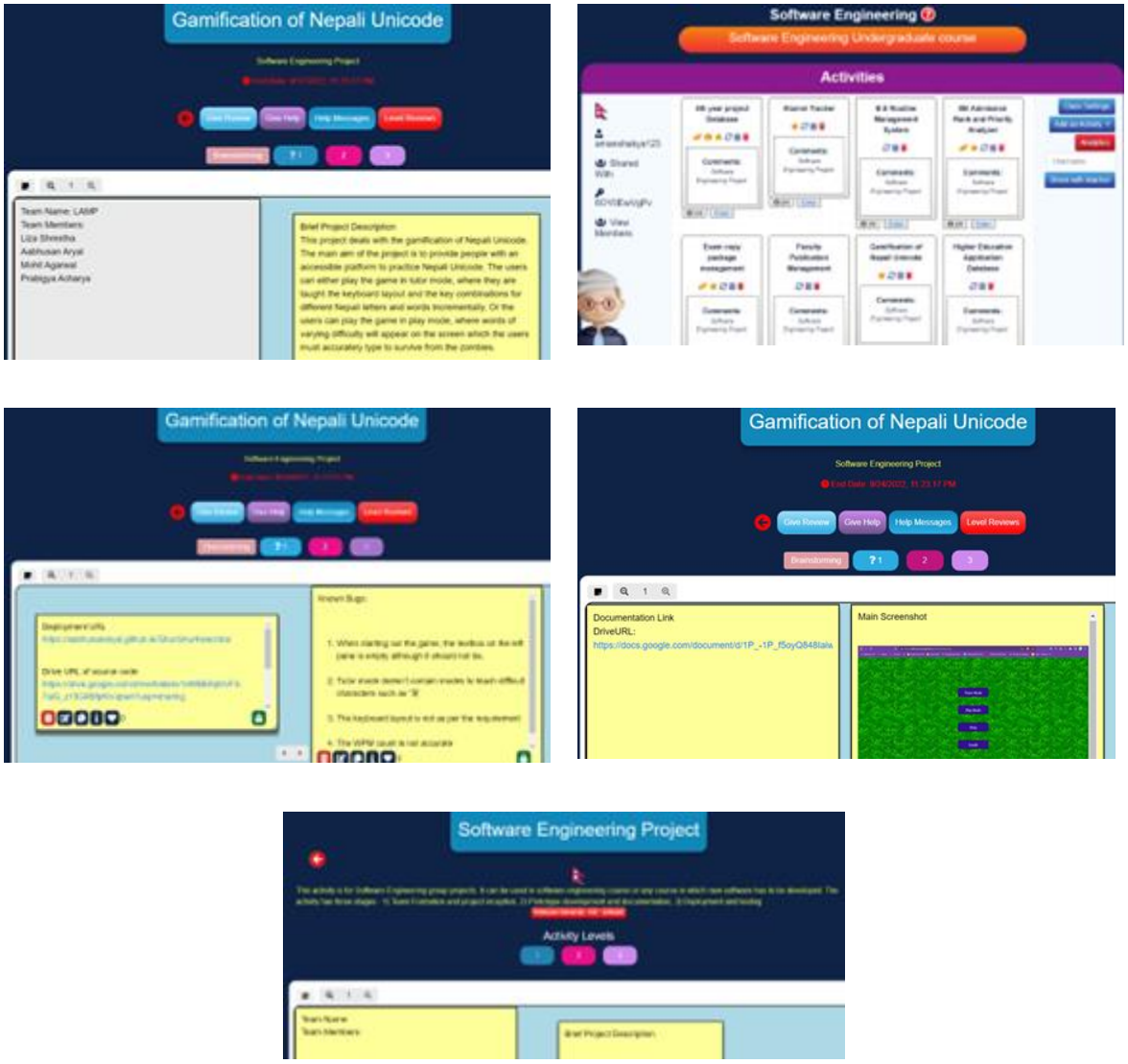

Figure 34. Screenshots of student projects, demonstrating team building steps, working groups and sharing of ideas in the Software Engineering course, fall 2022.

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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, to document it and to 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's 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. An activity was developed in the ICT-INOV platform for each for the 5 knowledge engineering projects for the course project. Activities were divided into the following steps.

Step 1. Team formation and project background study.

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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 description of the project along with their team's name and group members in 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 introduced in previous steps. Students posted screenshots and descriptions of the system on the ICT-INOV platform.

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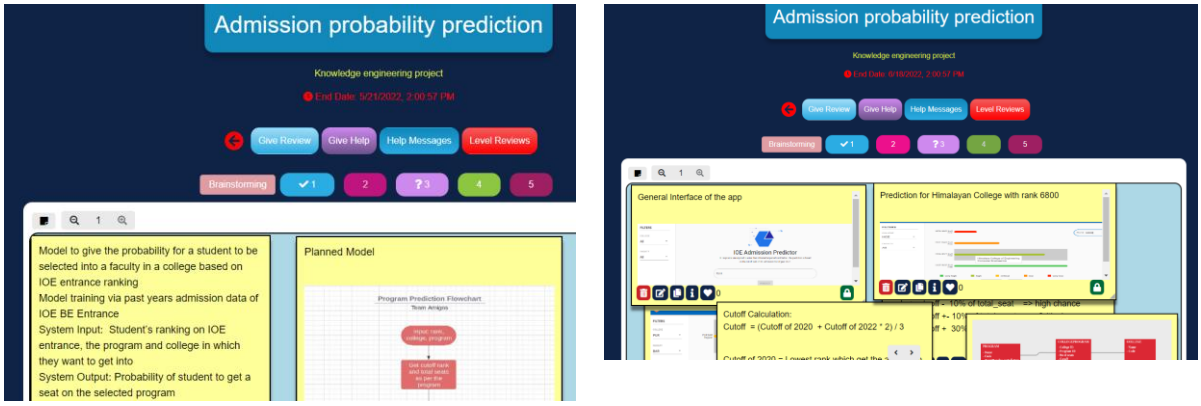

Figure 35. Screenshots of student projects, demonstrating team building, student workspaces and teamwork in the various stages of project implementation in the Knowledge Engineering course, fall 2022.

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11. Von Neumann Institute

11.1 Course: IT Services Design

11.1.1 Course description

The course introduces a practical approach 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 in practice the basic concepts of design thinking.

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 in 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 life quality of citizens through innovative ICT services.

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Step 3: Understanding users.

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 had 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 36. 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 is an obligatory course that 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 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 that were 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 the introduction of a new system or the enhancement of 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-centered approaches such as conducting research to understand past, present and future needs of the customer. Students were further encouraged to join the customer 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 as a result of 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.

From the pool of solution ideas generated in the ideation step, students were encouraged to select one to convert into a prototype. Students selected the most viable idea by creating lists of pros and cons. Criteria considered for evaluating ideas include the potential to achieve competitive advantage, financial aspects, available human resources and time constraints. Students created a prototype on the selected idea and delivered it to the customer for validation. Based on customer feedback students refined their prototype solutions to best 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 37. Students working in the Design Thinking Lab of Hanoi University, fall 2021.

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12.2 Course: Information Systems Design and Implementation

12.2.1 Description of the course

The course develops understanding on 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 on using designing tools, analyzing and designing accurately, then applying the design on implementation. Normally, this course is delivered in person. However, due to COVID-19 restrictions classes were conducted virtually in semester 2 of academic year 2021 – 2022.

12.2.2 Description of participants

This is an obligatory course that 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 theme. Subsequently, they were encouraged to research the theme and discover challenges and opportunities for improvement through information technology.

Step 2. Empathy.

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In order to thoroughly understand the problem, students identified stakeholders and created a RACI matrix. The RACI matrix helped them to define roles and responsibilities of stakeholders, 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 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 quantity and diversity of 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® for the benefit of 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 final outcome to stakeholders for validation. Stakeholders provided feedback, which the development team consulted for refining their designs.

The following are pictures that illustrate the use of the ICT-INOV design thinking platform in this course.

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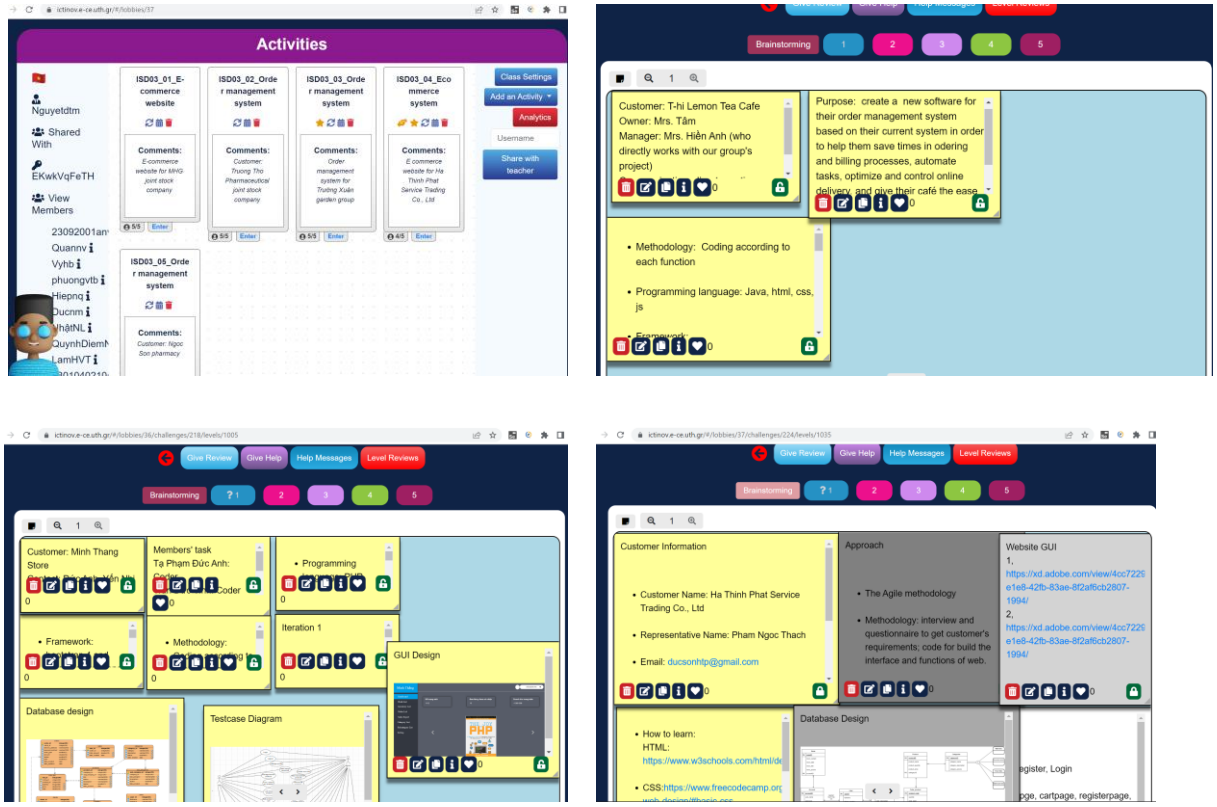

Figure 38. Screenshots of student projects in the Information System Design and Implementation course, fall 2021.

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.

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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 not only helped them gain knowledge but also 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 through the completion of game levels with increasing difficulty.

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Figure 39. 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 user and software, fundamentals of interface and application design and analysis of development trends in the field of interactive interface design. The course includes both a theoretical and a practical component. More specifically, the course aims at equipping learners with basic knowledge in

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the field of interactive interface design between users and software. Help learners apply and practice knowledge gained through specific exercises, projects, and products.

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 color-blind person to identify an item in the desired color when shopping on-line. Students interviewed individuals with disabilities to better understand difficulties they encounter in everyday activities.

Step 3. Ideation.

Students brainstormed listing numerous ideas towards enhancing accessibility for all to a software service.

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.

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Students gave access to the prototype to characteristic users, asking them to use it and provide feedback based on which they refined their design.

The following are pictures from student projects in the ICT-INOV gamified design thinking platform.

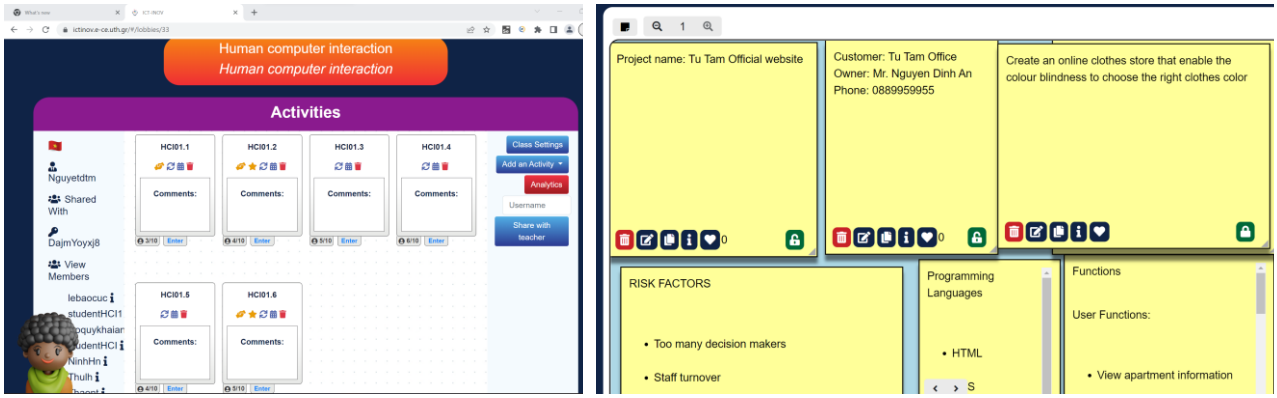

Figure 40. Screenshots of student projects in the Human Computer Interaction course, spring 2022.

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