PRO HACKIN'

Faculty of Mechanical Engineering and Naval Architecture

UNIVERSITY OF ZAGREB

PRO HACKIN' project report
Study #2: Design Methods and Tools in Product Hackathons – team interviews and reports

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

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1. Introduction

The Pro Hackin' project, in a broader sense, has two main objectives: to improve teaching and learning methods in engineering education and to promote cooperation between universities and industrial partners. As part of this project, a methodology was developed to support open innovation between universities and industrial partners. This was achieved by introducing hackathon-like events into the engineering courses and curriculum. Predominantly, these events could be integrated into various project-based learning (PBL) product development courses that often entail a linear process as a traditional approach, which enables rapid generation and exchange of ideas. The concept of product hackathons was adopted from software engineering and represents intensive problem-solving events that, unlike programming hackathons, focus on the design of physical/tangible technical products. Hackathons are defined as time-bounded events (usually 1-3 days) that group people in small teams to develop product concepts. Currently, this concept has not been widely implemented in mechanical and industrial engineering curricula. However, this project aims to explore the possibilities that hackathons offer within the context of product development courses (in mechanical engineering).

This report PR4 sums up the findings from the previous hackathon experiences and builds on the preliminary results of the PR3 "Manual for implementation of product hackathons in university courses". Also, it extends the current understanding of the "success" of introducing hackathon events in product development courses delivered by the project consortium. To do so, consortium members conducted various interviews and surveys to obtain personal feedback from teachers, trainers and students, as this project considers them as the main target group. As the obtained dataset from the PBL joint product development course is the most detailed and comprehensive one, we decided to extract further insights from it. The main reason is that this international course combines perspectives from different HEI students and potentially transcends the differences of integrating hackathons in individual HEI contexts.
This report is organised as follows. The developed methodology for the entire project is described in the following section, Prohackin' - Joint course description. The Data Collection and analysis procedure section explains the methodology of the performed research study to acquire a better understanding on the role and pros/cons of three hackathons conducted throughout the courses. The *First, Second and Third hackathon* sections further elaborate on the process and use of methods and tools by the teams at each hackathon, as well as their perspectives. The *Different perspectives on all three hackathons* section presents the teams' perspectives for all three hackathons, focusing on the term 'hackathon' rather than the team's approach. Finally, this report ends with a reflection on obtained findings and explores the potential for courses that benefit/could benefit at the consortium HEIs.

2. Pro hackin' - Joint course description

In order to be able to treat this document as a standalone resource, short introduction will be given on the project context. Pro hackin' (PROduct HACKathons for INnovative product development) is a project funded by the European Union under the Erasmus+ program. As a part of the project, each year one of the four universities (that compose the project consortium - University of Zagreb, Politecnico di Milano, University of Ljubljana, and TU Wien), in collaboration with one industrial partner, organise a joint product development course. This course also serves as a tested for trying out methodological improvements for planning and delivering hackathons as part of this project.

The overall educational goal was to foster self-regulated student learning and working on real-world industrial examples in time-constrained settings, while retaining all the required learning outcomes. Due to the nature of these hackathon events, the intensity of communication is even higher than in traditional PBL courses, which requires significant modification to existing learning/teaching and communication/collaboration setups. Of course, this leads to a need to modify and rearrange traditional learning/teaching approaches implemented in PBL courses.

The consortium members developed the initial version of the hackathon methodology during the first semester of the academic year '21/'22, combining elements highlighted in the literature on engineering design education with the experience gained during the previous educational initiatives they carried out in collaboration. However, this methodology was then revised and improved throughout the implementation in courses and by reflecting on the changes required in particular course editions (over the years).

As stated above, the course, jointly delivered by four universities, had an immense role in further refining the methodology. The joint course starts with an initial workshop and continues with three phases (problem definition, conceptual design, and embodiment design) in which mechanical engineering student teams work on a product design problem. Throughout the course, students worked mainly in a virtual manner on a design challenge proposed by an industrial partner. To be more specific, students mostly collaborated using virtual communication platforms/tools, as teams were composed by individuals from four universities (discussed more in later sections). Students were divided into teams of 7-8 team members (in general, two from each university).

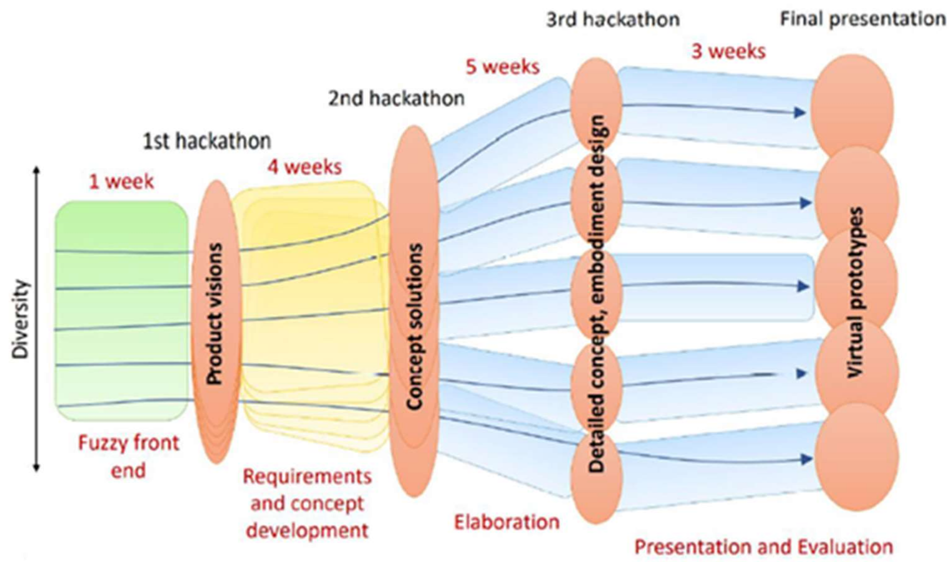

Figure 1 - The overall plan of the PRO HACKIN course [2]

During a course, one or two academic coaches were delegated to each student team, who then worked as the team's facilitators. The coach advised a team, helped communicate with the company, and explained the objectives of different course phases. Each phase finished with a hackathon (Figure 3).
For the purpose of the analysis presented in this report, we analysed one joint course edition in detail. In this edition, the industrial partner was Siemens Mobility, who outlined the boundaries of a design task. The design task provided to students was to improve the passenger experience in metros and create added value for the operator. This course edition was conducted online, except for the third hackathon, which was conducted as an event in a physical environment. This time "layout" of hackathons and their online/onsite execution allowed us to better understand the differences between different ways of executing similar events. To give more insights on the specificities of this course edition, there is a need to mention that 4 female and 35 male students on both undergraduate and graduate levels participated in the course. Four teams consisted of eight members, two from each institution, while one team had seven members.

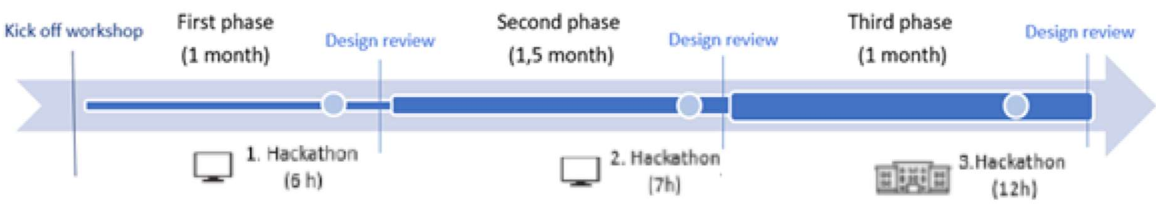

Figure 2 - Timeline of the project [3]

In the initial workshop, the industrial partner described the design challenge and university representatives introduced ICT tools that might allow students to communicate and collaborate throughout the course. The suggested ICT tools for communication were divided into two categories (Figure 4): 1) team-based communication for team members and their coaches, and 2) course-based communication for all course participants (company representatives, teachers, coaches, and students). Course-based communication included a general channel on "*Microsoft Teams*" installed at the universities, where students had access to all the necessary materials for each phase. Team-based communication consisted of three suggested tools: "Microsoft Teams", "Miro" and "Trello", which were aimed to help teams in the execution of tasks, management, and team meetings. In addition to video calls, students also communicated via social networks, instant messaging applications and e-mail. Cloud services such as "Google Drive", "ownCloud" and "Dropbox" were used to exchange files.

At the beginning of each phase, teams received an information package that included the hackathon‘s required outputs and suggested methods that could help to achieve these outputs.

In the first phase, teams got to know each other, created a team logo, and had to generate three product visions. Students were introduced to methods related to market and user research (e.g., user persona, political-economic-social-technology-environmental-legal (PESTEL) analysis, activities-environment-interaction-objects-users (AEIOU) framework and idea generation (e.g., brainstorming). At the end of this first phase, the first hackathon was held online via Microsoft Teams . In the first hackathon, which lasted 6 hours (split into two days), students conducted market and user research and generated three product visions. At the end of the first phase, students had to define functional requirements and present the visions to the industrial partner representatives. The representatives have chosen one vision per team to work on in the next phase.

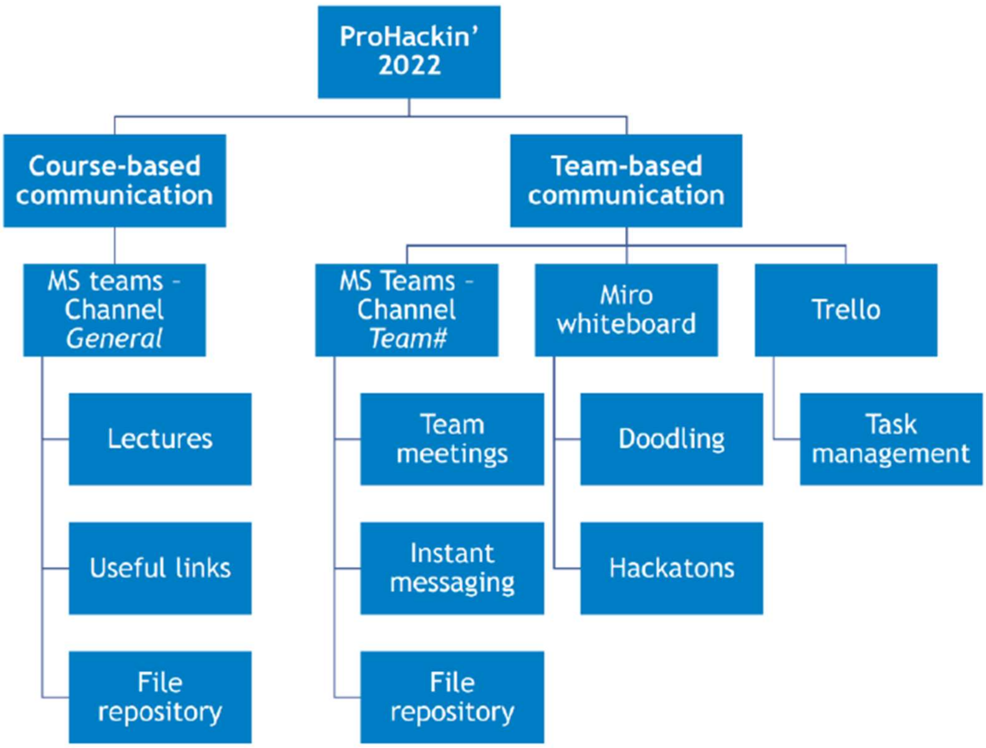

Figure 3 - Prohackin 2022 course communication [2]

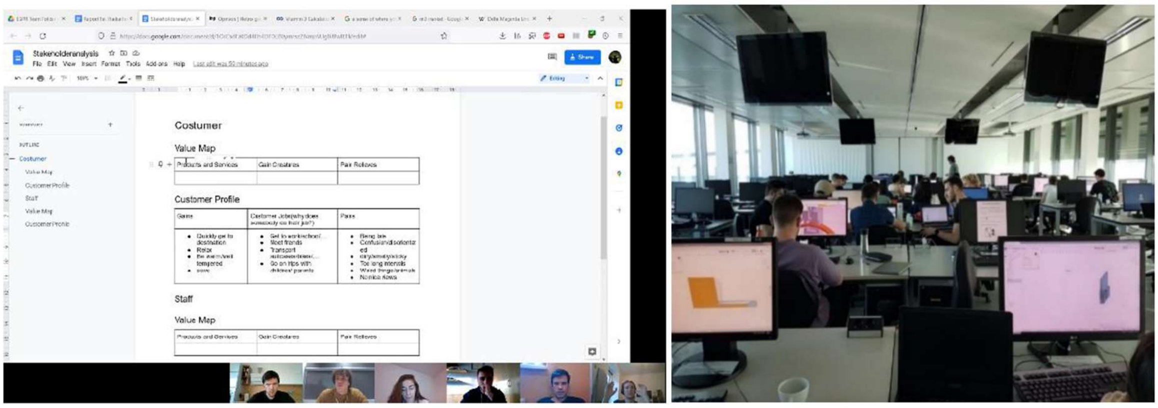

Figure 4 - Hackathons conducted online (left) and in person (right) [3]

At the beginning of the second phase, an introductory presentation was given explaining design methods for problem framing (e.g., a network of problems, functional decomposition) and concept generation (e.g., brainstorming, brainwriting, and morphological table). The main objective of this phase was to generate three concepts for the chosen vision. Considering all the information gathered from the coaches, in the second hackathon (duration: 7 hours, split into two days), students had to create several product concepts and write solutions for product functions. At the end of the conceptual design phase, students had to present the concepts to the industrial partner representatives. The representatives have chosen one concept per team to work on in the next phase.

Similarly, as in previous phases, at the beginning of the third phase, the introductory presentation describes the required final outputs. Building on the selected concept at the end of the second phase, students need to elaborate and detail this concept and, throughout the embodiment design, finalise the solution considering various DfX strategies. Finally, students need to present the final solution to the industrial partner representatives.

3. Data collection and analysis procedure

In order to obtain insights into the way different hackathons were performed by various teams, we collected data from reports that each team was required to submit after each hackathon, as well as transcripts of interviews conducted with team members, leaders, and coaches. A total of 40 semi-structured interviews were conducted with team members, team leaders and coaches.

The interviews lasted between 30 and 60 minutes (overall 27 hours). The interviews consisted of three sections, adapted to each interviewee's role. Different perspectives on each phase were collected by interviewing different roles in the project.

Some of the questions were common for all hackathons, focusing on the methods and ICT tools used, as well as participant impressions of them. Moreover, interviewees were asked to explain the allocated resources (e.g., time and team members) during the hackathon. In addition, specific questions for each hackathon aimed to shed more light on the contextual aspects of the hackathons. Examples of questions specific to each hackathon can be found in Table 1.

The interviews were analysed using thematic coding analysis to initially identify the methods and tools used, which were then reviewed for similarities and differences. The methods were categorised into subtasks derived from the course description, hackathon, and prior work on the project-based courses. Finally, a comparison table was created to identify methods used for each subtask. Each method was described by its advantages and disadvantages, and with the ICT tool utilised for conducting it and generating respective content.

Table 1- Interview questions [3]

Focus of questions	Example of an interview question
Questions common to each hackathon	What methods did you use? What tools did you use? What is your impression of the tools and methods you used? How did you allocate resources during the hackathon?
First hackathon: specific questions	How did you find user reviews?
Second hackathon: specific questions	How did you generate solutions?
Third hackathon: specific questions	How did you approach CAD modelling?

4. Results

The obtained results were divided into three subsections, each focusing on the specific hackathon and related insights. Finally, this section was wrapped up by bridging together various findings and relating them to the overall course structure.

4.1. First hackathon

This section presents student teams' usage of design methods and ICT tools during the first hackathon. For the first hackathon, students were introduced to methods related to market and user research, as well as methods for generating ideas. The methods used by students in the first hackathon were: PESTEL, adjusted method, User persona cards, AEIOU, interviews, secondary sources (reports) and brainstorming. Although the students were more thoroughly informed about these methods, for brevity, we will only provide their brief method descriptions as a part of this report. PESTEL (Figure 6) is an acronym for political-economic-social-technology-environmental-legal and provides a detailed overview of various factors of specific geographical areas (countries/cities).

Figure 5 - PESTEL method [1]

The user persona (Figure 7) is a fictional but realistic portrayal of a target user profile. Each persona represents an entire group of users. Figure 7 on the right shows an example of the implemented method and a description of the user (age, name, profession, interests, goals, and habits). For this method, students were advised to create characteristics of fictional users that fit their user research.

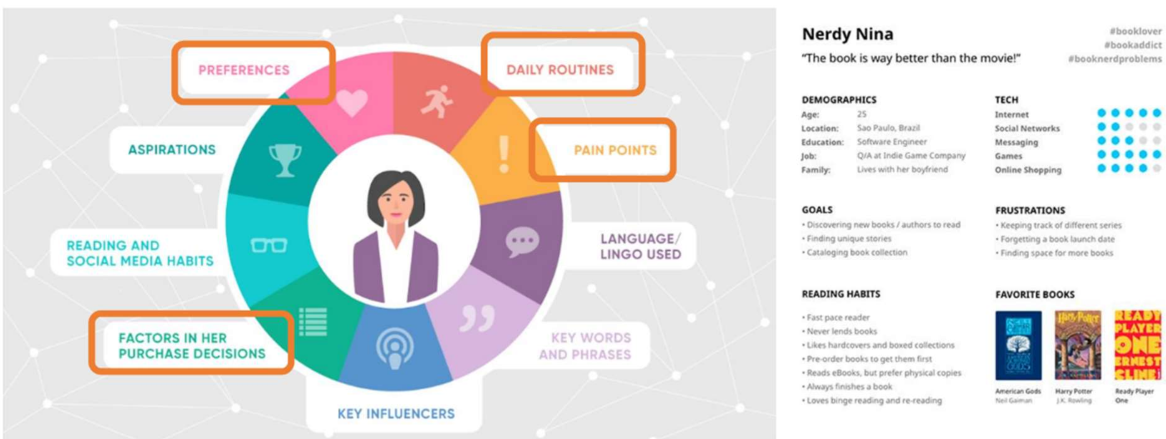

Figure 6 - User persona cards [1]

The AEIOU method refers to five categories to be observed and documented, which provide guidelines for data collection in user research. Each category (Activities, Environments, Interactions, Objects, and Users) is defined and forms the starting point of their user research study (but also for consolidation). The definitions of the categories can be integrated and modified to fit the chase objectives. Figure 8 shows an example of the AEIOU method template. The students' task was to fill in and adapt the method according to the given challenge.

DATE:	PROJECT NAME:	TYPE OF RESEARCH:
TIME:	RESEARCHER NAME:	

Activities	Environments	Interactions	Objects	Users

Figure 7- AEIOU method [1]

In addition to market and user research methods, this phase required additional methods for idea generation. The primary method presented within this phase was brainstorming (Figure 9), which was used to generate many ideas to solve the problems at hand. The ideas are not evaluated; atypical ideas are also welcome. Generally, a few rules were emphasised in this brainstorming introduction. Firstly, there are no bad ideas or criticism of other people's ideas. Secondly, lateral thinking is encouraged - the more ideas, the better. Finally, enabling and encouraging all team members and dividing them into sub-teams is perceived as beneficial.

Figure 8 – Functionalities of Miro board [1]

The virtual whiteboard Miro was used for all tasks during the first hackathon. The virtual collaborative board Miro (Figure 10) is a board-shaped tool for collaborative creation and development of ideas. It was used during the hackathon for sketching, structuring, and sharing information between team members. The use of different colours, shapes, lines, and the placement of notes facilitated communication and the exchange of ideas. It served as a valuable tool throughout the course, especially in the second phase regarding the virtual generation of ideas and the presentation of concepts. The useful functionalities were the possibility of being integrated into Microsoft Teams and its availability as a smartphone application.

4.1.1. Methods used in the first hackathon

Teams reported different working approaches in the first hackathon. To save time, team A was advised by their coach to work on user and market research in parallel. This team then presented their findings to the other team members to develop a shared understanding. The other teams (B, C, D and E) worked synchronously on each method. After the market and user research, all teams worked synchronously on the idea generation. Teams used different methods for the tasks in the first hackathon (Table 2).

For the market research, teams B, C and E performed PESTEL using a collaborative whiteboard (Miro). The advantage of this method was that it provided a detailed overview of the different market areas, and students reported that it was a good way to start the market research. On the other hand, teams reported that collecting all the information was difficult and took a lot of time. Team A used adapted methods as they only focused on specific aspects of the provided methods (e.g., PESTEL). They reported that this allowed them to focus on the most critical elements of the design problem at hand and saved time. However, they were aware that focusing on specific elements could lead to a limited understanding of the market and users.

For the user research task, teams reported using AEIOU, user persona, interviews, or secondary sources (Table 2). The AEIOU method received mainly positive feedback. Teams B and C performed it in Miro and reported that the method provided a detailed description of the users and their behaviour in the context of the design problem, i.e., metro coach in this case. Similarly, user persona was also used to provide a description of the users and their behaviour, but the focus was on capturing different perspectives. However, this method relies mainly on empathising with the fictional characters, which teams found difficult in this context. In addition, this method was very time-consuming, which could be the reason why only two teams (B and E) utilised it. Teams C and D conducted interviews via Teams, which were time-consuming but perceived as valuable as they enabled them to obtain a lot of useful information from the users. Team A utilised secondary sources (e.g. reports) and reported that this saved them time and provided them with information that could not be retrieved in any other way in the given timeframe. However, this approach was difficult to organise and distribute among the team members, as they often individually found similar sources when working independently.

All teams used brainstorming to generate ideas (Table 2). This method was perceived as helpful for creating three visions as it enabled synchronous work. Working on this task synchronously was particularly important for teams whose members were working on different aspects of market and user research, as it enabled idea creation that considered different perspectives. However, participants reported it was challenging to remain “abstract” and not fixate on a certain solution. For this task, all teams utilised a collaborative whiteboard (i.e. Miro) and reported that it helped them to have all ideas in one place.

Table 2- Used methods and ICT tools in the first hackathon [3]

Task	Methods	Methods pros and cons	ICT tool	Team(s)
Market research	PESTEL	+ Gives detailed views on various sections of the market; enables parallel work; great for beginning - Difficult to grasp all information; time-consuming	Miro	B, C, D, E
	Adjusted method	+ Possibility to focus on the most important aspects of the given task; saves time - Might overlook important aspects	Miro	A
User research	User persona	+ Provides different perspectives of the users - Time-consuming; hard to empathise with fictional characters	Miro	B, E
	AEIOU	+ Provides a detailed description of users - *None reported*	Google Docs	B, C
	Interview	+ A lot of useful information from a detailed interview - Time-consuming	Teams	C, D
	Secondary sources (reports)	+ Saves time; provides information that could not be retrieved in the given timeframe - Hard to do work in parallel	Internet	A
Idea generation	Brainstorming	+ Helpful with visions; simultaneous work - It is difficult to remain abstract and not fixated on a solution	Miro	A, B, C, D, E

4.1.2. Tools used in the first hackathon

During the first hackathon, most of the teams (B, C, D and E) worked with Miro from the very beginning to store and organise the information collected during the market and user research. These teams reported that Miro was a useful tool for collaboration. Only one team (A) did not want to "waste time" trying to understand a new platform like Miro. Instead, they used cloud document editing tools (e.g. Google Docs). Figure 11 represents Team C's Miro board, which clearly shows that the team worked from the first step of the first hackathon (team logo) to the last step (idea generation). The Teams channel was used for communication, both collaboratively and privately, depending on the requirements of the task at hand.

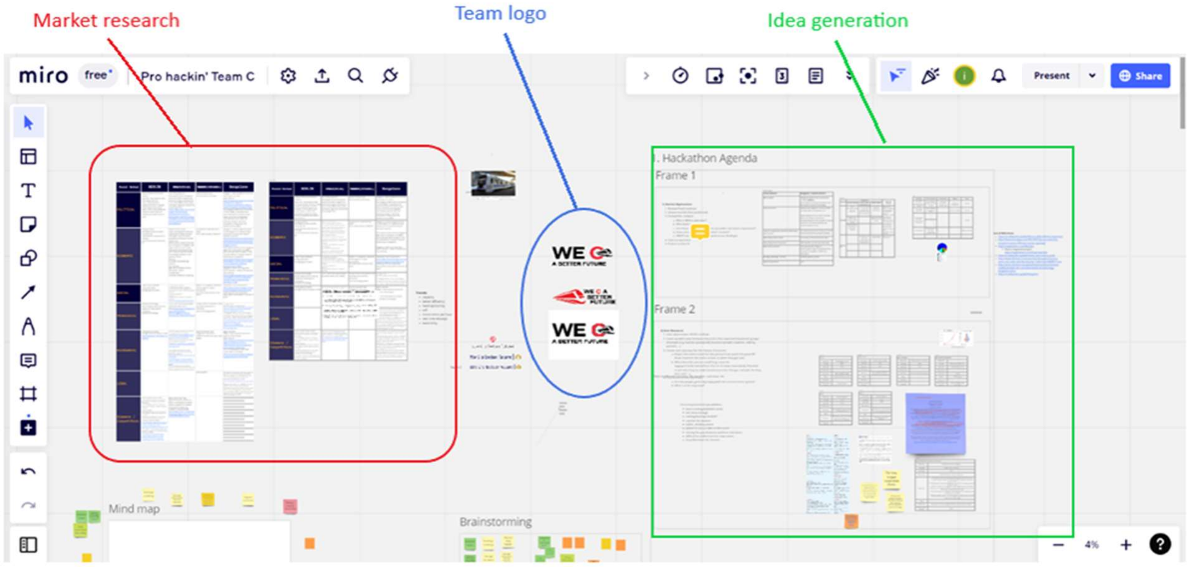

Figure 9- Miro board after the first hackathon – Team C [4]

4.1.3. Teams' perspective during the first hackathon

This subsection presents a detailed perspective on how students perceived the benefits of the first hackathon and to what extent it supported the delivery of the course's first phase. Table 3 shows results from the interview questions on the overall impression of students and hackathon organisation.

Teams had different impressions about the overall objective of the first hackathon. They were not used to having such an abstractly defined problem and had to think beyond immediate technical solutions. As such, this led them to conclude that the problem was too abstract and vague (despite this being the purpose of open-ended challenges and one of the main applications of hackathon events). However, Team E later realised the benefits as they could improve various aspects of their overall solution. Students suggested that providing the teams with handouts during the hackathon would be beneficial to students and simplify the way methods could be conducted. Also, they reported that their research phase ended up with "many materials" which were not utilised due to the limited time.

Teams also had different opinions on the organisation and provided support during the hackathon. Team A did not use all the given materials because they were perceived as unnecessary (in their opinion). Team B chose a market that could not support their high-tech solutions (too narrowed-down and inappropriately oriented focus). To prevent this, informing students about a broader picture of the design challenge earlier is necessary. Team C suggested taking the market research out of the first hackathon to give them more time to focus on their visions. They would like only to do the visions during the first hackathon, which would require re-organisation of previously conducted activities and frontloading at the very beginning of the course. Team D shares a similar opinion - remove market research from the first hackathon and focus on user research and idea generation. Related to the objective of the first hackathon, teams D and E suggested a narrowed-down problem definition. Team E would also like more time to prepare before the first hackathon.

Finally, utilising adjusted methods is conducted by only one team (A) in the first hackathon. Adjusting the methods to the problem at hand is considered and requires a higher level of design expertise. As team A was rated as having the best solution (by the industrial partner at the end of the course), it could be that this adjustment of the methods enabled them to get critical market and user research information in less time. It is interesting to note that teams perceived as high-performing (A and B) utilised overall different approaches in the first hackathon.

Table 3 - Perspectives on the first hackathon

First hackathon	Team A	Team B	Team C	Team D	Team E
Impression	Problem was too comprehensive	Abstract problem definition	Unclear task goal and assignment	Vague, too broad concept	Abstract problem, later great
Organization	Too many materials	Better preparation and information in terms of what comes next	Industry partner should do the research, teams during the hackathons do the visions. Remove the introductory lecture	Focus on the user and idea generation remove the market research. More specific problem	More time for preparation. Better problem definition and goal explanation during the first hackathon

4.2. Second hackathon

This section presents student teams' usage of design methods and ICT tools during the second hackathon. Students were introduced to methods related to problem framing and concept generalisation. The methods used by students in the second hackathon were: a network of problems, functional decomposition, morphological table, brainwriting and brainstorming.

Although the students were more thoroughly informed about these methods, for brevity, we will only provide their brief method descriptions as a part of this report. The Network of problems (Figure 12) is a graph consisting of nodes for problems and partial solutions. The edges of the graph join problems with problems (problem decomposition), problems with their solutions (concept mapping), solutions with new problems (problem framing) and solutions with solutions (concept detailing). It is used to perceive and understand problems and solutions to those problems better. It starts with a list of problems and solutions for this problem, from which new problems arise, and by filling in and “connecting the dots”, further, you get the entire network of problems and their partial solutions.

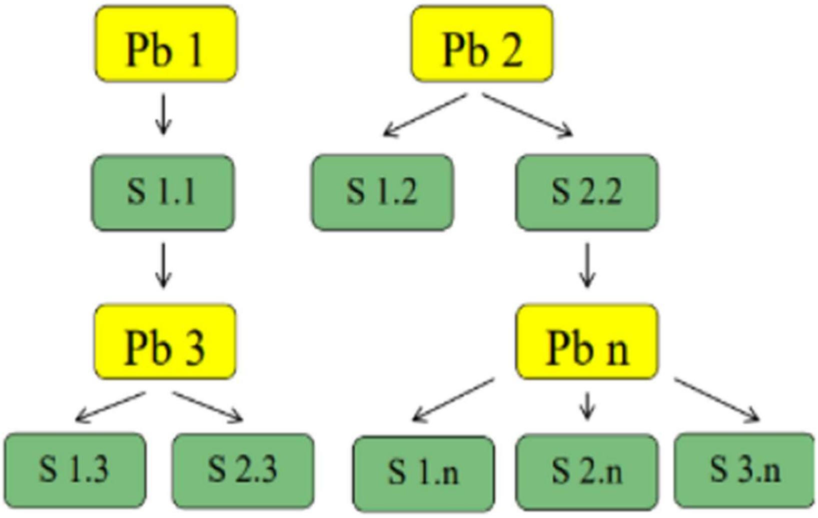

Figure 10- Network of problems [2]

All problems were categorized for a clearer overview of the entire network. Figure 13 shows an example of how an entire network of problems is developed from “one” problem. A legend next to the problem grid makes it easier to follow and clarify the network representation.

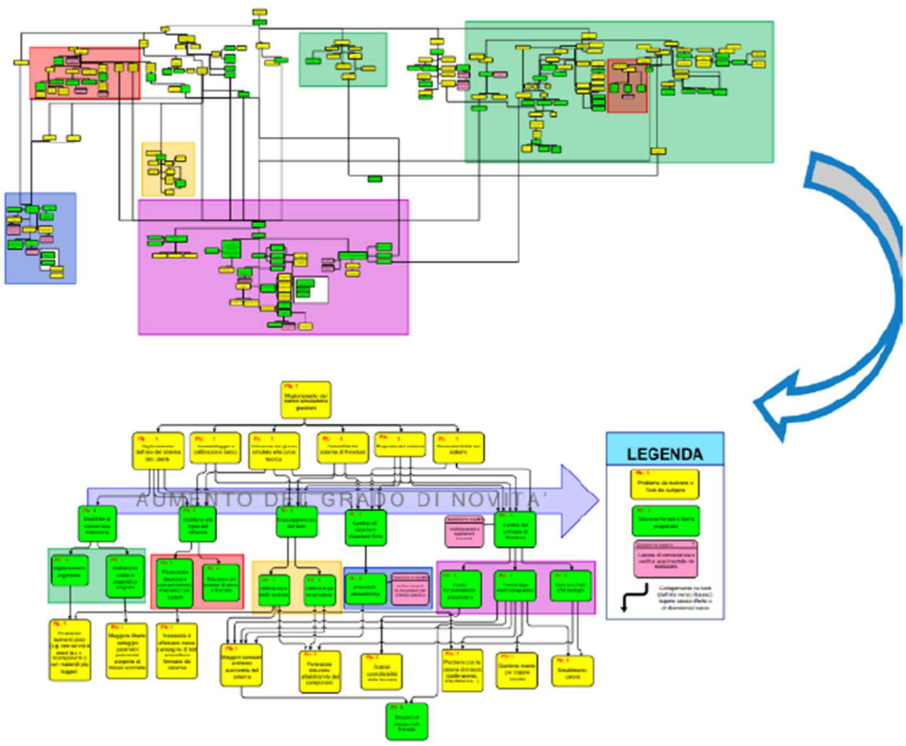

Figure 11 - Network of problems: an example [2]

Functional decomposition (Figure 14) is a method for representing sub-functions of the product and establishing the basis for concept generation. The functional structure represents a meaningful and compatible combination of sub-functions that comprise the overall function. The function describes the purpose (task) for which the product or its subsystem, assembly or component is intended, i.e. what it is supposed to do. Connections between functions must be carefully defined in terms of conversion of energy (red), material (blue) and information (grey).

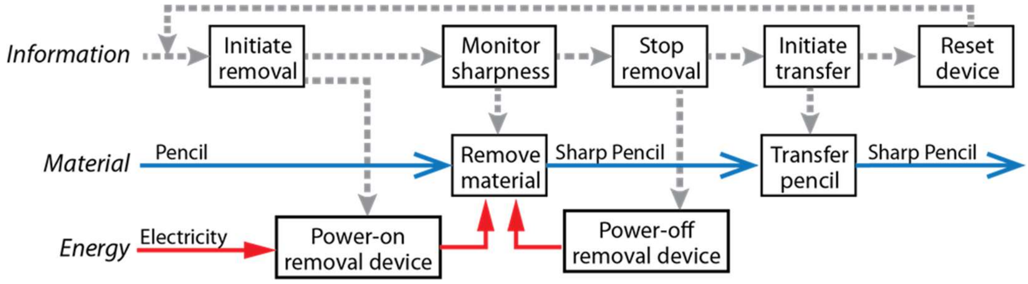

Figure 12 - Functional decomposition: an example [5]

The morphological matrix (Figure 15) is a method that captures various combinations of partial solutions. The rows of the table correspond to the sub-functions determined in the functional decomposition. The entries in the columns are sketches or descriptions of partial solutions for a specific sub-function, whereby an existing solution can be placed in the first column if it exists. Combining partial solutions for the sub-functions does not spontaneously lead to a final concept for the entire product. However, this method encourages designers to consider possible connections between partial solutions considering the main flows of matter, energy, and signals. A conceptual variant of a product (concept) is created by combining partial solutions in a way that meets the technical specification.

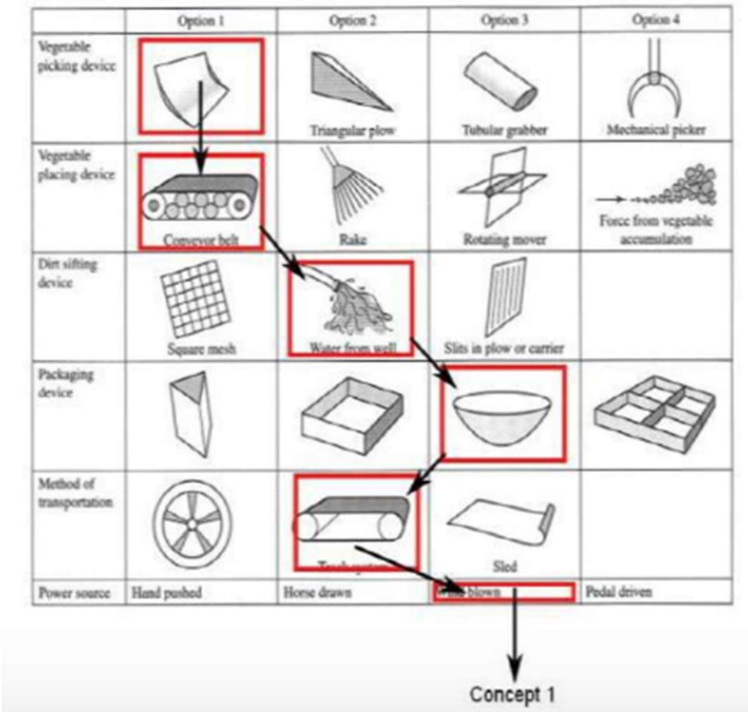

Figure 13- Morphological matrix: an example [2]

Brainwriting is a method in which participants are asked to write down their ideas instead of exchanging them verbally. The aim is to reduce the individual team members' dominance and foster the creativity of all participants. Figure 16 shows an example of the brainwriting method with 6 participants. The first step is to set the time frame for each round. In the second step, each participant writes down all their ideas in a table. In the third step, after the time of the first round has expired, the participants move to another participant's table, where they add, modify, and combine ideas. This iterative process is repeated until the tables of all 6 participants are filled. The final step is to group the related ideas.

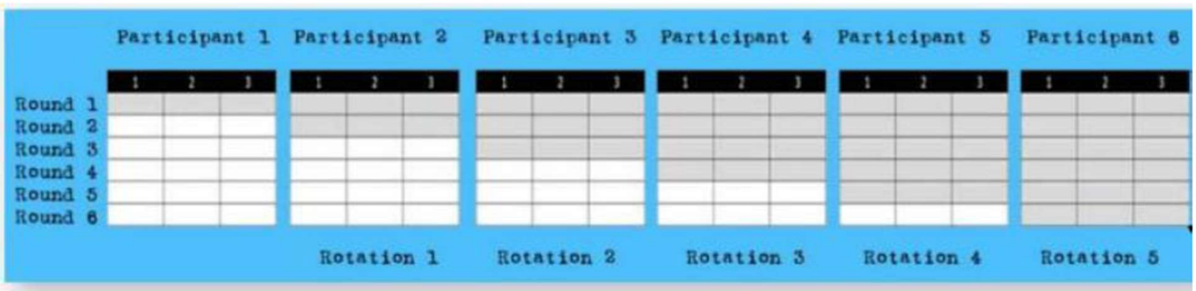

Figure 14- Brainwriting [2]

4.2.1. Methods used in the second hackathon

Like the first hackathon, teams reported on different approaches to structuring their work throughout the second hackathon. Team A had created a network of problems before the second hackathon to focus only on generating concepts during the hackathon. They split into three sub-teams for each concept - researched different concept aspects further, created sketches, presented them to the other team members at the end of the hackathon and carried out the concept evaluation. Team B initially worked together on the network of problems and then on the concept creation in three sub-teams. Other teams (C, D, E) also started the hackathon by creating a network of problems. However, they formed four sub-teams to generate a total of four concepts.

The teams used different methods for the tasks in the second hackathon (Table 4). Two methods used for the problem definition were network of problems and functional decomposition. All teams created a network of problems in Miro, allowing them to understand the passengers better. However, the network can quickly become overwhelming, making it difficult to avoid repeating the problems and comprehending the broader picture. Teams B and E created multiple networks of problems, each related to the topic searched by one person or a sub-team (usually two to four members). In contrast, teams C and D created a single network of problems that incorporated the results of all searches. Students reported that another tool (e.g. Visio, Draw.io) would be helpful for this method because it quickly becomes chaotic and overwhelming in Miro. Team C solved this problem by creating problem clusters and using different coloured sticky notes. In addition, the functional decomposition was created by two teams (B and D) in Miro. Its advantage was that it made understanding complex problems more manageable. On the other hand, it was time-consuming and difficult for students to understand the difference between functions and needs.

For the concept generation task, teams used the morphological table, brainwriting and brainstorming methods. For the morphological table, teams usually split up among themselves to search the Internet for partial solutions to the individual functions. Teams also created sketches using a collaborative whiteboard (e.g. Miro) or a CAD tool (e.g. SolidWorks, CATIA). These sketches were then presented using communication tools or transferred to a collaborative ICT tool (e.g. Google Spreadsheet, Miro) so all members could access them. These visualisations helped the team members to understand each other's ideas better. In addition to parallel work, this method allowed teams to describe solutions easily. However, teams also reported that it needed to fit the design problem, as it was challenging to visualise abstract solutions. The brainwriting method also enabled parallel work and helped teams to get different perspectives on their concepts. Finally, brainstorming was also carried out by all teams using Miro. This method helped users to think “outside the box”. However, teams reported that this way of working might become chaotic when a team works simultaneously.

Table 4- Used methods and ICT tools in the second hackathon [3]

Task	Methods	Method strengths and weaknesses	ICT tool	Team(s)
Problem framing	Network of problems	+ Easy to empathise with the passengers	Miro	B, C, D, E
		- Problem repetition; overwhelming		
	Functional decomposition	+ Easier to understand complex problems	Miro	B, D
		- Time-consuming; hard to understand the difference between functions and needs		
Concept generation	Morphological table	+ Easy to describe the solution; enables parallel work	Miro, CAD	A, B, C, D, E
		- Hard to visualise abstract solutions		
	Brainwriting	+ Gained different perspectives on different solutions; enables parallel work	Miro	A, B, C, D, E
		- *None reported*		
	Brainstorming	+ Thinking out of the box; productive	Miro	A, B, C, D, E
		- It gets chaotic when teams work simultaneously		

4.2.2. Tools used in the second hackathon

The virtual whiteboard Miro was used for all tasks during the second hackathon, with one exception. For the concept sketches and populating the morphological matrix, the teams used CAD tools, specifically SolidWorks.

Figure 17 shows Team C's Miro board after the second hackathon. It presents their outputs during the second hackathon - starting from problem framing to concept generation (morphological matrix and brainwriting), and one of their concepts. The Teams channel was used for communication, both collaboratively and privately, depending on the requirements of the task at hand.

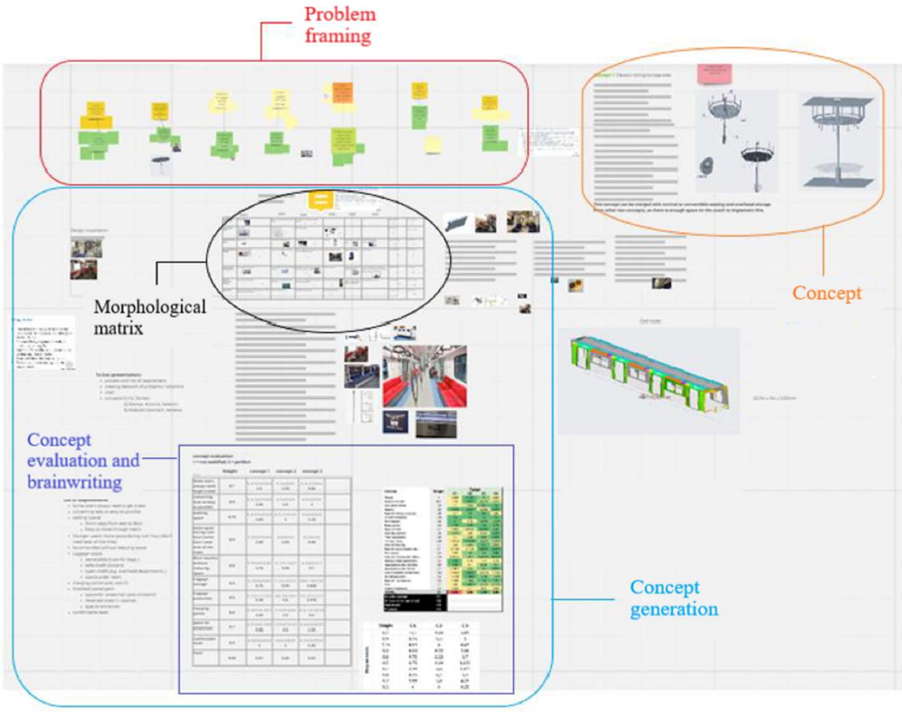

Figure 15 - Miro board after the second hackathon [4]

4.2.3. Teams' perspective during the second hackathon

This subsection presents a detailed perspective on how students perceived the benefits of the second hackathon and to what extent it supported the delivery of the course's second phase. Table 5 shows results from the interview questions on the overall impression of students and hackathon organisation.

Utilising several methods for the task enables designers to conduct the task more comprehensively. This is especially emphasised in the second hackathon, where all teams used three methods to generate concepts to reap the benefits of each method. In addition, teams B and C used two methods for the user research task, which might provide them with a better exploration of the design problem, i.e., the user needs. This focus on two user research methods might have benefited team B, as their sub-solution was rated as the most innovative. On the other hand, team C used the interview as the second method in this task, which might take too much time to reap the benefits within the given timeframe.

The impression of the second hackathon was, above all, an unclear start and confusion. The teams had not prepared sufficiently for the second hackathon, which could be the reason for their confusion at the beginning. Team A did not find all the tools and methods useful; it was quite the opposite. In their opinion, too many methods needed to be fulfilled, and they stated that "...the innovation gets lost along the way." Teams B and C also felt that it was unclear what they had to do and that they were lost initially. The leader of Team C explained that it was easier to work on the second hackathon because he knew his team members from the first hackathon. Team D executed the given methods but did not have enough time to implement them how they wanted. Team E had different ideas at the beginning of the hackathon but did not go through with them because they decided to continue in another manner. Teams C and E suggested a better explanation of the methods and outputs of the second hackathon.

In terms of organisational issues, Team A suggested introducing checkpoints in the future to make it easier for students to organise themselves. In addition, the methods should be adapted to the given problem. Many methods are used for more technical problem-solving. Due to the abstract nature of the problem,

the methods should be adapted to the given situation, or different approaches should be provided to students.
The lack of preparation is also evident in the statement "...remove introductory lectures because they are useless, either way, the coaches explain it again." from Team B, where the students relied too much on coaches. They knew there were no consequences for them if they did not attend the lectures and did not think about how it would affect the team. This cost the teams a lot of time during the hackathons (Team D). This may also be an indication that students were not able to adapt to short intensive activities adequately.

Table 5 - Perspectives on the second hackathon

Second hackathon	Team A	Team B	Team C	Team D	Team E
Impression	"...the innovation gets lost along the way."	Unclear, lost at the beginning.	"Better than at the beginning, I knew my team." Unclear what they had to do.	Executed, not enough time.	Confused, went in a different direction.
Organization and changes	Adapt the methods to the theme of the challenge, introduce checkpoints.	"The first hackathon was clearer than the second, remove introductory lectures because they are useless, either way, the coaches explain it again."	Better explanation of the methods. "Ask for 1 or 2 concepts, not 3."	More time.	Better explanation for the wanted outputs.

4.3. Third hackathon

This section presents insights obtained related to the third hackathon. The output of this hackathon had to be a detailed 3D model of the assembly of the selected concept, considering technical, economic, feasibility and maintenance aspects.
Students were introduced to methods for creating (e.g. CAD modelling) and evaluating (e.g. finite element analysis) virtual prototypes. Of course, students were previously familiar with 3D CAD modelling, however, they switched to a different CAD tool to allow for more manageable and convenient collaboration. Specifically, teams were given access to a fully cloud-based CAD system Onshape, which they can access via a web browser. An additional lecture explained more advanced aspects of CAD modelling and useful links (tutorials) for the Onshape CAD tool (Figure 18). Coaches were available to answer any questions on Onshape, and students were advised to complete a tutorial (consisting of two segments) before the third hackathon to familiarize themselves with the main CAD tool functionalities. The first segment ("Sharing and collaboration") described document sharing, collaboration tools (tracking modes, comments, assigning tasks) and publication procedures (creation and sharing, collaboration, notes). The second segment ("Navigating Onshape") included an explanation of the Onshape document (Onshape Part studios, section, measure, moving around the document), help resources (access and shortcuts) and, finally, model creation.

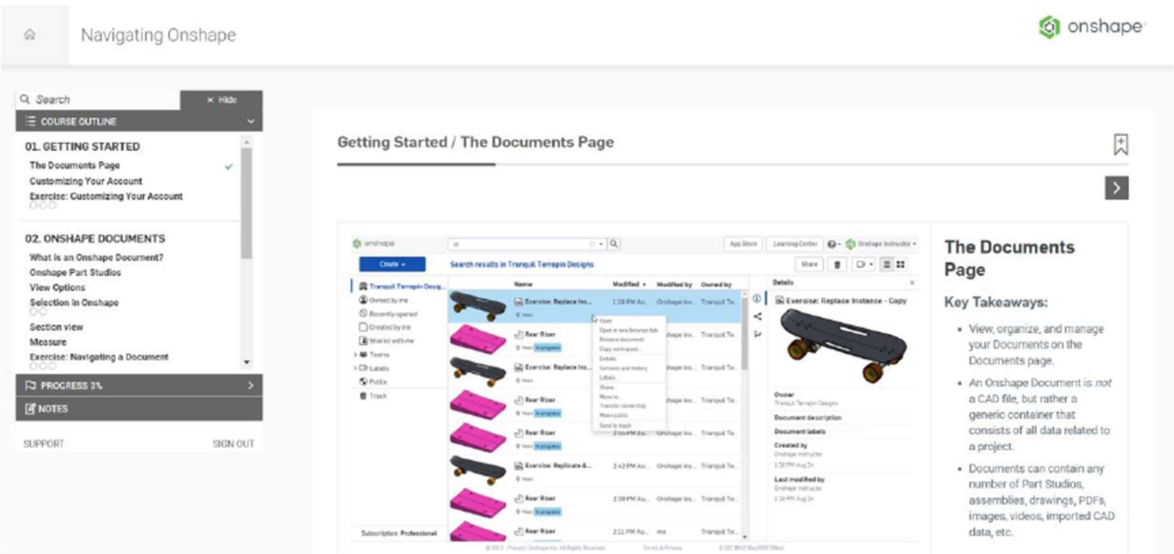

Figure 16 - Onshape tutorial via Learning Center [4]

4.3.1. Methods and tools used in the third hackathon

In the third hackathon, all teams split into smaller sub-teams. Team A split into three sub-teams, while other teams (B, C, D, E) split into four. Team A was divided by their prior work on concepts, team B by the country to facilitate communication, while other teams (C, D, E) were split by their knowledge and skills.
All teams employed the same methods for the tasks in the third hackathon (Table 4). The teams utilised collaborative CAD modelling in Onshape for virtual prototyping. Its advantage was parallel work on a virtual prototype with an always up-to-date version of the CAD model. On the other hand, this approach caused lagging, especially with large files (e.g., the metro coach model provided by the company). In addition, "non-physical" solutions were challenging to represent in Onshape (e.g., features of digital solutions). This was particularly accentuated in three teams (A, B, D) with digital sub-solutions (e.g., information panels).
Three teams (B, D, E) also conducted preliminary prototype testing using finite element analysis. This method enabled them to conduct quick feasibility tests. However, as teams used different ICT tools (Solidworks, CATIA) for this method than for the CAD modelling (Onshape), they encountered problems transferring CAD models to the finite element analysis.

Table 6 - Used methods and ICT tools in the third hackathon [3]

Task	Methods	Method strengths and weaknesses	ICT tool	Team(s)
Virtual prototyping	Collaborative CAD modelling	+ Parallel work on a virtual prototype; Up-to-date version of a CAD model	Onshape	A, B, C, D, E
		- Slow due to the large initial file; Difficult presentation with non-technical solutions		
Prototype testing	Finite element analysis	+ Quick feasibility checks	Solidworks, CATIA	B, D, E
		- Poor integration with used CAD tool		

4.3.2. Teams’ perspectives during the third hackathon

This subsection presents a detailed perspective on how students perceived the benefits of the third hackathon and to what extent it supported the delivery of the course’s second phase. Table 7 shows results from the interview questions on the overall impression of students and hackathon organisation.
Utilising only one method for the task is especially salient in the third hackathon. This aligns with the suggestions that later design phases are “narrower” (more “convergent”) than the early ones. Another explanation might be that students gathered experience throughout the first and/or second hackathons and were thus focused on fewer methods to reach the activity goal in time.
Teams B, C, D and E shared the same opinion that the third hackathon was an intense 12-hour in-person activity and that they had never had the opportunity to participate in something like this before. Team A felt that the focus should not be on CAD modelling as this was not suitable for their solution development, and their solutions did not include that many technical components. They would prefer to have had rendering and video training to make their design more realistic.
Considering the students' thoughts on the organisation of the third hackathon, teams A, C, D and E agreed that it would be better to split the hackathon into two days. On the other hand, Team B thought it was good that it took place on one day. Teams C and D believed better preparation would be more useful and would make the third hackathon easier for the whole team.
Team D proposed a concept that included natural mimicry, which was difficult to represent realistically without the appropriate skillset and knowledge (rendering).

Table 7 – Perspectives on the third hackathon

Third hackathon	Team A	Team B	Team C	Team D	Team E
Impression	Bad because focus is on CAD modelling.	Intense, “…you get used to the time frame”.	“Intense, great experience, I have never worked on a problem with a team for so long.”	“Tiring, exhausting, I could have used more breaks. “	“Exhausting, but very fun.“
Organization	Training in rendering and visualization. Split into 2 days of 6 hours each.	“Intense, but I like that it takes place in one day.”	“Better preparation of students - mandatory exercises, 30 minutes of modelling in Onshape.” Split into two days.	Better preparation before the hackathon, I would like to have more knowledge on how to present something more realistically. Split into two days of 6 hours each.	Split into two days.

4.4. Different perspectives on all three hackathons

This section presents the perspectives of the three roles (coach, team leader, and team member) within this course by further analysing the interviews conducted. Perspectives are analysed at the level of the entire course and not exclusively related to hackathons as in the previous sections.

The immense role of coaches throughout the course resulted in their clear overview of student performance throughout the course and individual hackathons. Therefore, interviews with coaches were explored in detail to understand their viewpoints better and gain insight into the course's operational level.

The coaches suggested that some of the suggested methods were perceived as unsuitable for this type of design challenge. When comparing with the challenge posed by the company Siemens Mobility a year earlier, the improvement of seats in the metro, the coaches felt that the methods were not suitable for a given problem ("improving the user experience"). The previous "seat improvement" challenge was focused on the physical aspects of the metro interior and narrowed-down challenge, and therefore, it was much easier to conduct the suggested methods in that case. However, as a part of tackling this challenge, coaches reflected that all teams experienced issues with their overall approach, especially in earlier course phases. "Improving the user experience" was an open-ended task (ill-defined and vague – intentionally) posed by the industrial partner, and the teams invested a lot of effort trying to understand the scope and focus of the challenge during the first hackathon. In addition, coaches noticed that teams would stop and ask them for help as soon as they encountered a problem, e.g. Team C was stuck with an endless network of problems, or Team B did not understand functional decomposition. As such, they perceived a lack of proactivity and overreliance on the coach's expertise. One way to improve student support could be to enhance the provided instructions and learning materials. Also, suggested methods could be contextualised and tailored more for specific tasks so that the teams have more time to develop required content during the hackathons. In terms of organising work in teams, the coaches advocated splitting up into several sub-teams. For example, they advised Team D to split up according to the made concept because this parallelisation of work would facilitate more focused work in a given short time frame. This was also a way to integrate Introverted and less communicative team members more easily.

Team leaders are team members responsible for coordinating and monitoring the team activities (and the team leader person changes for each phase). Team leaders, in their interviews, reflected on assigned responsibilities, the way they organised their work and preparation for hackathons.

Teams varied in terms of assigned responsibilities to respective team leaders. For example, when it came to voting and decisions, the team leader had the final say in team A, while the other teams' decisions were made collectively by voting and mutual agreement. In the latter case, leaders preferred voting within the team because the other members were also more involved. Still, all team leaders experienced the most stress and tension during the hackathons related to their phase. Within the context of team division, when distributing tasks between different team members, Team B did not want to split into sub-teams. This would prevent them from getting to know all the team members better, which could cause difficulties later in the project. On the other hand, Team D continued with the same division into sub-teams that had been established at the first hackathon, which, as it turned out later, was perceived as a mistake because it didn't help them get to know each other. They claim that it would have been a more comfortable and relaxed atmosphere if they had met at the first hackathon. In addition, team leaders stated that they prepared better for hackathons than other team members. They perceived that work during hackathons would be more efficient if every team member was equally well prepared and relied on the leaders and coaches as little as possible. As the team leaders changed after each hackathon (after each phase), they admitted that they reduced the effort in preparation for the following activities after finishing their role. One of the team leader's tasks is to set the schedule for how and when each method should be carried out. Dissatisfaction was expressed when it was impossible to carry out the methods within the given time limit. To name one situation, at the beginning of the second day of the second hackathon, Team D's leader felt the need to rush through all the methods to stay on schedule, but along the way, they moved away from the main purpose of the hackathon.

Finally, additional insights were gathered from team members to obtain their perspectives on hackathons and how they were delivered. Within that context, they reflected on hackathon aspects similar to those of coaches and team leaders.

Initially, dividing the hackathons (first and second) into two days was very satisfactory with all the members because it gave them more time to think and research. They believe that their concentration also wanes after three hours of intensive work and that they would not have such elaborate visions (in the first hackathon) and concepts (in the second hackathon). For concept generation, most interviewees stated that they would like to have the second hackathon in person because they would prefer to write all ideas on a real whiteboard. They thought the Miro board was an ideal substitute, but they still felt that live communication would be easier and faster. The burden of working synchronously in Miro for certain brainstorming cases was solved by splitting the team into several sub-teams of two or three team members.

The team members realised they should have prepared better for different course aspects. For example, team B wasted an hour and a half on functional decomposition because they weren't appropriately prepared and knowledgeable of the method. They admitted their expectations for the team leader to be in charge and guide them through the entire hackathon and that without massive support from the coach, they would have been "lost" and "off course".

4.4.1 Additional comments related to the potential tool improvements

This section presents suggestions, specified by course participants, for improving the tools used in all three hackathons. These improvements were extracted from the same set of interviews.

As MS Teams was used extensively throughout the course, participants expressed some issues they experienced when using it. The problems reported with Teams were that it is a "rigid" tool: "...when you send a message, it feels like sending an email." Obviously, this is not a limitation of the tool per se but more related to the perceived formality of the team communication via that tool. So many teams used instant messaging (e.g., WhatsApp, Telegram) for general communication for team members only, which proved very useful for teams to get to know each other and send information quickly. One team also reported technical difficulties during video calls, as they experienced mutual interruption while communicating due to an audio lag.

Information sharing was done in various ways and using different means. As such, this caused some difficulties for teams, but a small sample does not allow us to conclude the best possible way to collaborate and communicate in the given settings. Team A used cloud tools for data management (e.g. Google Drive) because they wanted to save time initially familiarising themselves with a new platform like Miro. Instead, they immediately switched to Google Docs ("...too much theory, not enough deliverables..."). Some students did not use cloud repository tools to share documents but did so more agilely by sharing documents via instant messenger (e.g. WhatsApp) or a task management tool (e.g. Trello).

For the third hackathon, students would find it easier to work only with the metro's reference geometry because the standard model, which consists of many parts and complex geometry, slowed down the performance of the used CAD system. For teams working on simple designs (and eventually simple CAD models) and not focussing on merely technical solutions (or technical aspects of it), this wasn't perceived as a large issue (A, B). However, they also reported that they would prefer a complete initial CAD model (provided by the industrial partner to better understand the surroundings and the context of the challenge) with essential parts such as doors, windows, seats, etc. Certain teams considered integrating "natural segments" into their CAD models but needed to learn how to perform such modelling. They believe that they should have had guidance for a more suitable programme to implement more abstract ideas.

5. Conclusion

This report explores the use of design methods and ICT tools in hackathons as part of the project-based course. Also, it provides insights into the way teams collaborated within the hackathon context, reflecting the differences between events conducted in a virtual and physical environment.

The results show that teams use different methods and ICT tools through three approaches: using only one method for the task, using multiple methods for the task, or using customised methods. In addition, teams considered several aspects when deciding on a method: the possibility of dividing the work among team members, the time needed to execute the method and their previous experience of using the method. The results on the use of ICT tools suggest that teams mainly use collaborative whiteboards and CAD modelling. In this context, tools that enable continuous sharing of ongoing work (e.g. cloud-based tools) show great potential for hackathons. Finally, the results show that it is possible to combine different tools to enable an easy transition between tasks (e.g. a transition from collaborative whiteboard to CAD modelling). Still, all these aspects should be further studied to gain deeper insights into the rationale and criteria for making decisions regarding the way methods are used.

These findings lead to several implications for educational practice. Educators should suggest that teams adapt methods depending on the design problem and distribute work among team members as much as possible. Also, students should be instructed to carefully explore the suggested methods. Otherwise, their lack of knowledge could lead to a perceived lack of value in utilising them. Regarding ICT tools, educators should suggest teams use cloud-based collaborative ICT tools and tools that are compatible (or tailored for) with different tasks. These allow synchronous interaction, which is of immense importance for the seamless collaboration of geographically distributed teams.

At the end of the project, companies gained many ideas and prototypes that can become new products. On the one hand, working on real-life assignments gave students the opportunity to learn the skills required by industry and gain experience working in intensive problem-solving environments. As such, this offers many opportunities for students to be better equipped with the relevant knowledge and skills for their future careers.

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