Manual for implementation of product hackathons in university courses

PRO HACKIN' - Project Result 3

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1. Introduction

Product development in a mechanical engineering context is a lengthy and complex process, requiring thorough background knowledge and precise documentation of design decisions. Characteristics that are not usually associated with hackathons. They are fast-paced, highly collaborative and competitive problem-solving events that allow for an intense knowledge exchange and the building of networks between participants, educators and trainers.

To evaluate whether this format can promote participation and student-centred learning in mechanical engineering students, the consortium of the University of Ljubljana, University of Zagreb, Politecnico di Milano and Technische Universität Wien conducts product hackathons in their joint Erasmus+ project Product Hackathons for Innovative Development – ProHackin'. These involved an industrial partner every project year, which provided a design challenge that participating students faced to boost their knowledge, skills and competences on innovative product design and development.

With this manual, the PRO HACKIN' consortium wants to share its findings from conducting product hackathons in collaboration with industrial partners within product development courses. Thereby giving attention to a higher education context where product hackathons must additionally satisfy the intended learning outcomes of the course and participants need to be assessed on their performance to receive grading.

2. What are Product Hackathons?

Product Hackathons, as well as design sprints, are time-intensive problem-solving competitions, just as regular hackathons but with a clear intention to develop a product in a mechanical engineering context. They aim to give impulses in a conventional product development process and create an open innovation framework between industrial experts, academic staff and students.

For additional information on the methodology and how we implemented and evaluated product hackathons please refer to our other project results:

Methodology for product hackathons in physical and virtual environments

Product Hackathons Case Study - Implementation and Evaluation

The following subsections describe:

1. The Intended Learning Outcomes (ILOs) that the PRO HACKIN' consortium set for this course, as these are essential to steering the whole structure and organization of activities and events. It also provide essential elements about the materials to provide students with in order to face the design challenge as well as general factors to consider for their evaluation at the end of the class, which are aligned to the ILOs.
2. The general structure of the course with reference to the traditional approaches for the development of design solutions and especially for new/innovative product development. This is to highlight how to adapt the course in order to facilitate the injection of product hackathons as a teaching strategy that swivels on the principles of student-centred learning and active learning.
3. The role and the responsibilities of all the involved stakeholders (from students to industrial partners), as such a course presents higher inherent complexity due to the emergence of several organizational constraints that go beyond what typically characterizes also the (not so) traditional classes about product development within a Project-Based Learning approach.

2.1. Aligning product hackathons with regular curriculum courses

Product development courses might be characterized by very different syllabi depending on the background of the teaching subject, on the specific study course it is placed in (e.g. mechanical engineering courses might mostly focus on design-related contents, while within management engineering courses the focus is mostly on the identification of resources for product implementation, scheduling, etc). Moreover, these could be also very different in nature, depending on the pedagogical approach that the teacher planned to implement (e.g. ex-cathedra lectures vs active-learning activities).

As said above, the introduction of product hackathons within a typical product development course increases the complexity of the course from an organizational perspective. However, at the same time, the regular pace of these events also offers the opportunity to set specific learning objectives for the new/innovative product development course and match them with the events, so that every single activity can be directly focused to ILOs.

In principle, the same approach can be replicated in different contexts that insists onto product development. Given the specificity of the PRO HACKIN' consortium and the goal of the project, the Intended Learning Outcomes are targeted also at covering knowledge, competences and skills that are currently less addressed by traditional classes.

Intended Learning Outcomes (ILOs)

Upon completing the course, students are capable of developing products methodically and partake in product hackathons as collaborative events to solve problems. This knowledge is intensively applied during the development of a product set to the requirements and specifications of an industrial partner.

More specifically each hackathon has the following intended learning outcomes:

Phase 1 „Problem definition and requirements clarification":

- Analyse a market within a specific industry regarding competitors, market developments, and important trends;
- Analyse the context of an application for a solution and the characteristics of potential user requirements;
- Synthesize knowledge from market and user research and use creativity to produce product visions;

Phase 2 „Concept Generation":

- Apply previous engineering knowledge for the development of technical solutions;
- Create a concept map that highlights the relationships between problems and solutions
- Compare competing solutions to select the most suitable one(s)

Phase 3 "Concept Evaluation and Embodiment design":

- Create virtual prototypes of the solution as a 3D CAD model with relevant tools
- Validate product design (e.g. with CAE tools) with regard to manufacturability and feasibility

Beyond these, there are also other ILOs which are transversal to the specific course stages and that concern the domain of soft skills, which the hackathon/design review sessions should be able to train directly with practical activities the learners are asked to face during the semester. These can be summarized into:

- Plan, set, participate in and document collaborative meetings and design sessions with peers;
- Prepare effective documentation and communication materials for each design stage targeted to relevant stakeholders;
- Deliver effective oral presentations to report the work done;
- Hold technical/technology-related conversations with relevant stakeholders (peers, project staff, technical experts, users, etc.).

Course Material

The materials, for a course that include hackathons in its set of activities, are to be considered beyond the typical set of references and/or slides that the students can traditionally access for more standard courses. Materials should include also elements to facilitate the interaction between subjects and to favor inclusivity and accessibility from geographically distributed contexts (also within the same country).

Materials, here, span both traditional means and original ones. These include:

- Reference books (suggested readings, excerpts, etc);
- Lectures and related slides;
- Audio/Video recorded lectures;
- ICT tools to facilitate communication (i.e. a distant communication platform that enables audio/video conferencing);
- ICT tools to facilitate online collaboration (i.e. distant interaction platform that enables data/info visualization and editing: i.e. tools for concurrently editable documents, spreadsheets, but also collaborative whiteboards as well as 3D CAD files);
- ICT tools to enable data storage and content sharing among course participants and team members (i.e. data repositories organized in folders with secured access)

Content-wise the course materials are kept essential to facilitate learners to focus on few extremely relevant design-related methods and tools they can proficiently apply during hackathons. For the context of new/innovative product development, the consortium proposes several lectures distributed through the semester. The topics are presented in brief with a practice-oriented perspective to facilitate immediate application. Within the semester, the topics are organized in order to be presented coherently with the stage the inherent contents are most relevant. These cover the following topics (some might be omitted, depending on the specificity of the design challenge proposed by the industrial partner):

- Market analysis methods;
- Technology search and scouting (with patent search fundamentals);
- User-centered design methods;
- Requirements identification and characterization;
- Functional decomposition;
- Idea generation methods
- Problem and Solution mapping;
- Concept formulation and evaluation;
- Computer-Aided Design fundamentals;
- Computer-Aided Engineering fundamentals.

Assessment

The assessment of students is obviously carried out with reference to the intended learning outcomes defined at the beginning of the course. Their achievements therefore concerns the skills the students displayed while they carried out the different activities they have been involved in during the semester. Given the interactive nature of the Project-Based Learning course proposed by the PRO HACKIN' consortium and the knowledge and time-intensive nature of the hackathons proposed as pedagogical intervention to boost active learning, the consortium suggests considering the following factors among the most determinant ones in providing relevant information for students' assessment and grading.

With reference to the abovementioned Intended Learning Outcomes and for the purpose of individual assessment and grading, the factors the consortium suggests considering with higher priority for a Hackathon-based PBL course on Innovative Product Development are:

- Contribution to the Team's Work (e.g. Proactivity in information search and sharing, creativity, analysis and synthesis skills)
- Degree and quality of interaction with teammates (i.e. capability to provide meaningful and constructive feedback, capability to leave room to other team members, capability to listen actively, etc.)
- Coherence with the project management plan/agreement with other teammates (e.g. on-time delivery of interim results, synchronization with other team members, etc.)
- Expected Quality of Outputs (e.g. adequacy of proposed results with reference to the specific project phase targets; correctness and richness of the results, etc.)

2.2. Adapted course structure

The hackathons take place within an academic semester (13-14 weeks) within a course organized coherently with the product development process (e.g. Pahl and Beitz). In this new methodology, 5 events inject into the traditional product development process. Three product hackathons are the core activities within the semester, complemented with the kick-off event and the final workshop. The three product hackathons address respectively the phases of

1. problem clarification/fuzzy front-end,
2. conceptual design and
3. embodiment/detail design.

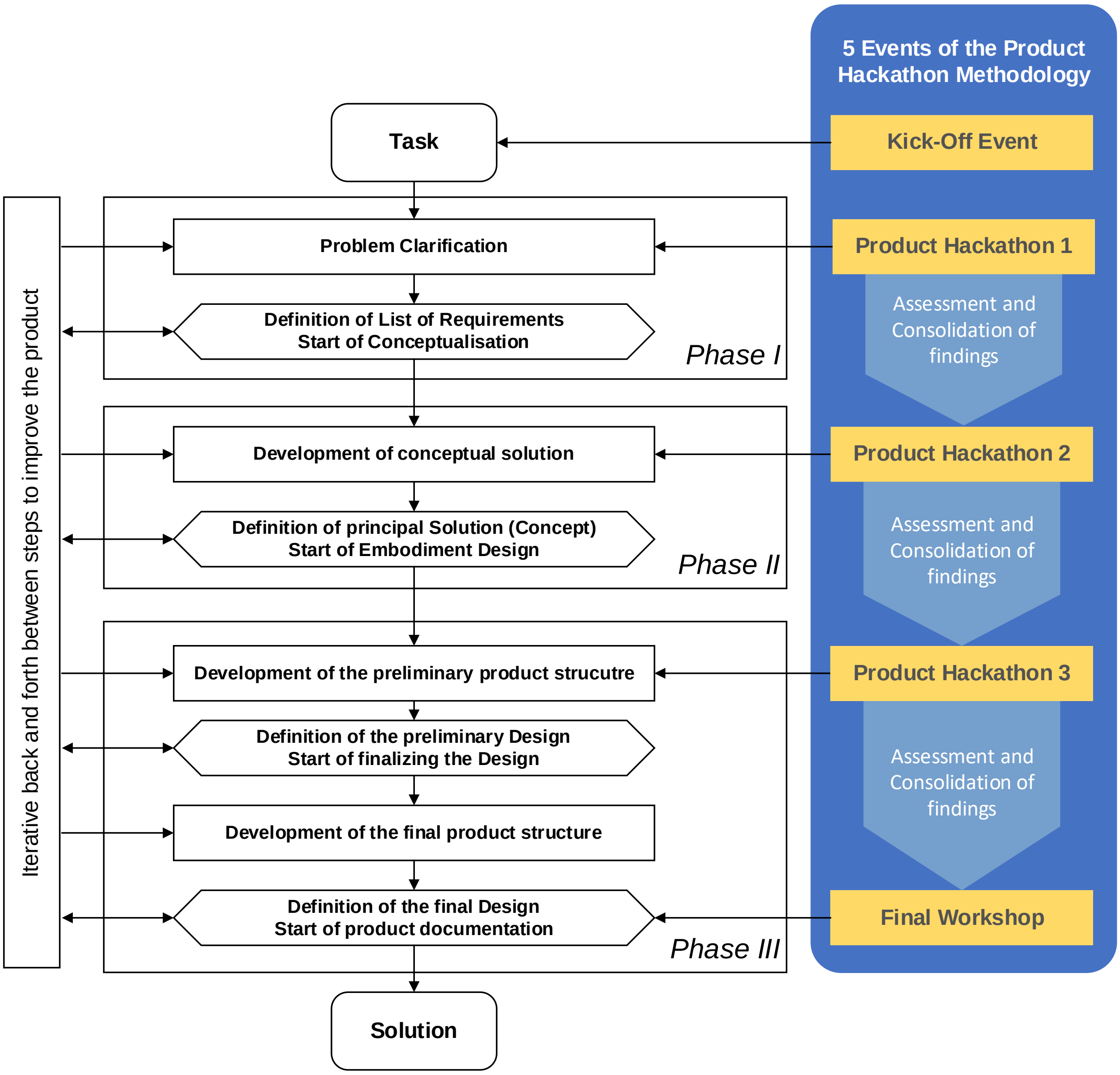

Figure 1: Hackathons intersections with the traditional product development process form Pahl and Beitz (1977)

These 3 phases, within the boundaries of the course, are named with more easy-to-understand denominations, in order to facilitate the comprehension by students, which are not necessarily familiar with the theory of design methodology. The three PRO HACKIN' Hackathon-based phases are then named:

1. Problem Identification and Clarification
2. Conceptualization
3. Virtual Prototyping

These respectively aim at processing information about a specific new product development case study (provided by a partner company) and generate new ones up to the embodiment of a virtual prototype of the solution, i.e. a 3D CAD model that details system parts, their layout, and the way they interact with each other (Figure 2).

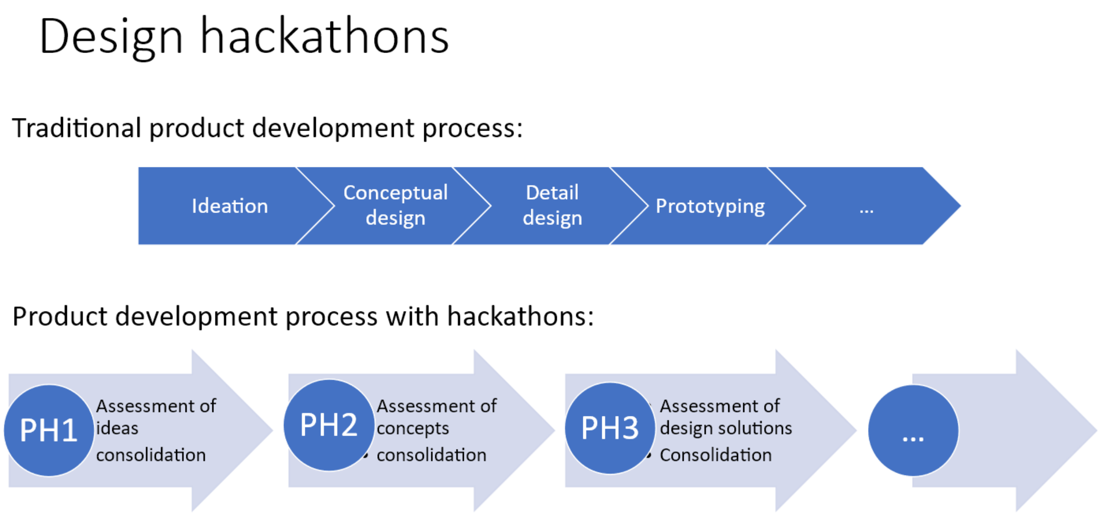

Figure 2: The comparison between a traditional product development process and one which is structured by means of hackathons. The latter proceeds by sprints that take place during these events.

The course takes place remotely for most of its implementation as it connects students from 4 geographically distributed universities. In the context of remote learning, as for the international PRO HACKIN' consortium, some additional organizational constraints to consider are presented together with successful strategies to address them. These are reported within the description of each phase.

For what concerns the implementation of an online course about innovative product design (structured coherently with the above product development process), the readers could refer to the materials of the ELPID project (www.elpid.org).

As part of the EU's Erasmus+ Programme, the PRO HACKIN' Consortium aimed at boosting the possibility of sharing experiences among students of different countries and boost the construction of a common European spirit in growing generations. The project offers the opportunity to create a wider, more diverse and inclusive context of study/work by revolving the standard structure of university-centred PBL courses: students within the PRO HACKIN' course work in international teams composed, ideally, by an (almost) equal number of members from the 4 universities of the consortium. The number of teams and team members requires an adequate planning by the educators. Among the relevant factors that are relevant to this choice, we would like to highlight the following ones:

- Availability of an expert academic coach/mentor to support the work of a team (i.e. every team should have its own academic coach/mentor, ideally two coaches, depending on the number of team members per team);
- Limitations due to the channels used for remote communication and interaction (online meetings might be less effective as the number of participants grows if the meeting is expected to be interactive and collaborative);
- Availability of the industrial partner to be involved in active learning activities with large number of teams (Every team regularly reports the outputs of product hackathons a few days after its conclusion, to receive company's feedback and steer the work before the next hackathon. More teams to review imply more time demands for the industrial partner).

Within the implemented PRO HACKIN' courses, that ideally involve 4o students per year, team members range typically from 8 to 10 members per team, which results into 4 to 5 co-design teams involved in the design challenge proposed within the course.

The following subsections describe in detail, within the course structure, what the events consist of and what their targets are for participants and for educators. This proposed structure can be, therefore, replicated as-is in classes sharing the same overall objectives. However, this might also serve as a general guideline for the adaptation of this structure to courses that share some commonalities (e.g. a stage/phase-based development of activities that requires concurrent interventions by different subjects at the same time, not necessarily related to technology-based education, such as medical staff training).

2.2.1. Kick-off event

During Kick-off students familiarize with the project objectives, both from an educational and from a technological perspective. The educators take care of making explicit the course plan and provide details about the overall expectations, both in terms of the expected outputs for the project/design challenge the learners will be designing for and of the intended learning outcomes the students will be provided with at the end of the course.

This event is also used to host the industrial partner which presents the design challenge, typically as a design brief containing expectations and requirements as boundary conditions to the specifications. In this section of the event, students participating in the project typically have the chance to ask the very first clarification questions and start interacting directly with the company/industrial partner's staff. To facilitate student engagement and to keep them constantly motivated during the whole course, the design problem is proposed in the form of a challenge against other teams

The mix of presented activities serve as a warm-up and activation phase for students to get acquainted with their team, coaches/mentors and workflow. In fact, as the kick-off event that takes place in a geographically distributed environment, this introduces some limitations of human interaction. Students might be organized into teams that are not co-located and therefore they might require some opportunities to start familiarizing in a setting that allows all the participants to present themselves. In order to establish meaningful relationships among all team members, interactive sessions aim at breaking down the virtual barriers, enabling everyone to connect, share backgrounds, and set the stage for open and supportive communication. This human connection is crucial, as it fosters a sense of belonging and mutual respect, setting a positive tone for the duration of the course among team members, which also have initial elements to understand how to exploit the individual skills of their mates to achieve the best possible project results. For these team-centered sessions, therefore, the PRO HACKIN' consortium suggests that the team members meet their peers and academic coaches in dedicated meetings (e.g. in breakout rooms) with open cameras and microphones by means of the ICT tools for remote communication the consortium selected for the course (the PRO HACKIN' consortium's choice is MS Teams as it is well integrated with other MS services that enable remote collaboration, document/file editing and storage).

The duration of the Kick-off event is susceptible to a series of constraints and conditions which are typically design challenge-specific. In general terms the overall duration of the event can range between 3 to 6 hours. This tame frame could be necessary to accommodate the interventions that the industrial partner considers essential to raise the participants' knowledge up to the required level that enables them to proficiently design solutions. In case these expected duration of the event exceeds a duration of 3 or 4 hours, it is strongly suggested to run the event into two subsequent days (e.g. 2,5/3 hours each).

2.2.2. Phase 1 – Problem Identification and Clarification

Phase 1 requires the different teams that address the design challenge to transform the design brief they received together with the presentation/description of the challenge into a design opportunity which is corroborated by evidence emerging from the market, both in terms of customer demands and technological opportunities. This phase is crucial, as understanding the market helps to align the forthcoming products with consumer needs and expectations, while technology and standards research ensures that solutions are innovative and feasible within current frameworks. Figure 3 visually describes the basic elements that characterize these stages, both as activities, outputs as well as information to process and elaborate during this phase.

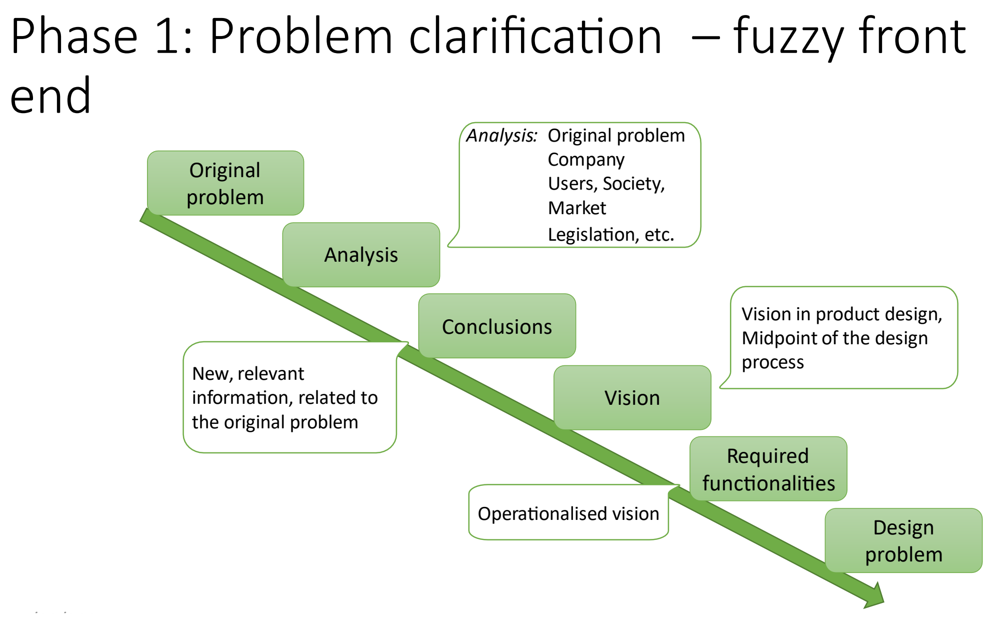

Figure 3: The sequence (iterations are not explicitly shown) of tasks/actions that characterize the phase of problem clarification. Each team needs to examine the problem provided by the industrial partner and transform ist definition into a design problem (with related subproblems).

The phase starts right after the conclusion of the Kick-Off meeting, as the problem, as presented in its original formulation as proposed by the industrial partner has been thoroughly discussed in dedicated timeslots.

Within this stage students mostly benefit from the introduction of these concepts to support them in the delivery of the expected outputs:

- Market analysis methods;
- Technology search and scouting (with patent search fundamentals);
- User-centered design methods;
- Functional decomposition;
- Requirements identification and characterization;

The consortium typically covers these topics by presenting approaches to determine contextual and user-oriented factors (e.g. PESTEL analysis, AEIOU observation framework, market segmentation and competitor analysis, as well as empathy-based methods such as personas and empathy maps). Technology oriented searches are mostly meant to enable participants to understand what is their freedom to operate in a specific technological sector (e.g. they check what are the existing patents that prevent further development) as well as to let them discover useful solutions that they can try to implement or be inspired by for their design challenge.

These topics can be addressed by means of a series of lectures delivered in a short period (within the same week) to favor the integration of contents among them and close to the first hackathon (before it) to provide participants with an almost immediate opportunity for application and testing. The topics highlighted above are typically presented in 2 or 3 lectures having a duration of 90-120 minutes each. Lectures, which are held remotely, are recorded to enable students that could not participate in to watch them to realign knowledge. For some specific topics the lectures might be pre-recorded to let students watch them and then participate in Q&A sessions with the lecturer.

As the hackathon commences, participants from each team bring together their research findings. This collaborative effort is essential to synthesize information, allowing teams to pool their collective knowledge and creativity. The primary goal here is to brainstorm effectively and yield three distinct product visions. This task, despite close to idea generation, is not a surrogate or a preliminary version of concept development. Participants, to be both visionary and grounded in the realities of market and technical research at the end of the project, should not aim at crafting final solutions at this stage. Educators as well as mentors/coaches should encourage students to generate ideas and solution concepts by brainstorming solely (at least for this phase) with the goal of extrapolating requirements from those solutions, to corroborate the visions.

The co-evolution of problem and solution is a well-documented phenomenon in the literature. Human brain progressively re-elaborate the information about the problem and its formulation by generating solutions that manage to partially address them, in a virtuous circle. This process is extremely powerful for both problem analysis and solution generation as it leverages a natural and consolidated thinking process. Generated solutions, especially in collaborative brainstorming sessions, help different participants to generate a shared model of the problem as its inherent implications emerge together with ideas and concepts: these elements become crucial for design requirements identification. On the other hand, the same process is essential to identify suitable solutions as this happens when a proposed idea perfectly matches the requirements that characterize the conditions to consider the (design) problem solved.

Therefore, an essential part of this stage sees the team works to specify product requirements, which involves a detailed discussion on what the envisioned products should achieve, the problems they aim to solve, and the benefits they will offer to the end-users. Defining the product type is another key objective, requiring teams to articulate a clear vision for the product category and how it fits within the existing market landscape. The process then delves into identifying (sub)functions and constructing a functional model, tasks that are vital for breaking down complex systems into manageable components in the next phases of the project. This modelling is the backbone of product development, guiding teams in understanding how various parts of the product will work together to perform the necessary functions. Required functions are expected to emerge in this phase, but participants need also to be warned that new ones will emerge as soon as they will start consolidating concepts in the next project phase.

From a practical point of view, the hackathon takes place in a remote environment as well as the kick-off event. This means that the duration of the event could not be the same proposed for a live one. However, it is necessary to underline that the delivery of outputs might require extended durations. For this reason, the PRO HACKIN' consortium suggests the hackathon to have an overall duration of approximately 8 hours, which should be distributed into a couple of consecutive days. To reduce the limitations that emerge from the need of synchronizing the agendas of students from 4 different countries, the consortium also suggests that this online product hackathon takes place in the late part of the afternoon, potentially covering 3 to 4 hours per day (e.g. 15-19h or 16-20h). Both the meetings should be opened and closed by the project staff, whether they are professors or coaches. During openings it is relevant to recall the objectives of the whole phase and of the hackathon, both in terms of outputs to generate and of learning objectives to achieve. During the closing sessions the educational staff should trigger the participants to reflect on what they did, how they performed their activities and criticalities to consolidate the learning.

Following the intense collaborative and creative efforts of the first hackathon, students are presented with the opportunity to engage with the company during a design review session. This is a critical juncture where the preliminary outputs of phase 1 are vetted and refined. Students clarify and further develop functional requirements, ensuring that the visions are not only innovative but also technically and economically viable. At the end of the design review session, the company select the best vision(s) per each team and provide them with suggestions and additional constraints to be considered to continue with the development of the project in the next phase. These meetings last approximately 2 hours overall, in order to allow the teams a design review time of 25-30 minutes each.

2.2.3. Phase 2 – Conceptualization

Phase 2 concerns the generation and the development of design concepts by the design team. In terms of information processing, the team members need to start from the functionalities required to satisfy the problem provided by the industrial partner and turn it into a design problem. This is characterized by engineering functional requirements which, on the one hand, serve as a steering guide for the selection of the best technologies, working principles and mechanisms to implement in the solution that steer the selection of technologies. On the other hand, they allow to estimate the suitability of their integration by providing measurable criteria to compare the performance of the solution with.

This process typically takes place in between the end of the first review with the company staff to evaluate the outcome of Phase 1 and the beginning of the second hackathon.

Then, Design teams meet for the product hackathon and produce concepts to generate the required output for this phase. During the hackathon, the teams ideates and develop solution concepts through the help of techniques that leverage brainstorming-based methods for idea generation (e.g. Brainwriting, 3-6-5, Braindrawing, SCAMPER, 5W&1H, etc.) as well as design-by-analogy techniques (e.g. Bio-Inspired Design, Patent.-based creative stimulation, etc.). The definition of solution concepts typically takes place as an accumulative process that collects partial solutions capable of addressing one or more (in any case few) specific subproblems or delivering specific sub-functions. Some of these partial solutions address different problems, while others address the same subproblem. The latter, therefore, compete with the other solutions in the same subset for the implementation in the final technical system. This approach requires, on the one hand, the provision of techniques for problem and solution representations (e.g. the Network of Problems by OTSM-TRIZ). On the other hand, it requires the introduction of techniques for the combination and/or the integration of partial solutions into a unique solution concept. Different combinations of partial solutions might originate quite different solution concepts that might compete or that cover different market segments. To this purpose, all the teams benefit from the adoption of morphological charts/matrixes that help in the selection of relevant partial solutions to combine. The co-design teams, finally, provide a rough evaluation of their product concepts by means of measurable criteria based on the requirements set at the beginning. These enables the quantitative ranking of solution based on the qualitative perception of their capability to fulfil the requirements.

The last stage of these process (especially concept refinement and evaluation) might also take place after the end of the hackathon in case the development of solution concepts requires additional efforts and a longer duration.

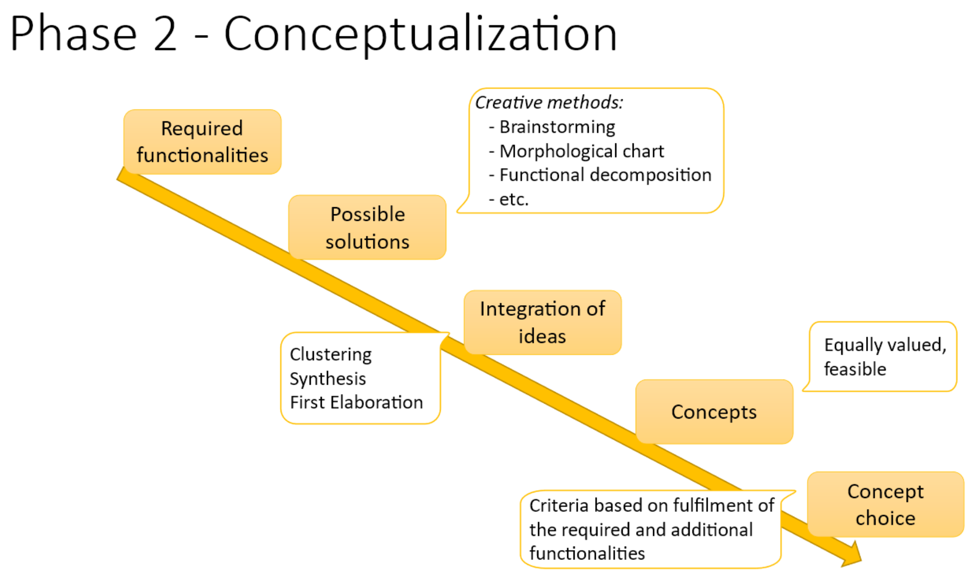

Figure 4: The sequence (iterations are not explicitly shown) of tasks/actions that characterize the phase of conceptual design. Each team needs to define which partial solutions might address the design requirements emerged from the outcomes of Phase 1 and integrate them into a system that globally addresses the original problem set by the industrial partner.

For a proficient hackathon, the students need to be already familiar with the design methods and tools they could mostly benefit from, which the consortium suggests them to exploit. For this reason, also during this phase the consortium's lecturers delivers remote lectures in order to cover the following topics (the topics that were also presented in phase 1 might be repeated here in case they were not introduced during the fist part of the design project):

- Technology search and scouting (with patent search fundamentals);
- Requirements identification and characterization;
- Functional decomposition;
- Idea generation methods
- Problem and Solution mapping;
- Concept formulation and evaluation;

As for what concerns the organization of remote lectures in Phase 1, lectures in Phase 2 are typically collecting more than one topic within the same event, whose overall duration remains in between 90 and 120 minutes. Coherently with Phase 1, they are also delivered a few days before the hackathon. Phase 2, differently from the others, is the one that mostly benefits from a closer interaction among team members. Within the implementation of the Erasmus+ project, short mobility periods are foreseen for learners and teachers/trainers and this perfectly answers the need to let co-design teams to interact in real life. For this reason, the mobility period of the Erasmus+ coincide with the timing for the second hackathon, which should take place in the most convenient location to facilitate the participation of co-designers. Within the boundaries of the PRO HACKIN' project, the live hackathon takes place in one of the consortium's countries, as planned.

Within the days of the live hackathon, the teams will be involved with their members in extremely intensive sessions of collaborative design. The duration of the live hackathon depends on a wide variety of factors, which include:

- The specific design challenge at hand;
- The availability of the industrial partner to provide continuous or sporadic supervision during the event;
- The availability of equipped meeting rooms that enables proficient co-design sessions during day-long events;
- The availability of project staff for the whole duration of the event.

Live product hackathons within the PRO HACKIN' project might rage from one full working day (8 hours) to more than 2 working days (e.g. 16/18/20 hours). Depending on the hackathon duration, its planning can be both concentrated in a single day or distributed into a couple of days. These events are time intensive and therefore it is suggested that students self-organize the planning of the activities as well as the policy for breaks and the timing for eating/drinking.

Before Phase 2 ends, the design teams have the chance to present their advancement to the company staff during the second design review meeting (similar durations as for Phase 1). Here teams present a selection of their best concepts (typically 3 to 5) for the evaluation by the industrial partner. At this stage, the industrial partner collects the concepts generated by all the teams and listens to their presentations. Afterwards, the industrial partner internally defines the best options for each team and communicates this to each interested party, so that the teams can continue with the development before the beginning of the third hackathon in Phase 3.

2.2.4. Phase 3 – Virtual Prototyping

Once the concepts are presented and the best one, per team, has been selected by the company to continue with the development, the team members move back to one of the topics they were exposed to approximately at the beginning of their academic careers as industrial engineering students: 3D modelling. Within the third project phase, in fact, students provide a more clear structure to their solution by identifying the general layout of subsystems (unless already emerged before the end of the second phase).

Here they mostly require to identify relevant product subsystems and product parts, define their interactions and interfaces in order to formalize the final layout for the solution into a 3D CAD model that visually represents the embodied, despite virtually, prototype needed for a preliminary estimation of the whole solution.

In this phase of the project, therefore, the students require knowledge, competences and skills that cover the needs of the 3D modeling. For such a purpose, the consortium delivers some additional lectures that also enable the harmonization of knowledge among the different team members. These lecturer cover the topics of Computer Aided-Design and Computer Aided-Engineering and simulations.

Their duration and planning within the duration of the phase is coherent with what already presented for Phases 1 and 2.

With reference to Figure 5, whose blue boxes describe a complete prototyping activity up to the production and assembly of a physical prototype, it emerges clearly that within the PRO HACKIN' project the course is focusing on the activities up to the embodiment and the implementation of preliminary detail design principles. This happens as the physical prototyping stage is extremely time consuming in a wide variety of application domains and very few opportunities emerge to test functionally a solution with a physical prototype. The choice to interrupt the development process at the stage of virtual prototyping, in any case, ensures that the students acquire most of the essential knowledge and skills necessary to cover the sections of the product development process which are most frequently overlooked in traditional mechanical engineering study programmes.

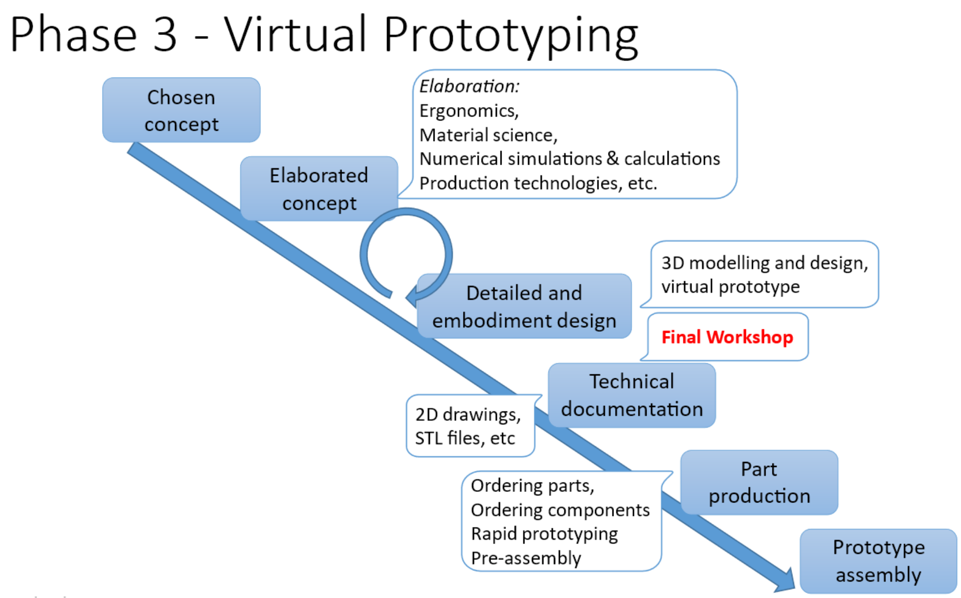

Figure 5: The sequence (iterations made explicit just between concept elaboration and embodiment design) of tasks/actions that characterize the phase of virtual prototyping. Each team needs to define which subsystems and parts might compose the product concepts proposed for the final solution and integrate them into a well modelled 3D assembly.

The design teams, in principle, might start developing the specific parts of their 3D assembly right after the conclusion of the second review meeting and planning the work breakdown among team members. For such a purpose students leverage collaborative CAD systems that enable online concurrent/synchronous interaction within the same file, differently from the large majority of existing PLM solutions.

During the hackathon, which this time takes place remotely, the students might decide to focus on the activities they consider the most crucial to finalize their proposals for the company. The set of activities range from the definition of system parts to the integration of system parts inside the 3D assembly file. This mostly depends on the availability of time of team members before the hackathon and their motivation to conclude the project positively. The teams who regularly worked in between two hackathons will probably come at this stage with most of the subsystems already synthesised into a 3D CAD model. On the contrary, those teams whose members just seldomly addressed their duties will probably need to cover more aspects during the third hackathon. For this reason, the identification of the appropriate duration for this stage requires a clear understanding of the working conditions and efforts produced by each team. However, the PRO HACKIN' consortium suggest that the duration of the third hackathon should be coherent with the first one. This should be also communicated in advance to students, so that they can plan the remaining part of the work without the need to rush up to conclude the work and generate what is expected.

Their outcomes are then presented to the company for a last round of feedback before the final event. During this third design review meeting (same duration proposed for the other two phases) the design teams exposes their design solutions to the company, in order to show their strengths and peculiarities with reference to the original problem. The industrial partner's staff returns immediate comments to the teams so that they can finetune their concepts before the final event and correct potential conceptual or practical mistakes.

2.2.5. Final Event

The final event represents the closing moment of the whole course at the end of the semester. This event takes place in a single date and with a limited duration. This offers the consortium partners the chance to recall the general purpose of the project and of the whole course the participating students attended. This should enable the students to appreciate the opportunity they were given and that luckily they catch with enthusiasm. Relevant contents to deliver during the introduction to this event concerns the whole development process they have played an active role in as well as the learning outcomes they gained at the end of the course. The role of the company that, as industrial partner, supported students with the provision of a design challenge, experts' presentations and design review meetings.

Co-design teams are then asked to present their solutions to the general audience, thus including members of the team they are competing with for the design challenge. This helps students to appreciate the capability of the approach to generate, for the same general problem, a series of different solution concepts that, despite differently, address the same problem. At the end of each presentation the company might ask questions to the teams and appreciate or call into question their choices and/or answers.

At the end of the round of presentations, the evaluation committee for the design challenge, which is composed exclusively by company's staff members, assigns the company award to the team proposing the best solution in terms of innovative potential and quality of the design. This technical expert evaluation contributes to describe the quality of the work students did and therefore has to be considered, together with the factors mentioned in Section 1, to the assessment and grading of solutions.

2.3. Roles and responsibilities

The organization of the course require different subjects to cooperate synergically so to ensure the success of course, both in terms of knowledge acquisition and goodness of the generated solutions.

2.3.1. Industrial Partner

The industrial partner provides a theme for the product hackathon challenge. One for the whole project, with different targets by hackathon/process phase. Together with the academic staff (Professors and Coaches/Mentors), the industrial partner establish a topic of interests and shapes the design challenge in the form of a design brief. Experts from the industrial partner additionally give presentations on domain-specific knowledge to the students. They remain available for questions and review outcomes after each hackathon.

2.3.2. Students

Students are working in teams on the challenges during the hackathons. They require background knowledge in mechanical engineering disciplines, a basic understanding of the product development process and CAD/CAM. Particularly motivated students can be identified and recruited from the pool of well performing students from previous lectures and through dissemination activities at the university, such as postings at the notice boards, using the social media outlets of the student council, word of mouth advertising etc. From practical experience, we learned that students are particularly interested in the course if the industrial partner has a high reputation.

2.3.3. Coaches/Mentors

Coaches initially facilitate team-building activities and introduce students to the workflow and tools to be used during all activities. During hackathons, they recapitulate the goals and methods initially and provide help with timing activities. They remain available at all times to give methodological feedback as well as evaluation of technical feasibility of the proposed solutions. They also foster collaboration and steer the reflection at the end of the hackathon on results obtained by the team and its design process.

2.3.4. Professor(s)

They are required to provide general supervision on the team activities during the whole semester. Whenever the situation requires the additional injection of specific knowledge to address the design challenge, they also deliver thematic lectures to cover potential knowledge gaps the students need to fill.

2.3.5. Manager(s)

They organize the activity in terms of its management. In brief the inherent functions can be summarized into the following items:

- Establish the relationship with the industrial partner
- Negotiate a design challenge
- Define a calendar of activities to enable participations by all the involved profiles
- Set calls and meetings to facilitate the delivery of activities among all the involved profiles
- Facilitate on-site logistics during live events

3. How to implement a Product Hackathon in practice

The following section complements the description of the procedure to implement a PBL Hackathon-based course in a geographically distributed context with a series of brief advices the readers might consider as additional guidance.

These are intentionally presented in brief as this document aims at serving as a technical guide for its implementation in real operational contexts where active learning and student-centered learning takes the utmost importance, independently from the domain of application (e.g. mechanical engineering as well as other engineering branches, as well as other disciplines such as medicine, etc).

Section 4 provide a general overview of the suggested timing to activate/start each organizational step to carry out and a graphical summary of the following activities

3.1. Before the course starts

This short section provides in bold a set of necessary actions and activities that the organizers of a Product Hackathon needs to consider within the logic of a PBL Hackathon-based course on Innovative product development. These suggestions might be helpful also to support the organization of product hackathons in general, considering that part of the inherent activities are in principle similar across different domains and application areas compared to mechanical engineering.

Putting together a team of coaches

- Recruit coaches by prioritising their experience in systematic engineering design and as design coaches/supervisors/facilitators
- Provide coaches with one or more sessions of knowledge alignment
- Enable mentors to help with the organization of the hackathons.
- Make coaches familiar with the ILOs for the course

Recruiting an Industrial Partner / Experts

- Hypothesize students' interests and pick an industrial partner that covers the domain
- Contact the partner and propose them a collaboration on the educational activity
- Highlight mutual benefits (open innovation initiative and improved learning for students)
- Clarify

Defining challenges with industrial partner

- Why is the problem a problem
- Who should benefit from the solution
- What is the goal
- How should students achieve the goal

Organizing lectures and expert talks

- Reflect on the course topics and select the best candidates for catchy remote lectures
- Check the experts availability during the project execution and with reference to the expected moment in which the lecture/expert talk should take place

4. Step-by-step implementation strategy

The following overview provides a step-by-step guide on how to implement product hackathons in regular product development courses from scratch, beginning from the early phase of finding an industrial partner.