D3.3: Human-centred UX Design and Evaluation

A positivistic user interaction concept

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Abstract	The scope of this deliverable is to describe the user interface of the COROB solutions designed based on a positivistic interaction concept. The deliverable includes user group description, persona, and the user interface for the corob solution.
Keywords	User experience, usability, user interaction concept, design guidelines

CHANGE CONTROL

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Important remarks:

- The contributors listed in this table and on the front page are the report's primary editing authors. It is important to note that all COROB partners are contributing critical technical contributions to this ongoing work.

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EXECUTIVE SUMMARY

This document describes the user interaction philosophy for the COROB project called positivistic user interfaces. It presents guidelines and principles for the design of all user interaction related aspects of the COROB project. Results from user-centered methods to describe future COROB users, persona description, design, and continuous evaluation of a workflow-oriented, positivistic user interfaces (UI) and user interaction are documented.

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ABBREVIATIONS & GLOSSARY

3D	Three-dimensiona
AI	Artificial Intelligence
CAD	Computer-Aided Design
CTA	Call-To-Action
DPP	Digital Product Passport
FSTP	Financial Support to Third Parties
GMAW	Gas Metal Arc Welding
GUI	Graphical User Interface
HCD	Human Centered Design
HITL	Human In The Loop
HMLV	High Mix Low Volume
HMI	Human-Machine Interface
HRC	Human-Robot Collaboration
HRI	Human-Robot Interaction
LLM	Large Language Model
NDT	Non-Destructive Testing
QA	Quality Assessment
SOP	Standard Operating Procedure
SD	Standard Deviation
TA	Thematic Analysis
UCD	User-Centered Design
UI	User Interface
UX	User Experience
VR	Virtual Reality
WAAM	Wire Arc Additive Manufacturing

1 INTRODUCTION

A central goal of the COROB project is to ensure that the solutions provided will empower non-technical operators to extend the workforce in this sector. Human-Centred Design (HCD) – also known as User-centred Design (UCD) - is a philosophy and design methodology that originated in the 1960s and evolved throughout the 20th century [17],[21].

HCD and UCD are currently reemerging and regaining popularity in multiple sectors as their integration into management strategies has the potential to generate a competitive advantage in the long run. Applying UCD and HCD means focusing on future users of the technology and adapting the system features to suit their needs, improve their working conditions and increase their productivity.

In industrial manufacturing, we are witnessing a shift from the techno-centric paradigm of Industry 4.0 to the human-centric paradigm of Industry 5.0. The Industry 4.0 paradigm focused on digitalizing production and automating processes with a techno-centric approach, overlooking the role of human workers. To counteract this, the Industry 5.0 paradigm proposes a value-oriented vision that promotes digitalization at the service of worker wellbeing and environmental sustainability. This vision promotes an effective collaboration between humans and machines, where robots take over repetitive and potentially harmful operations, allowing workers to focus on more meaningful tasks that require higher-level cognitive skills [13][15].

Collaborative robots (cobots) are introduced in Small and Medium Enterprises (SMEs) that manufacture High Mix Low Volume (HMLV) batches with the purpose of empowering workers rather than replacing them with machines. Together the human and the robot form a Human In The Loop System (HITL), where they complement each other in a dynamic way [15].

HCD constitutes a promising approach to come up with tailored Human-Robot Collaboration (HRC) configurations and relative User Interfaces (UIs) that meet the requirements of specific use cases in manufacturing.

2 POSITIVISTIC USER INTERFACE FOR HUMAN-ROBOT COLLABORATION

In the present project, we introduce the novel idea of a Positivistic User Interface (UI). This idea involves designing an interface – the user-facing layer of COROB digital platform – in a data-informed way and with the goal of stimulating the proactivity of users, hence facilitating the adoption of new, complex, technologies such as the GMAW and WAAM multi-robotic cells.

The central idea of a positivistic UI is to make sure that users only interact with actionable information or tasks. The interface is designed to increase situational awareness by showing what can be done, contrary to current user interfaces that show what is broken, by providing numerous error messages.

Positivistic UIs can benefit from the integration of AI systems to support decision-making. Such AI systems can learn and filter out non-actionable data and thus align with the principle to only show remaining task or control options. Such AI systems also can incorporate recommendations on which of the remaining task options should be chosen, to support decision-making. A positivistic user interface thus removes the need for the user to interpret errors and error messages. Additionally positivistic user interfaces help the user to focus on available actions, thus minimizing stress and limiting task complexity.

The positivistic user interface shall empower users, supporting positive reinforcement in learning and solution-focused guidance.

This positivistic UI concept can be applied to all interactive aspects of the COROB platform and other applications developed within the COROB project:

- The workplace module UI of the COROB digital platform where operators are guided along the executive steps of GMAW and WAAM procedures, respectively.
- The Virtual Reality (VR) simulation where users can access a digital twin of the two cells and thus monitor and interact with the cells in real-time, from a remote location, accessing the simulation by wearing a VR headset or from web-app - developed under Financial Support to Third Parties (FSTP) solution COVRIT - accessible via a computer.
- The training and Quality Assessment (QA) application for non-expert users (WP 2) where operators can train and deploy pretrained supervised Machine Learning (ML) models for the assessment of welds quality by labelling data subsets captured by the sensors in the robotic cells (e.g. images, time series data).

All types of user interaction and user interfaces are designed to adhere to guidelines for the design of positivistic user interfaces. In the following paragraphs, such guidelines will be listed (Section 2.1) and exemplified by referring to common applications that implement them (Section 2.2).

2.1 DESIGN GUIDELINES FOR A POSITIVISTIC USER INTERFACE

Based on the extant academic knowledge on the design of HRC systems and the relative UIs [12][15][20] and on semi-automated welding [7], a positivistic UI that facilitates the collaboration of humans and robots, should be based on the following principles and application-specific design guidelines:

Table 1: Design principles and guidelines for Positivistic User Interface.

Principles	Application-specific design guidelines
Keep the human(s) in the loop	Keep process critical information on the equipment status and on the production parameters visible (via status indicators, key performance indicators, gauges, and graphs).
	Keep emergency buttons always visible.
	Request input from human operator in a timely and context-aware manner (via actionable notifications, alerts/alarms, and confirmation prompts/modal dialogs for actionable tasks) to allow rapid adjustment of time sensitive tasks.
Facilitate learning and acquisition of higher-level skills relative to technology use	Provide guidance for the completion of the semi-automated welding procedures (via wizards, checklists, process flow-diagrams, progress bars and breadcrumbs).
	Keep Standard Operating Procedures (SOPs) and other relevant documentation (e.g. tutorials, reports) consultable, ideally positioned for situated action in the user interface.
	Implement learning support (possibly via AI-based tools) to guide users during task execution (in production mode). n.
	Enable users to learn about welding either by presenting real time data and views or by enabling revisiting of data like welding parameters or trajectories (e.g., in a digital product passport)
Support (non-expert) user(s) proactive troubleshooting of robotic technology	Provide actionable and resolutive feedback in the case of detected errors/malfunctions in the robots (e.g. with pop-up messages or wizards depending on the severity of the error and via multiple modalities)
	Provide explanation of root cause of errors/malfunctions and combine this with positivistic design for actionable recovery from these malfunctions (see Fig. 13).
	Suggest reporting of errors/malfunctions to supervisory/maintenance figures in the organization (especially when severe) (see Fig.14), when a positivistic solution is not possible.
Minimize task complexity and reduce cognitive load	Minimize number of steps needed to complete process. Enable re-use of preset assemblies and pre-used set-ups (see Fig.9).
	Reduce cognitive load by following best practices in user interaction design (driving user attention with colours, easy identifiable symbols, respecting gestalt principles)
	Allow for personalization if user profiles are implemented.
Provide on demand guidance	Provide contextual help on-demand (tooltips, overlays, chatbots).
	For learning different guides or AI-based mechanisms could be investigated (depending on the proposed solutions by beneficiaries).

2.2 EXAMPLES OF POSITIVISTIC USER INTERFACES ELEMENTS

Some examples of how such principles have been implemented in common applications:

- On top of simply flagging a spelling or grammatical error, tools like Grammarly, Google Docs, or even smartphone keyboards suggest correct alternatives. They guide the user toward the right spelling or phrasing without emphasizing the mistake.

- In installation wizards in software setup (e.g., Microsoft Office or Adobe Creative Cloud installers), the user is guided towards how to complete the installation and customize it, instead of halted. If a step cannot be completed (e.g., a dependency is missing), the wizard displays actionable next steps to resolve the issue (e.g., a download link for the missing component).

- Web forms typically have a validation for values or indications if entered values are out of range or not compatible with the input field.

- The commands Undo and Redo should be supported in an UI; examples are standard Microsoft Office products like Word where you can go back or forward in a series of interaction events the system recorded.

3 UNDERSTANDING USERS

3.1 SPECIFYING THE USERS OF THE COROB PLATFORM

The COROB platform will be deployed in the production floor of custom manufacturers where human workers operate and control the collaborative robots. The intervention and supervision of operators both for GMAW and WAAM robotic cells can be conceived as a socio-technical system whose performance is influenced by the behaviour of operators, by the nature of the task at hand and by the environment in which it is executed.

Bagdasarov et al. [4] listed the factors that should be investigated for effective HRC, divided in three subgroups:

1. Personal characteristics of the employee (e.g. age, gender, background, adeptness and familiarity with advanced technology, attitude, technology acceptance).

2. Organizational factors of the workplace (e.g. leadership style, organizational culture).

3. Type of robot (e.g. hardware and software features of the model, level of autonomy).

To understand the needs of future users of the COROB solution, to describe user groups and how one can design for empowerment of these user groups, the following methods were used:

1. A survey to investigate attitude, preferences and technology acceptance of individuals employed in the automation sector toward semi-automated arc-welding.

2. Focus groups with workshop characters to understand and summarize different perspectives on the future user within participants within the COROB consortium and external to the consortium.

The main goal of the focus groups was to discuss how the introduction of such technology will affect the work routine of production staff and which skills the COROB operator should have to use the technology effectively.

In fact, recent academic reviews [22] suggest that the use of industrial robots as a collaborative, human-centered technology is still limited and emerging. Robots are typically developed by engineers with a techno-centric approach with the goal of achieving full automation. The perspective of the end-users is often overlooked, and it's not clear who will be responsible for the set-up, operation, and maintenance of the technology [22].

3.2 SURVEY ON FUTURE RECEPTION OF COROB SOLUTION

Due to time and geographical constraints, a web-based survey was designed that employees recruited via the COROB consortium partners could easily fill-up – with an average completion time of ca. 14.67 minutes.

The survey included the following sections:

- Basic demographics (age, gender, mastered languages).

- Questions on professional experience and on affinity for technology (measured via Affinity for Technology Interaction items (ATI, 2019) [11]).

- A description of the use scenario of the COROB GMAW multi-robotic cell that invited the respondent to put themselves in the shoes of a production operator who has to use this new technology to complete the welding process following a preset workflow and via the HMI.

- 35 closed items related to the use of the COROB GMAW multi-robotic cells. Participants are asked to rate to which extent they agree to each statement on a 5-point Likert scale (from ''Strongly disagree'' to ''Strongly agree'') [2]. V.4 open questions investigating:

  - Preferences on the human-robot interaction modality described in the scenario.

  - Preferences on the task allocation between the human operator and the robots.

  - Suggestions on the nature of the process-related parameters to be displayed on the UI.

The 35 closed items were taken from foundational models in information system theory and Human-Robot Interaction (HRI):

- 10 items from the Technology Acceptance Model (TAM) Reloaded by Bröhl and colleagues (2016) [6]. From the original questionnaire, only the variables (i.e. items) addressing the interaction with robots and presenting significant correlation coefficient with the variables Behavioural intention to use the technology and Use behaviour have been selected. Amongst all the dimensions, here we report only the most critical ones in relation to the adoption of the COROB GMAW solution by the workforce.

  - *Job Relevance*: how applicable the technology is to a user's professional tasks and/or responsibilities.

  - *Legal Implication (Occupational Safety)*: how safe close interaction with technology is.

  - *Perceived Safety*: general users' feeling of security when using technology.

  - *Self-efficacy*: the user's confidence in their ability to effectively use the technology after receiving training.

  - *Perceived Usefulness*: how much users believe the technology improves their performance or productivity at work.

  - *Behavioural Intention*: the likelihood that users will adopt or continue using the technology at work.

  - *Use Behaviour:* user preference for the robot over other machines at work.

  - *Output Quality*: user expectation on quality of results produced by the technology.

  - *Perceived Ease of Use*: how simple and easy the technology is to operate for the user.

  - *Result Demonstrability:* how tangible, measurable, evident and provable the output produced by the use of technology is.

- 19 expert-validated items from the HUROX questionnaire by Apraiz and colleagues (2023), I selected dimensions that were not addressed by TAM Reloaded, still they influence how users experience interaction with robots [3]:
  - *Learnability*: it measures the degree users can successfully perform a task via a newly encountered UI and the likelihood that they can become proficient at that task with repeated use (with 3 items)
  - *Controllability*: it refers to the extent to which a user feels in control of a technology and its actions, and the ability to customize its behaviour according to their needs or preferences (with 6 items).
  - *Trust:* it indicates the belief of a person that a technology will function as intended and will not harm them or others (with 1 item).
  - *Satisfaction*: it assesses how much a user is pleased with the use of a technology, as the result of its utility, ease of use and trust (with 8 items).

The survey was initially designed in English and then translated to Castilian Spanish and to Greek to facilitate its distribution, with support from Microsoft Copilot.

3.2.1 Survey findings

The small base of respondents (N=12) limits the generalizability of findings to the general population. Nonetheless, the survey allows us to collect preliminary insights into the future reception of the COROB GMAW solution, based on descriptive statistics. Only completed survey's respondents where the participant consent form was accepted were considered.

- Demographics: the median age of the sample (N = 12) was 30 years-old with ages ranging from 21 to 41 years. All participants were male and each of them mastered two or more Indo-European languages. Role and years of expertise: among the respondents, mechanical engineering was the most represented role (4 respondents) followed by specialists in robotic welding (3 respondents). Roles in innovation and machinery operations each appeared twice, with one respondent specifically working in advanced manufacturing research.

- ATI scores[1] [11]: the ATI average sample score is 4.47 with a Standard Deviation (SD) of 0.67 denoting a high affinity for technology and moderate variation in individual scores. A Cronbach Alpha of 0.71. indicates acceptable internal consistency across items.

- TAM Reloaded scores[2] [6]: we report a synthesis of the responses to critical dimensions included in the survey and what they indicate.

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[1] The standard format of the Affinity for Technology Interaction (ATI) scale uses a 6-point Likert scale without a neutral midpoint to encourage directional responses. However, to ensure consistency across the entire survey, a 5-point Likert scale (ranging from Strongly Disagree to Strongly Agree) was used instead. While this adaptation introduces a neutral midpoint and slightly reduces response granularity, conceptual alignment of scale anchors was preserved. Reverse scoring was applied to negatively worded items. For analytical comparability with the original 6-point scale, a rescaling method was applied to interpolate 5-point responses to their 6-point equivalents (linear transformation) [6][11].

[2] The original items in the Technology Acceptance Model (TAM) are typically assessed using a 7-point Likert scale, offering great granularity in capturing respondents' attitudes. However, to ensure consistency across the entire survey, a 5-point Likert scale (ranging from Strongly Disagree to Strongly Agree) was used instead While this adaptation reduces the number of scale points, it retains the essential interpretive range and directional meaning of responses. Care was taken to ensure that the semantic anchors aligned closely with the original intent. For

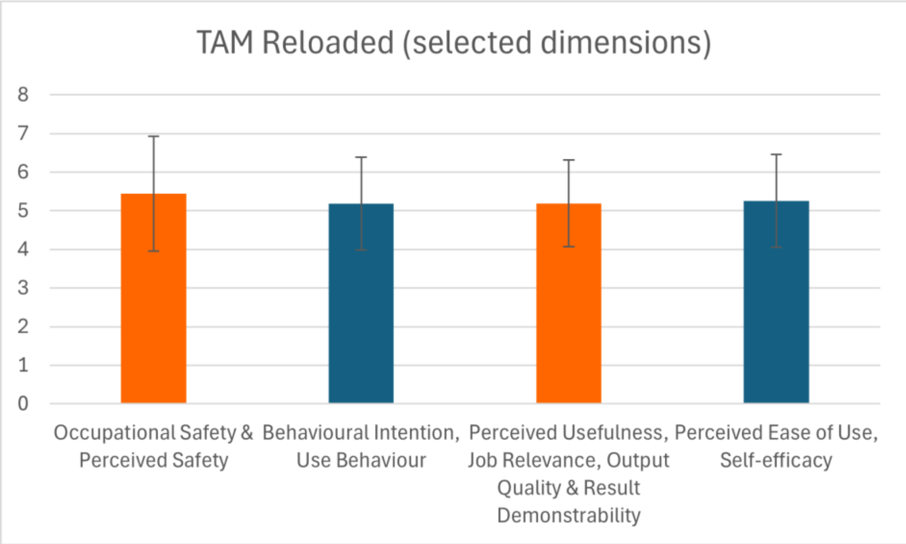


Figure 1: TAM Reloaded (selected dimensions)

The dimensions of the TAM Reloaded have been incorporated based on conceptual alignment (i.e. overlap of measured construct).

- Occupational Safety & Perceived Safety (Composite Mean: 5.44; Composite SD: 1.49): indicate that respondents generally agree they feel safe at work, but with noticeable variation in perceptions.
- Behavioural Intention, Use Behaviour (Composite Mean: 5.19; Composite SD: 1.20): indicate that respondents are likely to engage with COROB GMAW robotic work cell with moderate consistency.
- Perceived Usefulness, Job Relevance, Output Quality & Result Demonstrability (Composite Mean: 5.19; Composite SD: 1.12): indicate that respondents see the COROB GMAW robotic work cell as useful and relevant to their work tasks and routines and are confident in its ability to weld.
- Perceived Ease of Use, Self-efficacy (Composite Mean: 5.28; Composite SD: 1.20): indicate that respondents generally believe that they will easily learn how to operate the COROB GMAW robotic work cell intuitive, and feel reasonably confident in their ability to operate it effectively, with some variability in individual comfort levels and perceived competence, highlighting potential areas for targeted training or support.

HUROX questionnaire dimensions' scores [3].

analytical comparability with the original 7-point scale, a rescaling method was applied to interpolate 5point responses to their 7-point equivalents (linear transformation) [2][6].

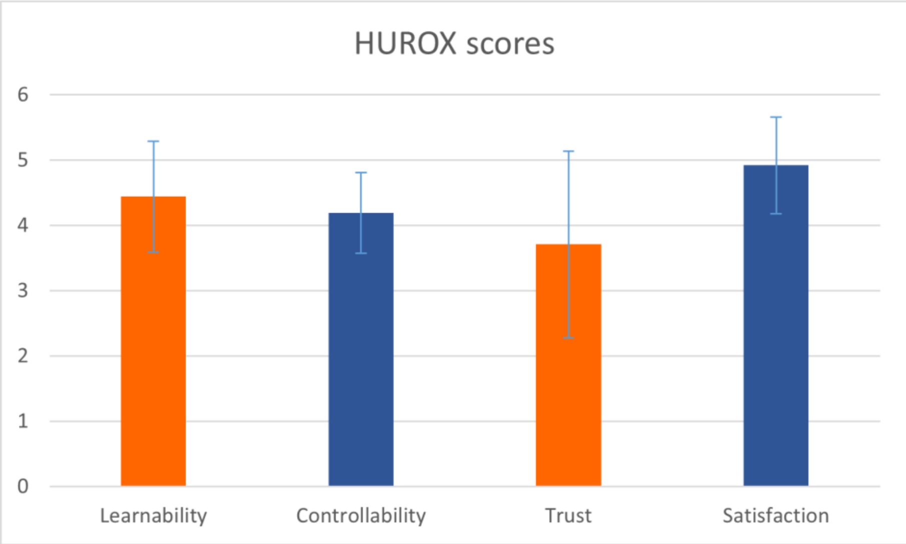


Figure 2: HUROX scores

- Learnability (Mean: 4,44; SD: 0,85) suggests that, on average, respondents believe that they would not very easily learn how to operate the robotic system via the UI with proficiency, with low variability in responses.
- Controllability (Mean: 4,19; SD: 0,62) suggests that, on average, respondents believe that they would not easily feel in control of the robotic system performance, with very low variability in responses.
- Trust: (Mean: 3,71; SD: 1,43) suggests that, on average, respondents believe that they would not trust the robotic system to do the right thing at the right time, with more than moderate variability in responses.
- Satisfaction: (Mean: 4,92; SD: 0,74) suggests that, on average, respondents believe that they will be quite pleased with the use of the of the technology.

Overall, results from the survey are slightly contrasting. On the one hand, the TAM factors of suggest that respondents intend to adopt the GMAW robotic system, on the other hand, the technology appears complex and not easy to learn and master. These results suggest that users are willing to adopt the technology, but it's introduction should be accompanied by appropriate training of the workforce to ensure its optimal use. The human-centered design of the interface to control the two multi-robotic systems would also facilitate its operation by novice users. In the future, the survey should be distributed to a larger pool of respondents to ensure the generalizability of results to the population and calculate inferential statistics to examine the significance of findings.

3.2.2 Defining the future COROB operator

3.2.2.1 Focus group planning

Focus groups constitute a qualitative research methodology commonly adopted to stimulate collective brainstorming and discussion in a selected group of participants (ca. 5 per session), with one or more facilitators.

The insights gathered during the focus groups contribute to answer the main question of how the deployment of the COROB solution will affect the workforce in custom manufacturing production floors. In particular, the following sub-questions were posed:

- Which skills do operators need to use the COROB GMAW and WAAM system effectively? Does the use of the two systems require high-level skills? Which ones?

- Which challenges would operators face when using the COROB GMAW and WAAM systems?

- Which strategies would operators adopt to overcome solve issues?

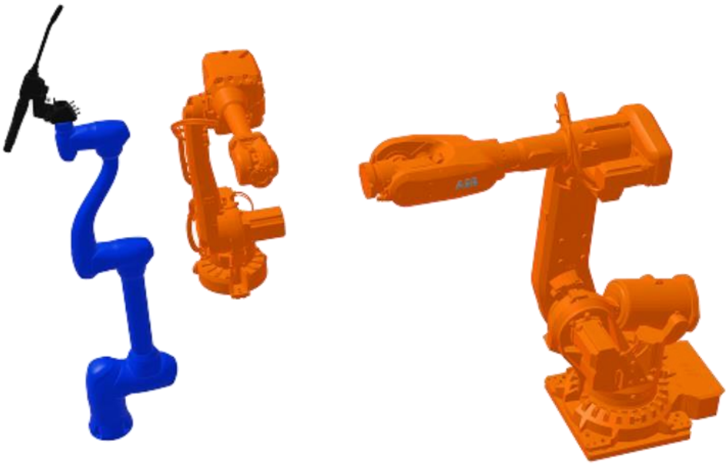
The sessions took place online (via Microsoft teams) due to logistic reasons and were automatically video-recorded and transcribed, with prior consent of the participants. The focus group with COROB partners was shortened to 30 minutes due to time constraints, whilst the one with external experts lasted ca. 60 minutes.

Both focus groups followed a predefined, semi-structured guideline.

After a brief round of introductions and icebreaking session (5 min), the participants were asked to join a digital whiteboard (a link was shared) to start the focus group activities.

First a high-level overview of the solution current under development in the COROB project was provided, focusing in particular on the user interaction flow for the GMAW use case (see Fig.3) and for the WAAM one (see Fig.4), that delineated how tasks are allocated between the robots and the human operator in broad strokes (10 min).

Jigless Gas Metal Arc Welding



A group of 3 coordinated robots in a cell, takes over the jigless Gas Metal Arc Welding (GMAW) of metal workpieces to be joined.

Following a preset assembly (uploaded CAD file), the multi-robotic cell performs the following actions:

- The two robots pick up and align the workpieces.
- The cobot joins the workpieces in a weld bead by manipulating the welding torch along the seam following toolpath.
- The robots automatically stop if an anomaly is detected by sensors.
- One robot inspects the quality of the weld bead via ad-hoc sensors.

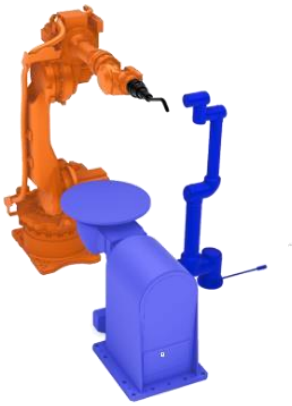
As a shop-floor operator who has to operate the multi-robotic cell, these will be your main duties:

- Bring the bin with workpieces to weld inside the cell.
- Go out of the cell, lock it and set-up the technology via an Human-Machine Interface (HMI) panel (a graphical user interface)
- Via the HMI, check the list of received welding jobs, check the pre-view of how the robots will follow the pre-set trajectory and execute a pre-configured GMAW assembly as robots are available.
  > If the workpieces are not standard, create a new custom assembly via the trajectory manager with ad-hoc toolpath.
- Monitor that nothing goes wrong via live camera feed displayed on the HMI.
  > In case of problems during the pick-up of workpieces, intervene and position them manually.
  > In case of detected anomalies/faults and automatic stop during welding, try to fix issues according to displayed suggestions and continue current task (real-time adjustment) or discard it and start anew.
- Inspect the quality of the weld bead by checking specific indicators captured by the robots' sensors.
  > In case of issues, you can report to expert for review and reweld the workpieces.

After these steps have been completed, the following assembly on the list can be initiated.

Figure 3: GMAW user interaction flow – high-level overview

Wire Arc Additive Manufacturing



A group of 2 coordinated robots in a cell, takes over the Wire Arc Additive Manufacturing (WAAM) of metal components to be repaired.

The metal component undergoes manual 3D scanning and then is placed on the rotary table in the cell by a shop-floor operator.

Following a preset assembly (uploaded CAD file, positioning instructions, requirements), the multi-robotic cell performs the following actions:

- Pointcloud is generated.
- A preheating system warms up the metal component to ensure effective welding.
- The robot manipulates the welding torch, depositing layers on the substrate for a 3D repairment.
- Robotic sensors monitor the progress of the process.

As a shop-floor operator who has to operate the multi-robotic cell, these will be your main duties:

- Via the HMI, upload the 3 CAD positioning instructions and requirement files to create and confirm task.
- Ensure correctly positioning of the workpiece on the rotary table, according to instructions.
  > if needed enter the cell for manual positioning.
- Proceed with workpiece scan.
- Define repair toolpath via external software (screencasting to HMI and command it to robots.
- Check and confirm that safety requirements are met.
- Start WAAM process and monitor progress.
  > If needed, customise the monitoring parameters.
  > In case of detected anomalies/faults and automatic stop during welding, try to fix issues according to displayed suggestions and continue current task (real-time adjustment)
  or restart anew.
- Inspect the quality and confirm whether it is acceptable (comparison with theoretical CAD).

After these steps have been completed, the following repair can be initiated.

Figure 4: WAAM user interaction flow – high-level overview

Then, after ensuring that the overview was clear, participants were invited to read the fictional description of four potential operators of the GMAW or WAAM cell, with specific backgrounds (see Fig.5 for an example) (5 min).

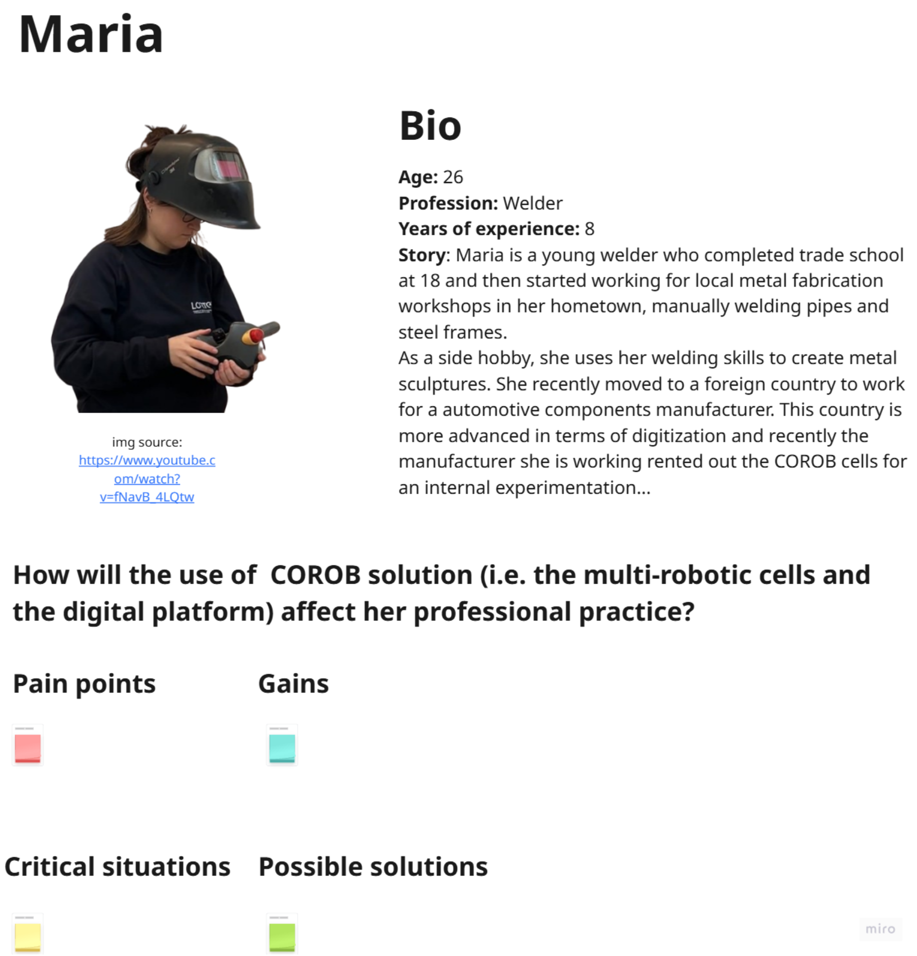


Figure 5: User persona – Fictional description of future COROB operator

Participants were asked to carefully read the bio of the user persona to understand what their background was and then to imagine which pain points (i.e. difficulties) they would face when using the robots for welding, the gains they would experience (i.e. how the use of the technology would benefit them), which critical situations (i.e. challenging events) could arise from its use and which possible solutions they would adopt to overcome them. Participants were invited to share their thoughts out loud and discuss together, writing their notes on the post it at the same time. The facilitator sought to encourage equal participation and create a safe space to promote respectful dialogue, eventually clarifying key points and reformulating individual insights to ensure shared understanding.

3.2.2.2 Focus group preliminary findings

The video-recordings and automatic transcripts of the two focus group sessions were reviewed and compared to correct mistakes. Then the verbatim transcript was manually coded to identify recurring themes and patterns via Thematic Analysis (TA) [5] (see Table 2).

Table 2: Themes identified in focus groups on COROB operator specification

Themes	Description	Representative quotes
Complementary knowledge & Upskilling	The future COROB operator should possess a combination of advanced technical and welding skills to be able to appropriately set up the robotic systems and inspect the quality of the final weld.	*…He (John) might be a robotic engineer, but he still doesn't know anything about welding...so no prior welding knowledge…means he cannot decide what is a good weld...therefore he cannot classify the model well, in my opinion…* *...The setup procedure and getting through all the setups is the most challenging part for any welding process...* *...The deficiency that I see is that she doesn't have experience in robotics and welding...*
Increasing Human-Robot Collaboration	In future custom manufacturing (with HMLV production), robots and humans should work as colleagues. As the technology matures, there might be less need for manual labour.	*...We have skilled human workers who have these robots as their staff...* *…The aging workforce also has less ability to do heavy labour…* *...More technological basic and reading experience is better for the COROB technology than even having a well-trained eye (for welding) ....* *...There we have machine learning coming, which will get better than humans at some point, which is for sure*
AI assistants & Knowledge transfer from expert to juniors for collaborative problem solving:	AI should be integrated at software level to provide guidance to operators via the UI. It should be trained on SOP documentation and on recommendations from expert operators. Expert operators should transmit to novice ones best welding practices.	*…It's very important that it has to have a lot of information for the end user and not only about the process, but also the machine manuals, error codes, maybe a chatbot that you can even say "hey, the machines give error code ABC, what should I do?"…*

Overall, when reviewing the proposed user profiles, participants from both focus group sessions agreed that the presence of experienced welders (like Jody, see Figure 7) is still relevant at the moment, but they would need some programming skills and familiarity with robotic technology to operate the COROB cells. Participants also hypothesized that in the future, as welding robots mature due to advancements in ML and AI, the need for deep knowledge of welding process and for the ability to assess the quality of weld beads with human senses might decrease. Human knowledge is particularly critical in the initial set-up of the robotic system and in the quality assessment step: once the robots learn how to perform a custom welding configuration, they are able to repeat it serially.

A lesson learnt is that in the future 1:1 sessions with industry experts within and external to the COROB consortium might generate deeper and more exhaustive insights compared to focus groups with multiple participants.

3.2.2.3 Persona for COROB solution

Within the numerous activities within the COROB project, analysis of material and based on the questionnaire we identified some key persona to describe future users of the COROB solution.

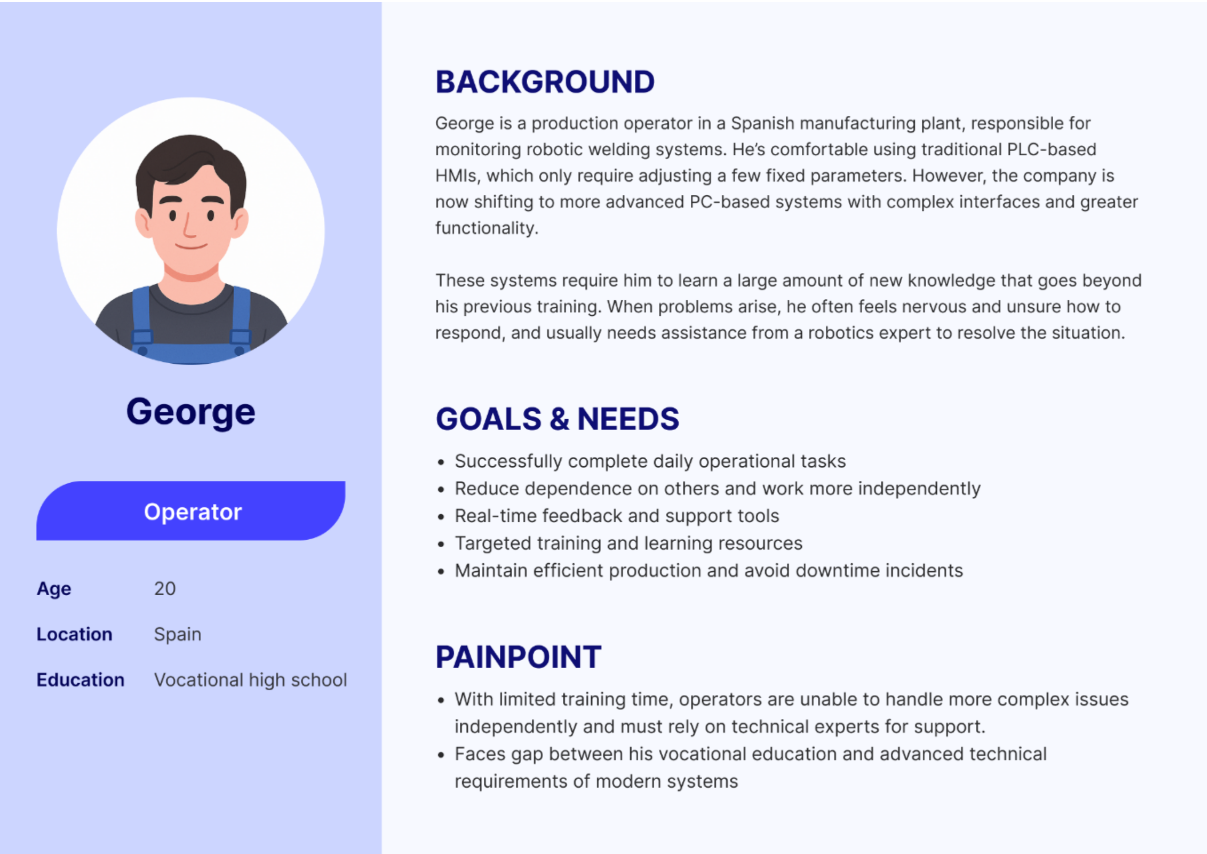


Figure 6: Final COROB persona of operator that requires up-skilling and training for the COROB solution

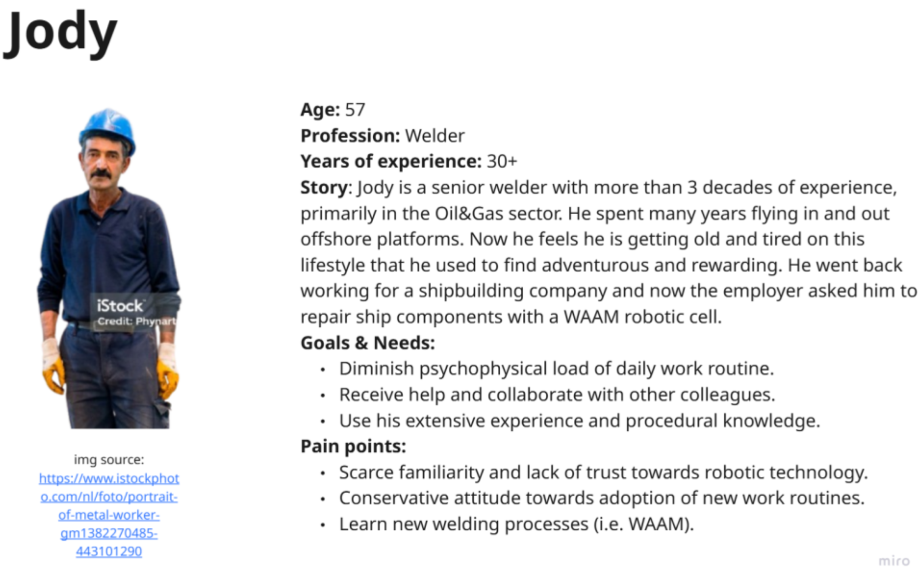


Figure 7: Final COROB persona of operator that requires up-skilling and training for the COROB solution

3.2.2.4 Supporting learning

To support learning and training of operators in COROB, starting M6 as an activity within WP 1 and 2, a series of studies was conducted. In study 1 (M6 – M12) we not only sketched a first draft of the user but interface but also investigated how gamification can be used to enhance learning of the tasks. Figure 8 shows the two variants we developed comparing a standard welding user interface with positivistic task guidance and specification of welding parameters, vs the gamified version.

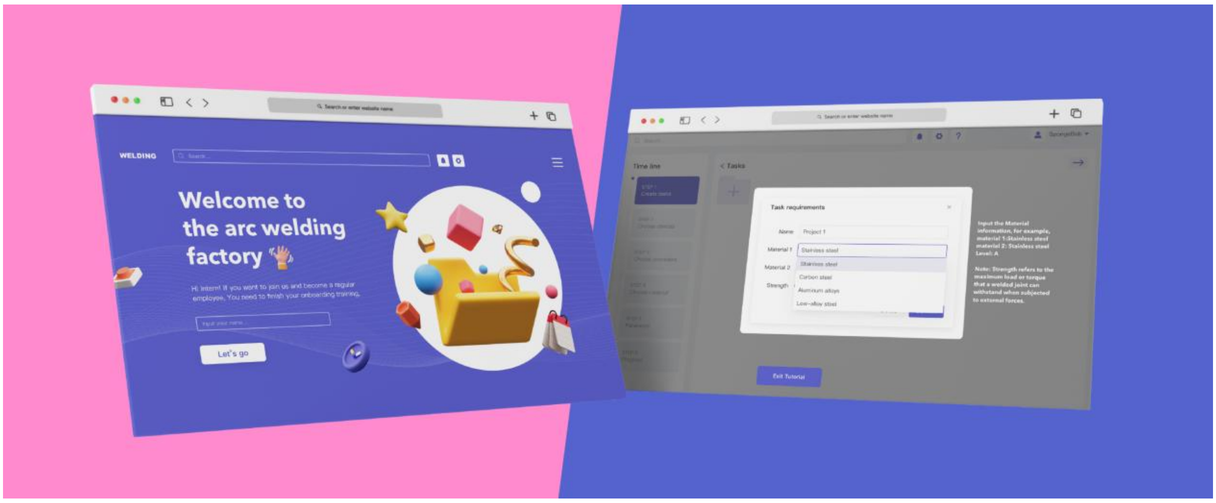


Figure 8: Standard welding UI vs Gamified UI

To understand the effect on gamified tutorials that incorporated a challenge-based gamification approach, we conducted a user study, asking people with no welding background to learn about welding and welding parameters. N=20 participants conducted 5 tasks (create a welding task, choose device(s), choose a welding procedure, choose material, and set parameters) in a between-group usability study set-up. We assessed task completion time, task completion success rates, standardized User Experience Questionnaire (UEQ) and a final interview. Approval was achieved by the Ethical Review Board of the Eindhoven University of Technology, Department of Industrial Design.

The results of the gamification study show that gamification did not have any significant effect on learning and ease of learning, nor did it improve the user experience. Looking into the qualitative results from interviews we learned that most of the participants felt that gamification in terms of point achievements is not an appropriate format for work-related activities. Participants mentioned gamification is contradictory to the perceived seriousness of welding work.

Results and findings of the study on gamification for learning have been presented during the general assembly in M12. Based on the gathered feedback, a series of possible alternative approaches to support learning were investigated.

To support (novice) users of the COROB solution we want to empower them to learn, supporting their individual intrinsic motivation [24], defining it as an enhancement of meaning, competence, self-determination, and impact. This empowerment is supported by knowledge empowerment and psychological empowerment. For the knowledge empowerment the focus is on using chatbots that operate with artificial intelligence support on a (local and task specific) set of manuals, instructions, and knowledge. We assume that knowledge is not passively received but is actively constructed. We thus want to design to support users' individual active operation, exploration and understanding of specific tasks.

In terms of psychological empowerment, we know users often experience anxiety, frustration and self-doubt when faced with systems errors and failures. Thus, the positivistic user interface addressed error handling by positive reinforcement and enabling solution-oriented feedback instead of error messages.

We designed for three representative design principles an iteration of the COROB User Interface, added interface elements that support:

Table 3: Design principles

Principle	Explanation
Principle 1: On demand guidance	Users can actively request assistance as needed during system exploration by using a chat-bot and contextual help for learning.
Principle 2: Solution-oriented error handling	When facing system anomalies or user operation errors, the interface provides clear and actionable advice on possible next steps, instead of error messages.
Principle 3: Corrective reinforcement	When users overcome operation errors, the system provided additional timely and positive feedback to enhance operational confidence.

Based on an extended version of the COROB UI (Version 2.2), we conducted a user study with n=6 to investigate the learning aspects. Participants were master students, performing 3 learning tasks and answering a standard usability scale (SUS). Results show that the usability of the learning extensions leaves room for improvement with a SUS score of 61,5 average. A key aspect is the support for learning with a natural language interaction for example an AI-supported chatbot.

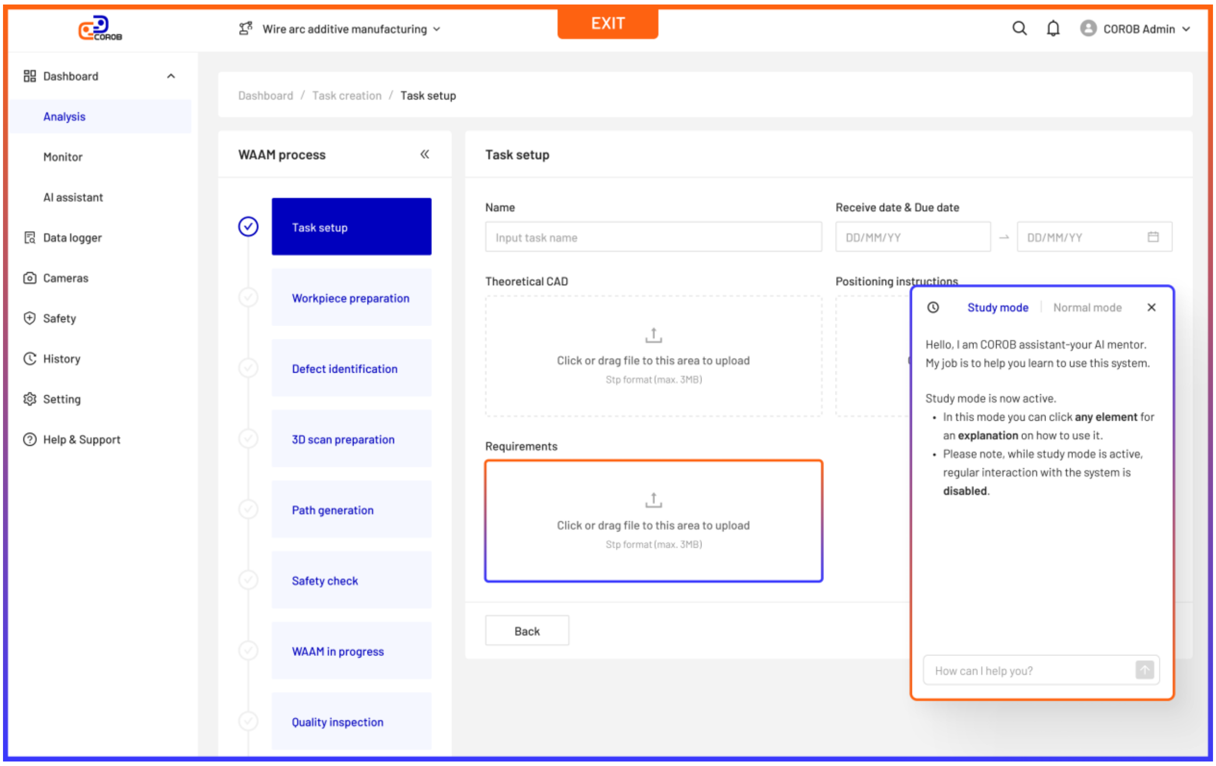


Figure 9: Study mode in the Chatbot

To support novice users with learning the UI proposes to support learning with contextual information and help indications in the task flow, to enable (AI-based) support for decision making and error recovery and to envisage natural language interaction (chat-bots).

These recommendations on how to support learning were used to ensure that the application for non-expert users that can train ML models for Quality Assurance is designed to support learning, as well as other developments of beneficiaries (e.g. VR application).

4 DESIGN OF COROB PLATFORM POSITIVISTIC USER INTERFACE

To the best of our knowledge, HMIs for the control collaborative robots in custom manufacturing are not typically designed with a user-centred approach. Most industrial HMIs are proprietary, and their design and development is vendor-specific, not standardized, negatively affecting the consistency of the User Experience (UX) [20].

The COROB digital platform UI mock-up has been developed (M12 – M24) with a user-centred and iterative approach. The design of the COROB platform included as a first step a depiction of the workflow for the different welding cases, the design of a framework and the development of a positivistic user interface experience.

4.1 WORKFLOW

Before designing the COROB UI mock-up the task and user interaction flow for the COROB platform was delineated. Figure 10 shows the interaction for the use case of GMAW and Figure 11 shows the use case of WAAM.

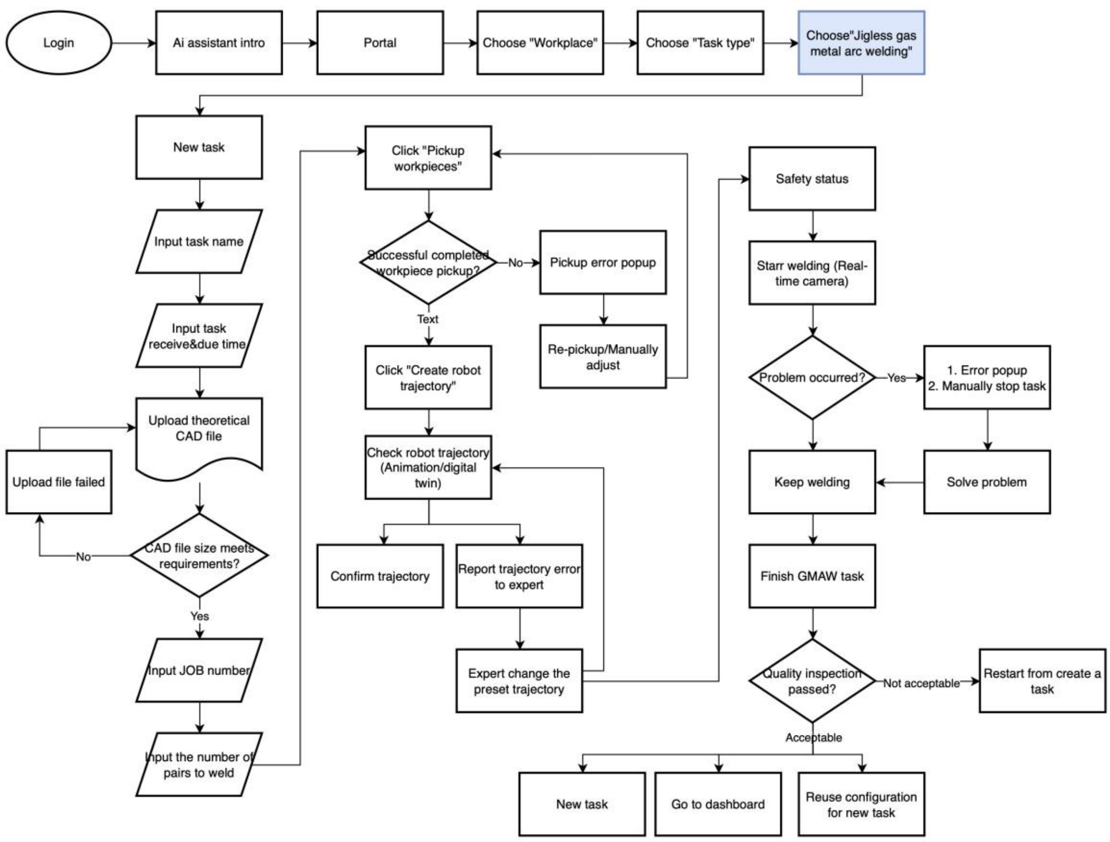


Figure 10: User interaction flow for jigless GMAW

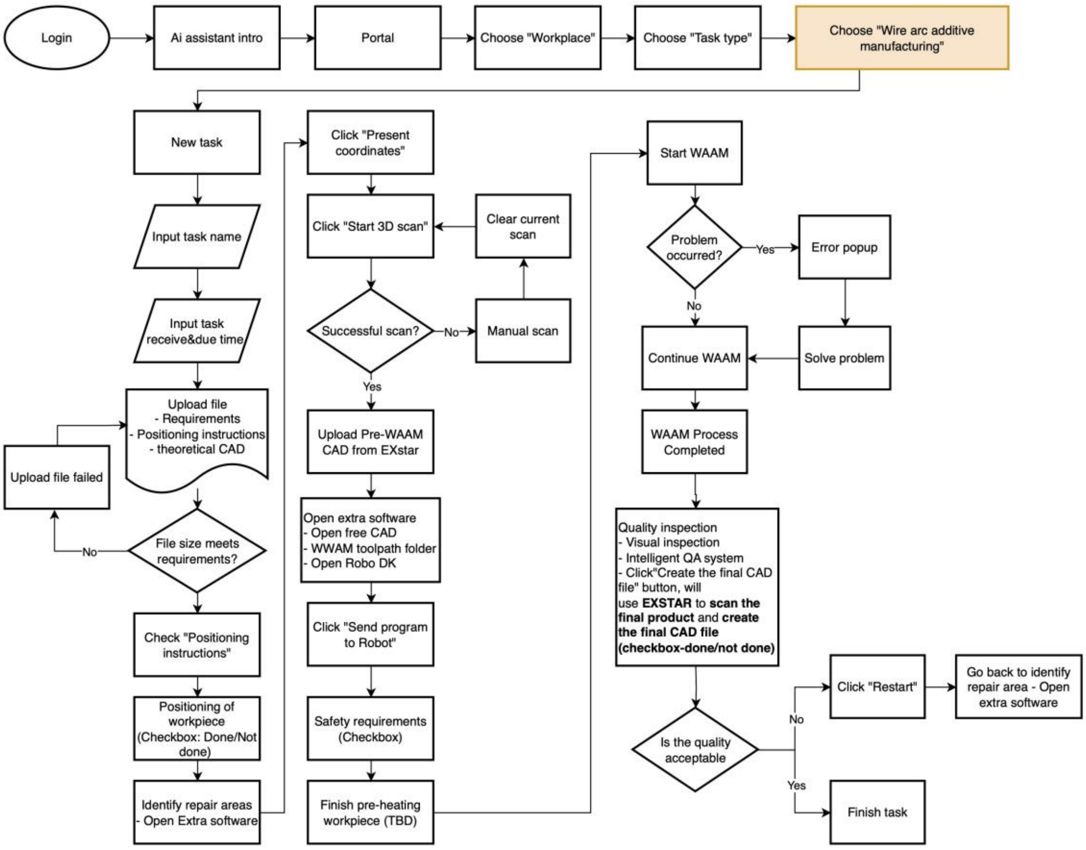


Figure 11: User Interaction flow for WAAM

4.2 DESIGN, UI DEVELOPMENT AND EVALUATION

A first draft of the user interface was already established in M6 to understand basic functions and parameter and enable early studies on how to support novice users in terms of learning. The user interface was iterated from V.0 to a first draft version V1.0 that was revisited and iterated to enhance workflow description and then inspection of the user interfaces. The iterations were based on periodically evaluating the designs in heuristic evaluation sessions with partners from the COROB consortium. The sessions evaluated the quality of the mock-up UI screen with reference to the heuristic guidelines proposed by Frijns and Schmidbauer [12].

Key improvements and discussions were mainly based on workshop activities during the general assembly (GA, 1st year) and alignment with user persona and intended future users was performed during the general assembly in M18.

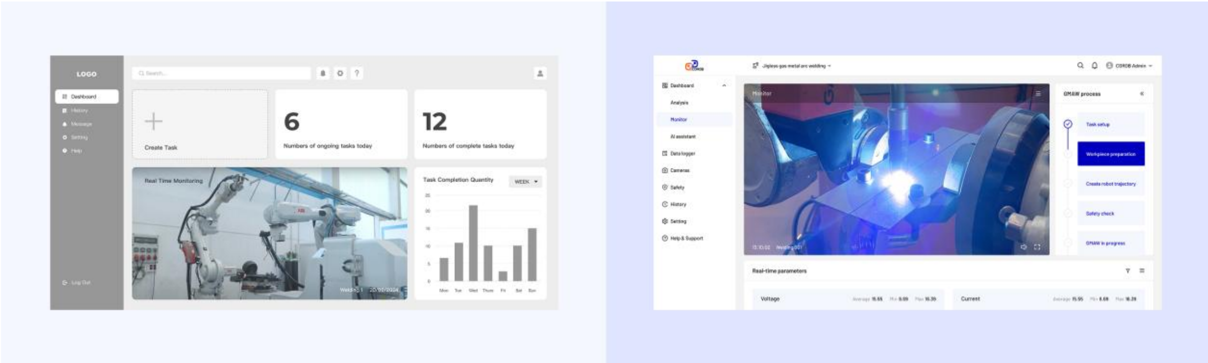


Figure 12: First version vs V2.2

A selection of the most representative UI screens from V2.0, in particular the ones that show an implementation of the above-listed principles and guidelines for the design of a positivistic UI for HRC are presented in the following sections.

5 COROB'S POSITIVISTIC USER INTERFACE

5.1 UI GRID

The COROB User Interface Design was optimized for a screen size of 1440x900 px, Gutter: 16 px, Margin, 24 px. As shown in figure 13, the layout includes a fixed left sidebar and a grid-based right content area, structured as follows:

- A: Full width for breadcrumbs or global operations.
- B, C: Two equal sections with a 1:1 ratio, suitable for parallel content presentation.
- D, E, F, G: Four equal (1:1:1:1) sections for multiple modules or functional panels.
- H, I: Two sections with a 1:3 ratio, highlighting the main content while reserving space for supporting information.

In practical applications, the proportions of each column can be adaptively adjusted according to different resolutions and screen sizes to ensure consistency and scalability.

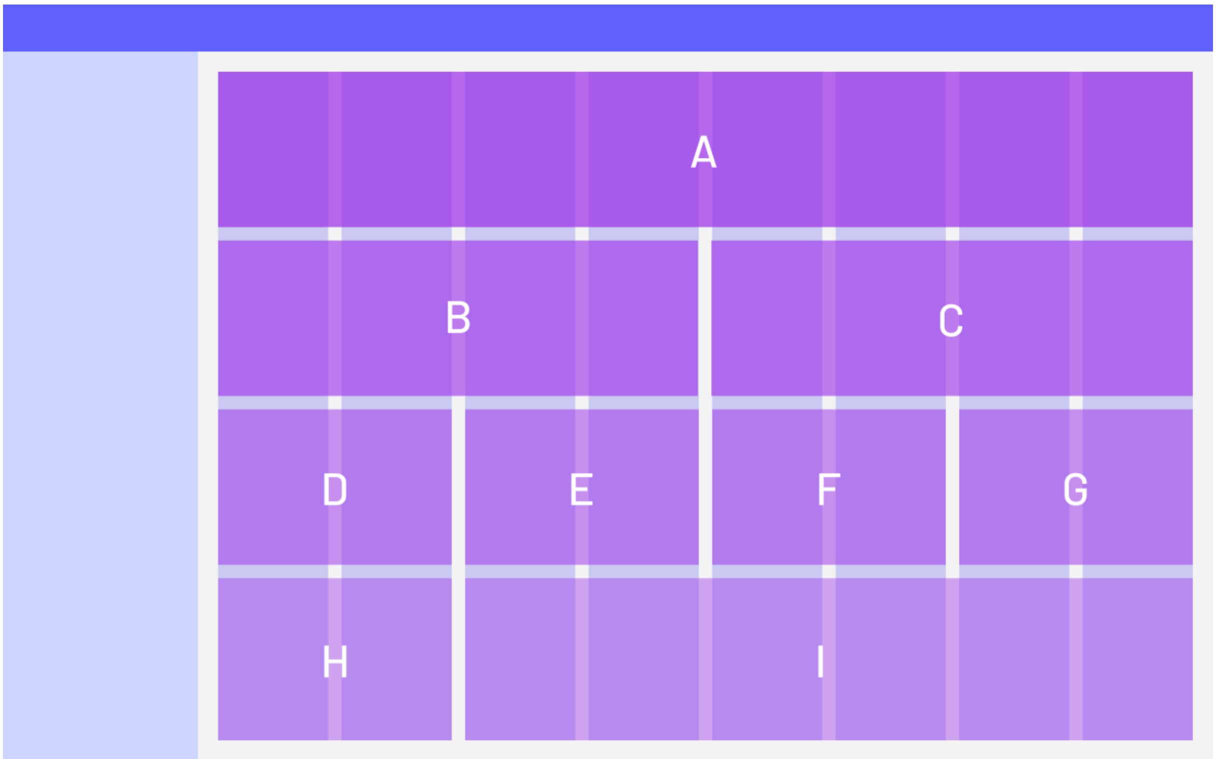


Figure 13: Alignment for UI with Workflow Indication to the left and spacing for elements to the right

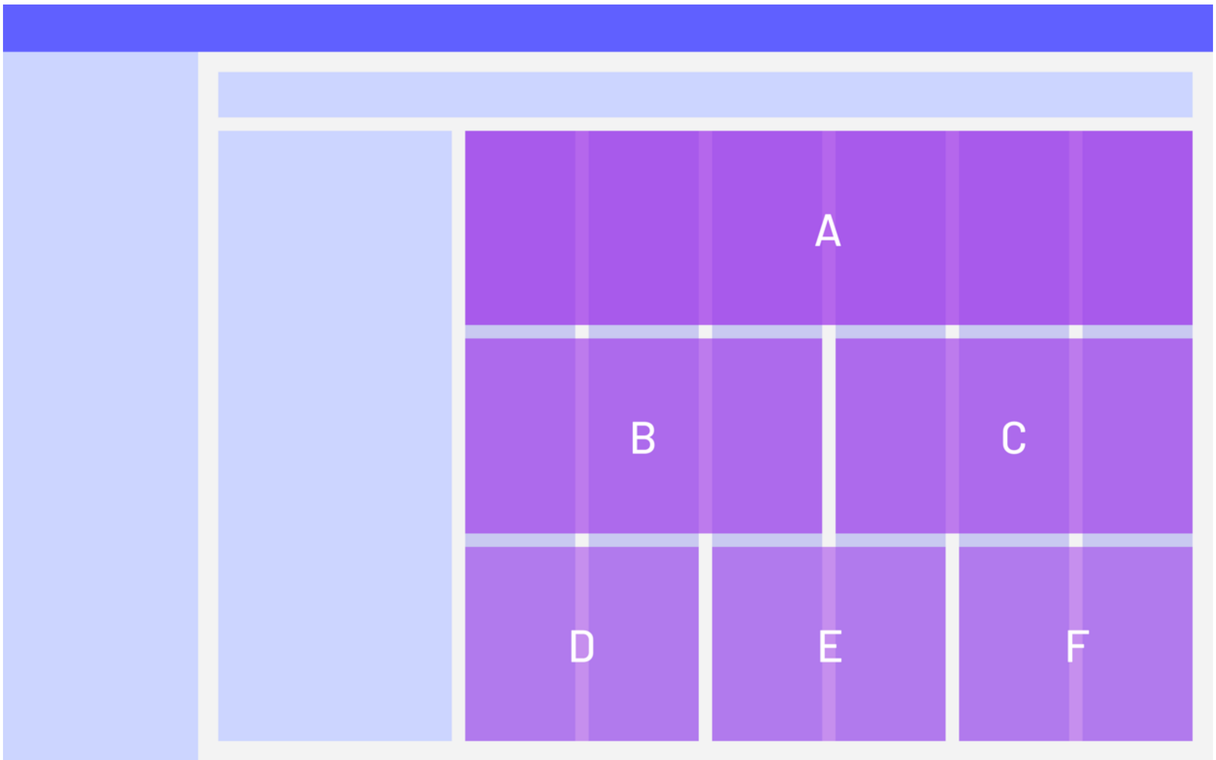


Figure 14: Alignment for the UI with Workflow Indication and additional menu on the left for sub-elements in a more detailed workflow

5.2 COLOR SCHEMES AND ARTWORK

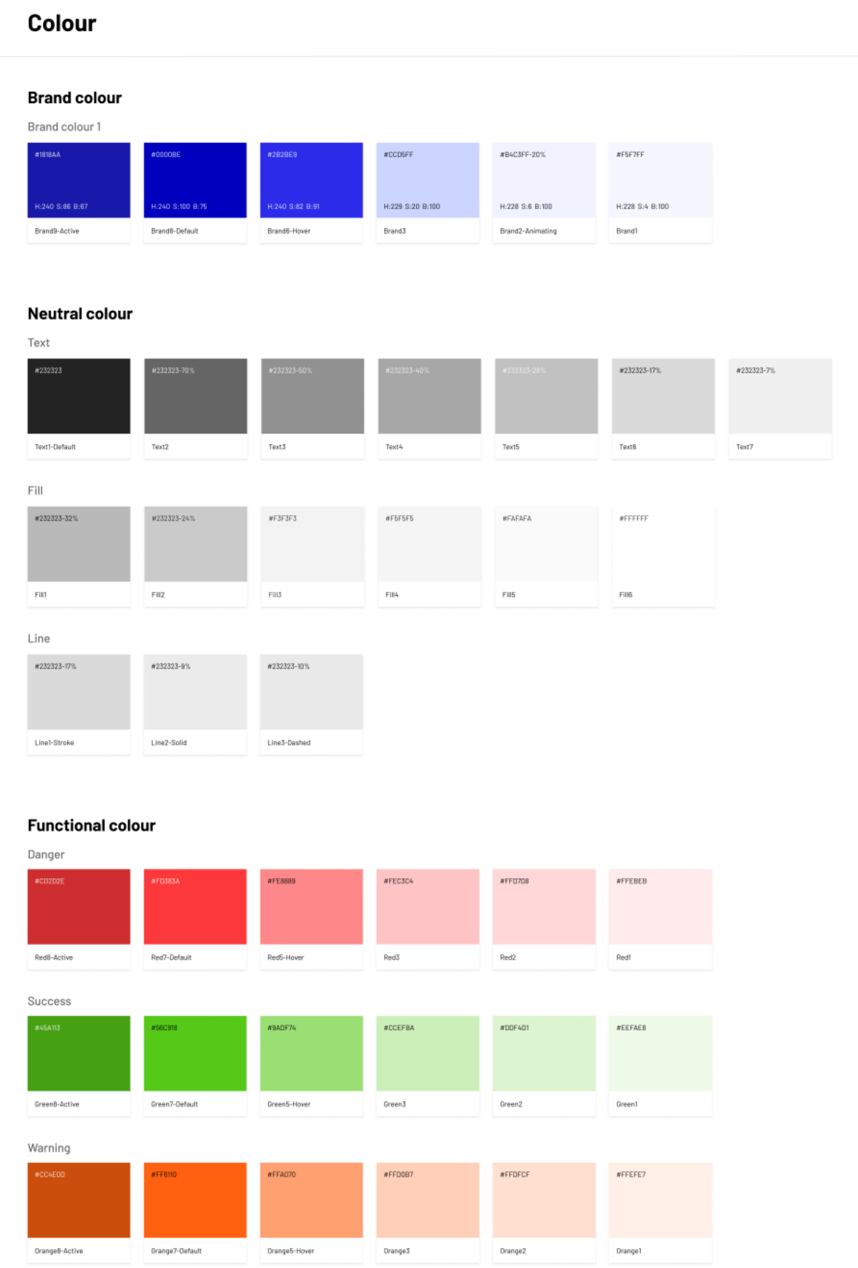


Figure 15: Colour Scheme definition

Typography

Font

Regular	Medium	SemiBold
Barlow	**Barlow**	**Barlow**

Font scale

Font size (px)	12	14	16	18	20	24	30	34	40	46	56	68
Line height (px)	18	20	24	28	30	36	44	48	60	68	84	102

Style name	Sample	Font size	Line height	Font weight	Description
H1	COROB	40	60	Semibold	Headline
H2	COROB	34	48	Semibold	Title-XXL
H3	COROB	24	36	Semibold	Title-XL
H4	COROB	20	30	Semibold	Title-L
H5	COROB	18	28	Semibold	Title-M
H6	COROB	16	24	Semibold	Title-S
Body	COROB	18	28	Medium	Body-XL
Body	COROB	16	24	Medium	Body-L
Body	COROB	14	20	Medium	Body-M
Body	COROB	12	18	Meduim	Body-S
Caption	COROB	24	36	Regular	Caption-XL
Caption	COROB	16	24	Regular	Caption-L
Caption	COROB	14	20	Regular	Caption-M
Caption	COROB	12	18	Regular	Caption-S

Figure 16: Typography Proposition

Radius

Radius type

Border radius	Scenario
2px	Basic components such as buttons and input fields
4px	Container components: cards, modals, popup
Fully rounded	Components designed for emphasis or differentiation

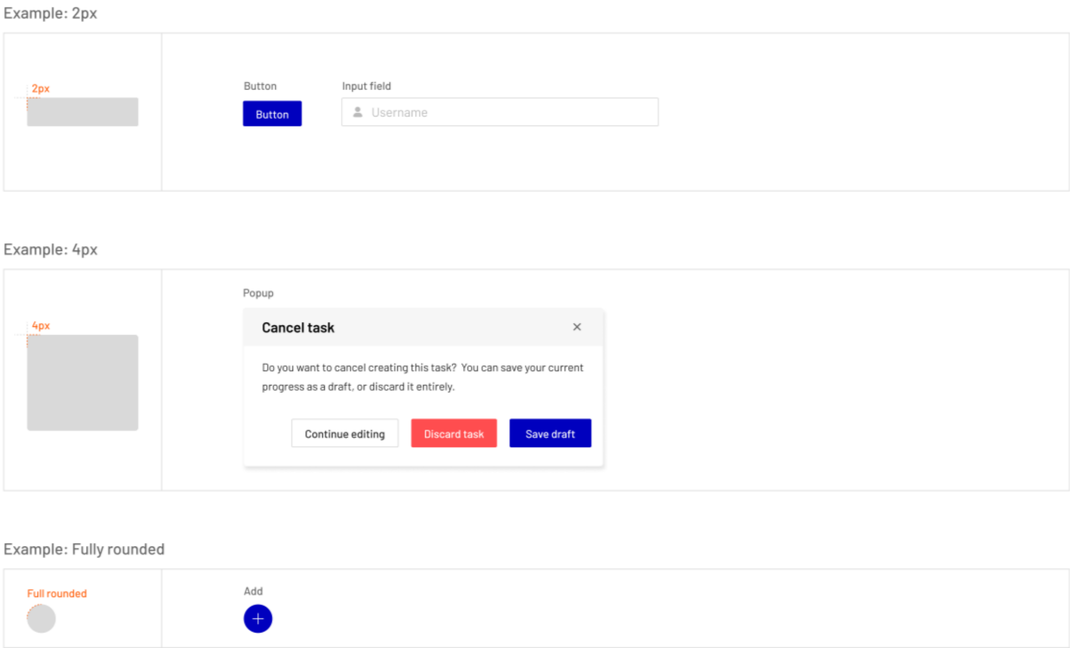


Figure 17: Radius Type and Borders

5.3 USER INTERACTION: ITERATIONS, DEVELOPMENTS AND EVALUATIONS

Main portal and onboarding UI screens

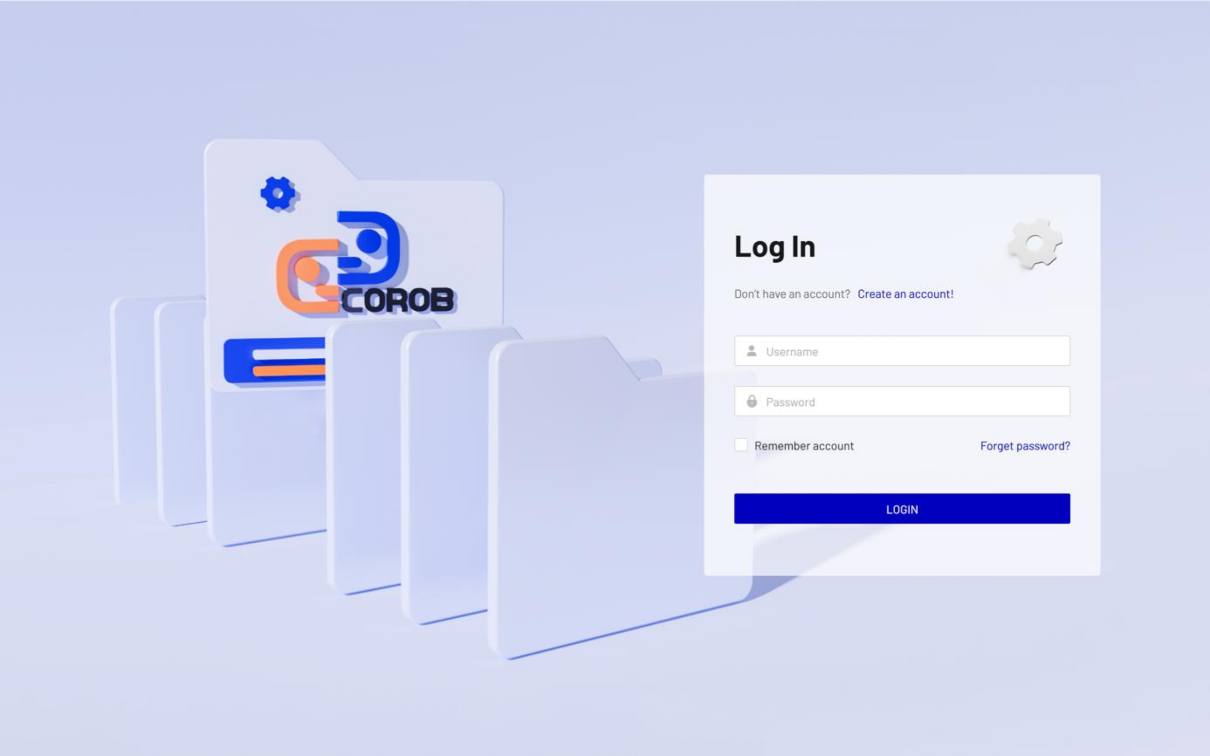


Figure 18: COROB Digital Platform UI - Login page

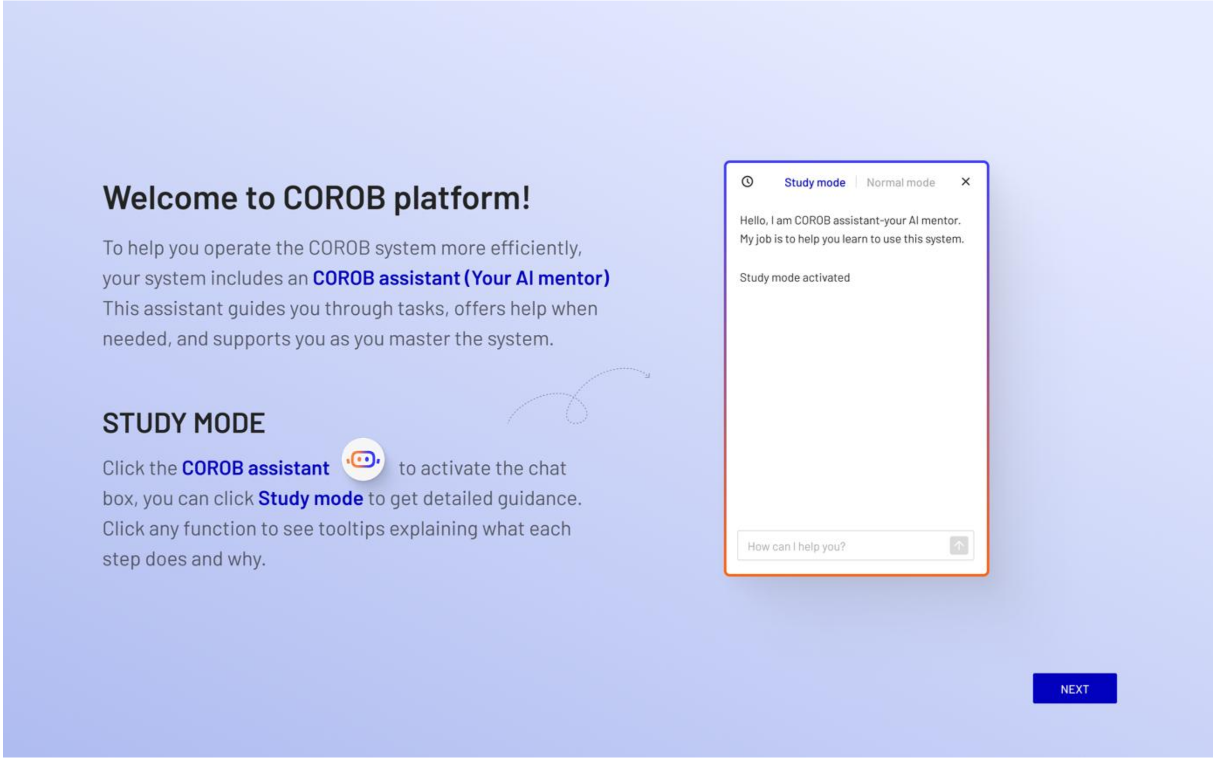


Figure 19: COROB Digital Platform UI - Onboarding - Study mode

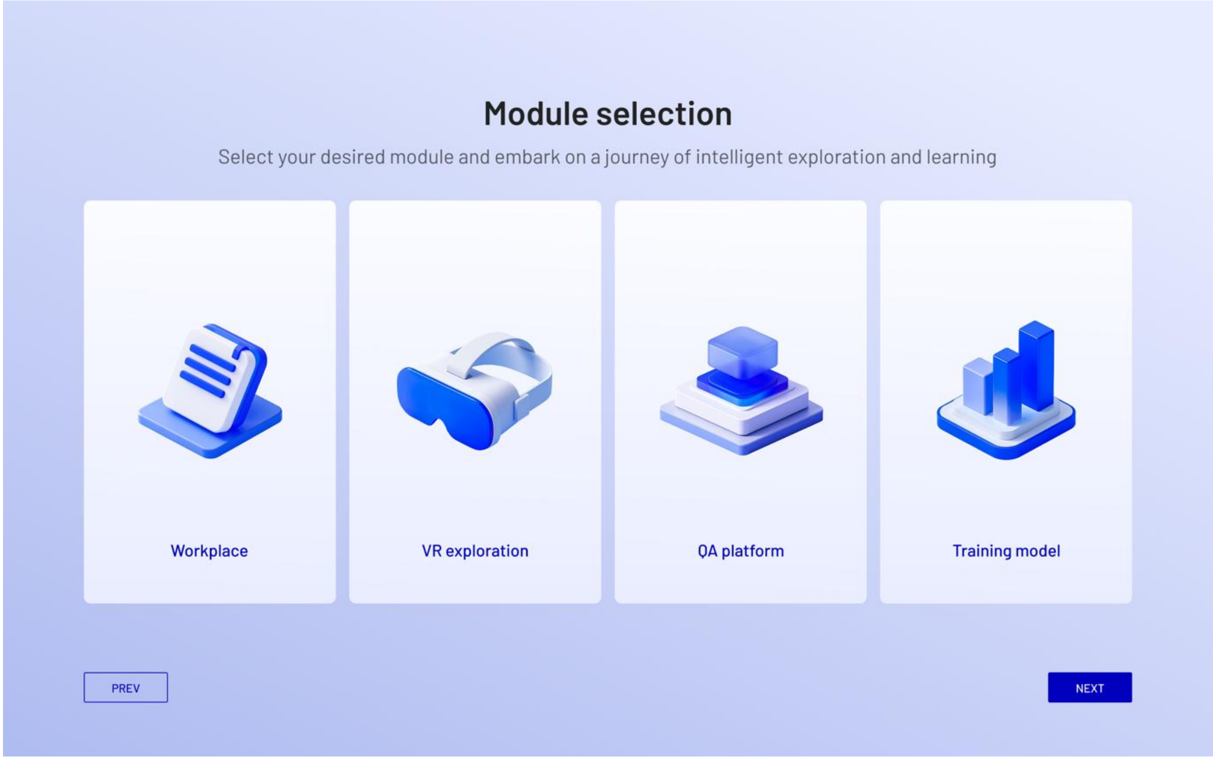


Figure 20: COROB Digital Platform UI - Module selection

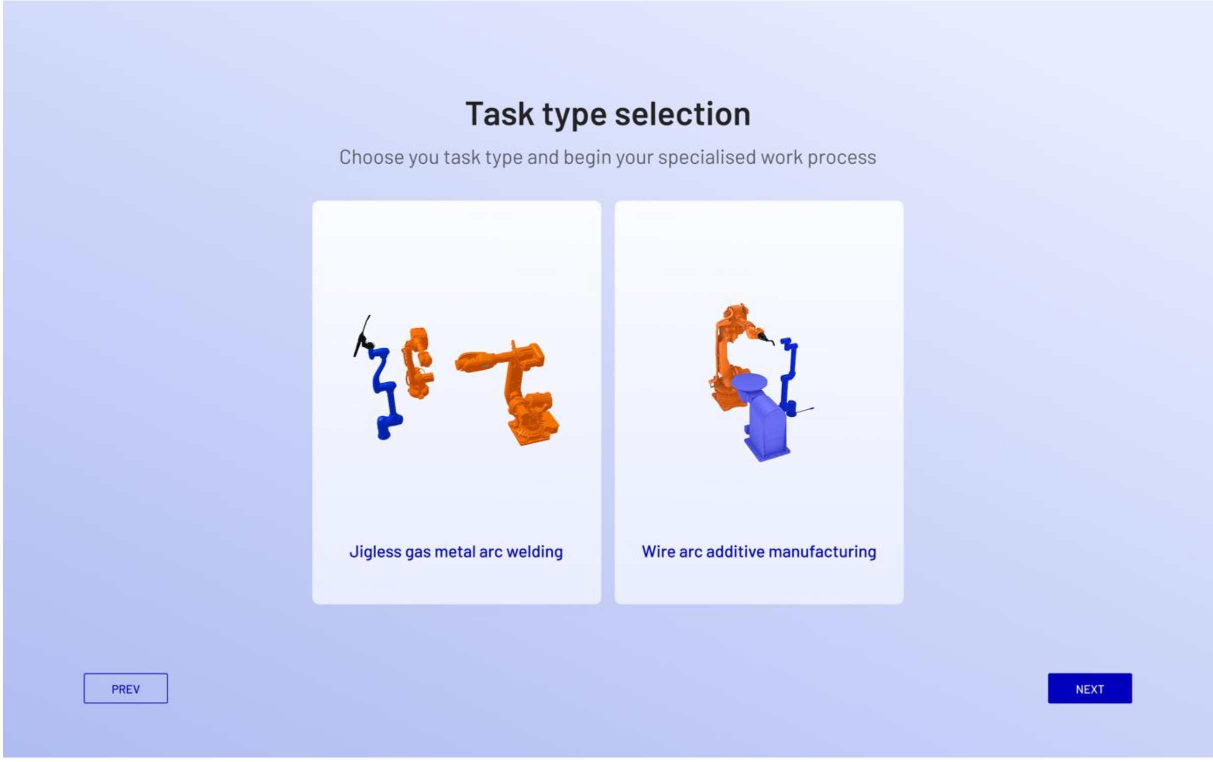


Figure 21: COROB Digital Platform UI - Workplace module – Task type selection

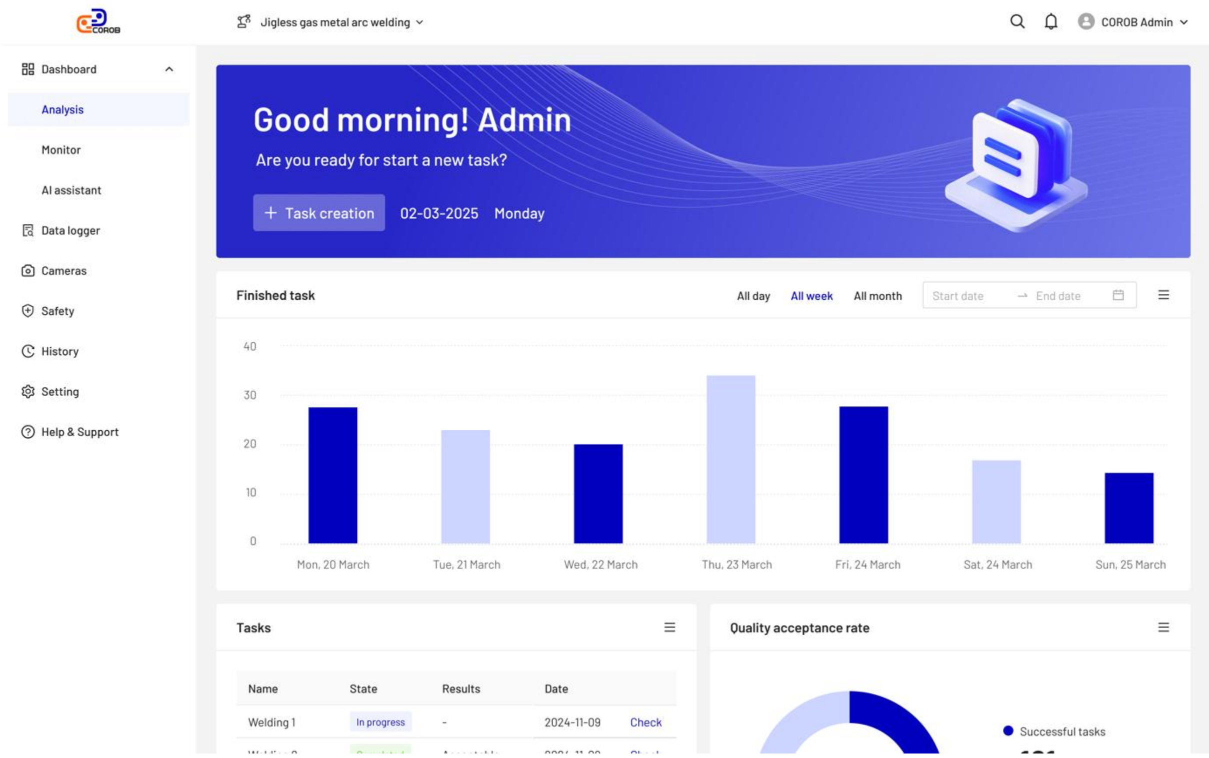


Figure 22: COROB Digital Platform UI - Workplace module – Task type selection – Dashboard section for general analysis

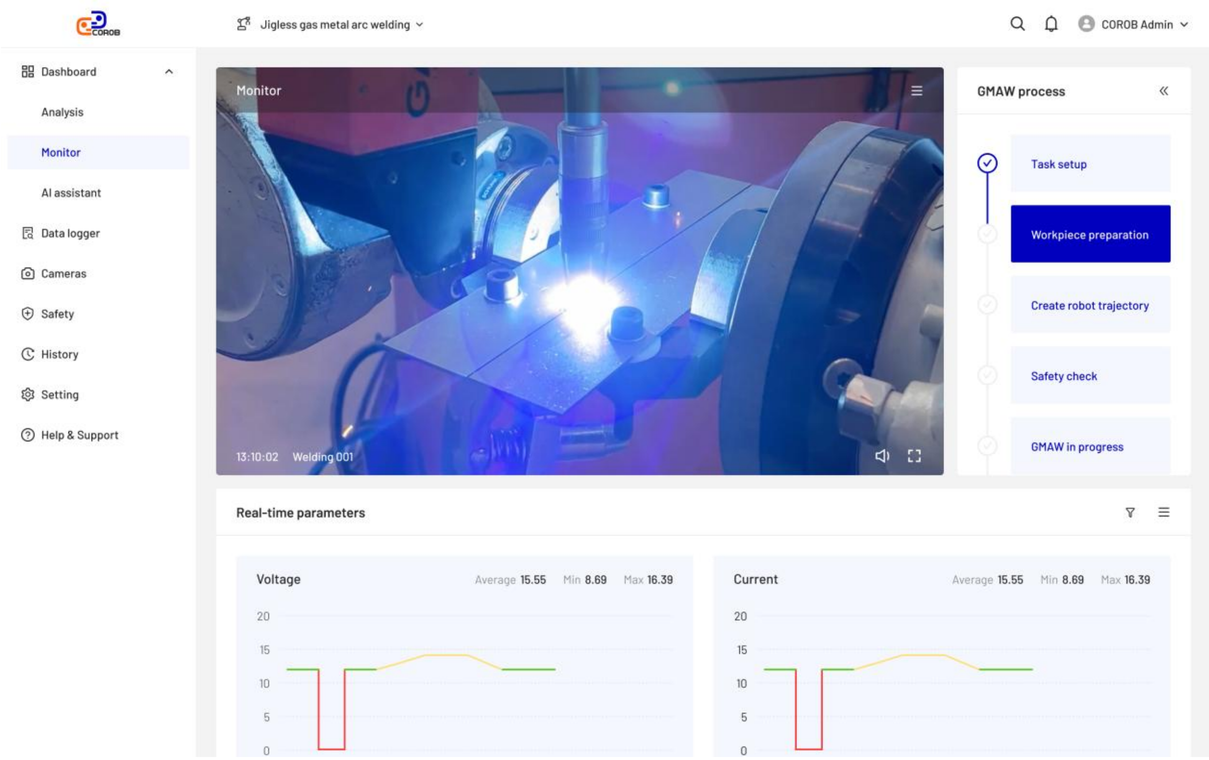


Figure 23: COROB Digital Platform UI - Workplace module – Task type selection – Dashboard section for process monitoring

5.3.1 GMAW UI screens

The COROB digital platform includes two separate workspaces for each of the two COROB use cases, jigless GMAW and WAAM. The following UI screens portray the main steps of the jigless GMAW process and show how the design guidelines for a positivistic UI have been implemented.

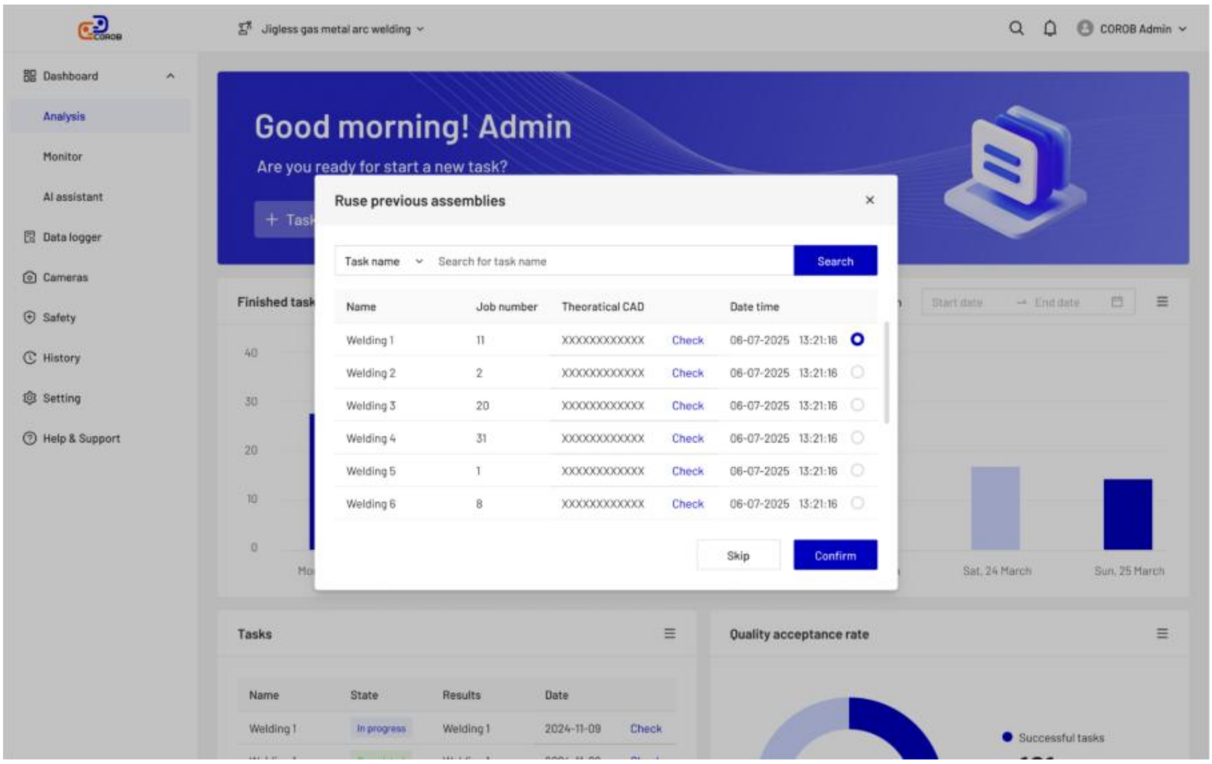


Figure 24: COROB Digital Platform UI - Workplace module – jigless GMAW – Reuse of previous assemblies

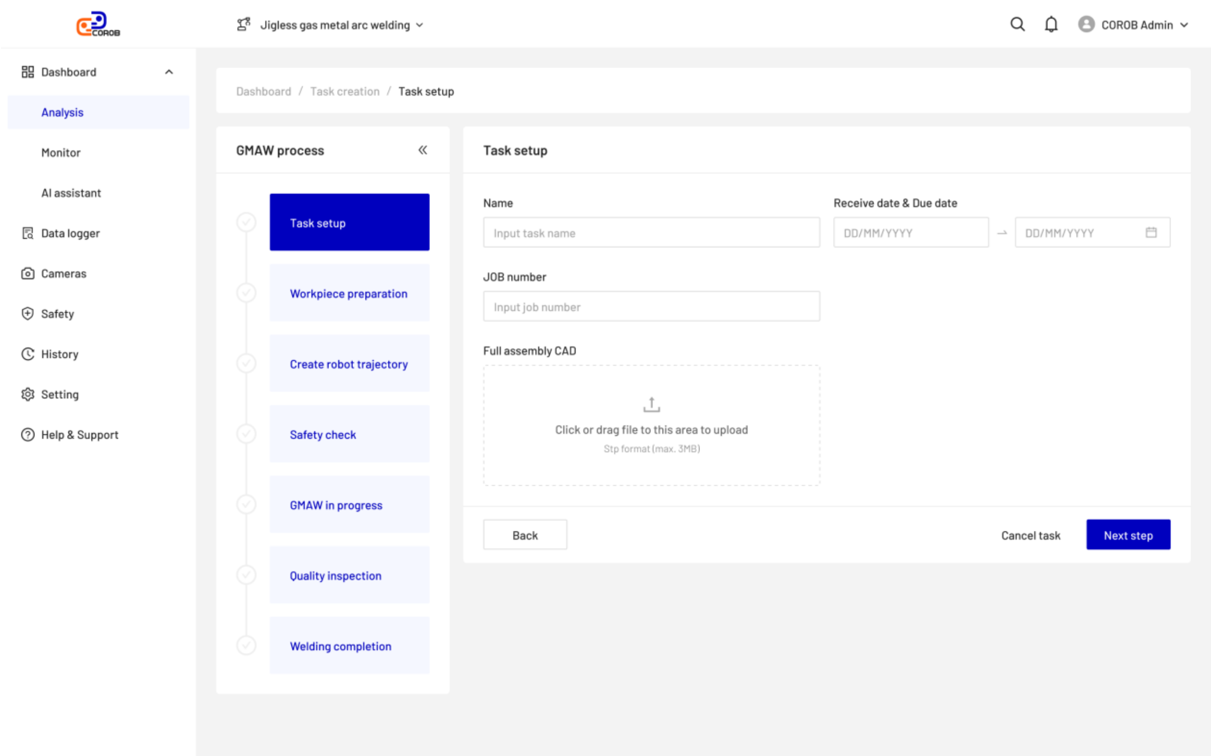


Figure 25: COROB Digital Platform UI - Workplace module – jigless GMAW – Set up of new assembly

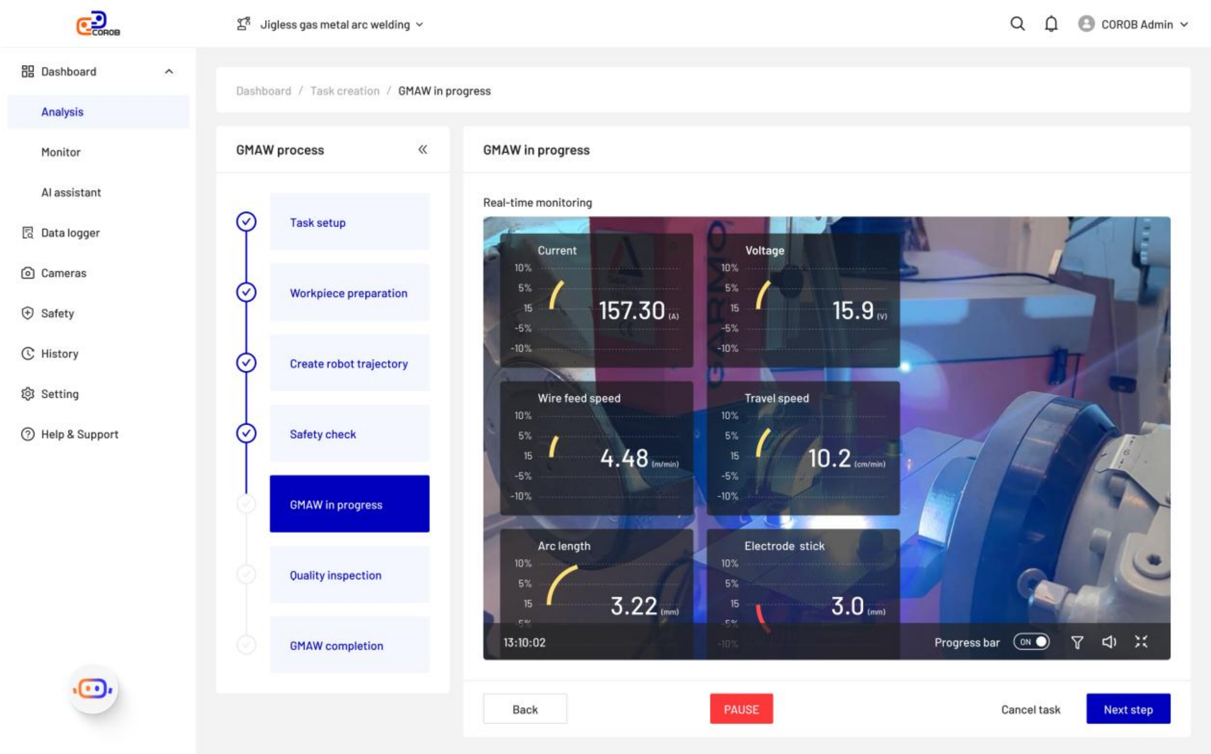


Figure 26: COROB Digital Platform UI - Workplace module – jigless GMAW – Real time visualization of process parameters

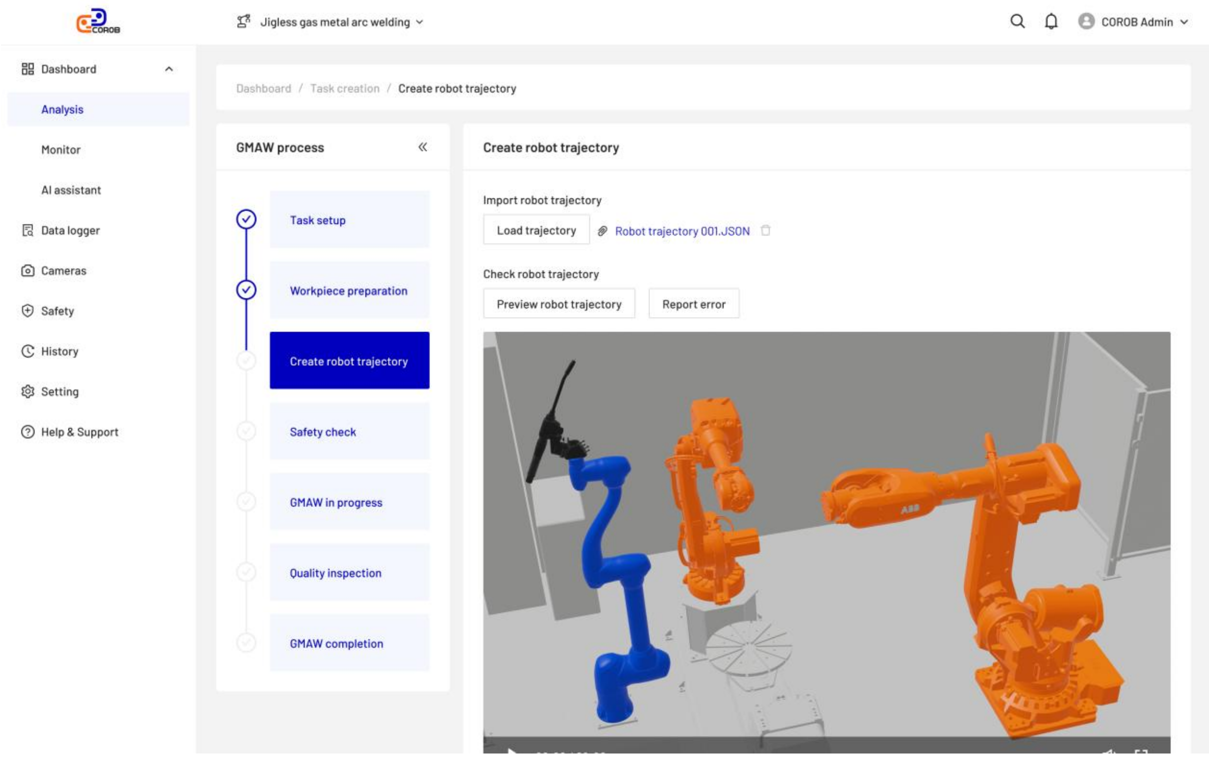


Figure 27: COROB Digital Platform UI - Workplace module – GMAW – Preview of robots' trajectories

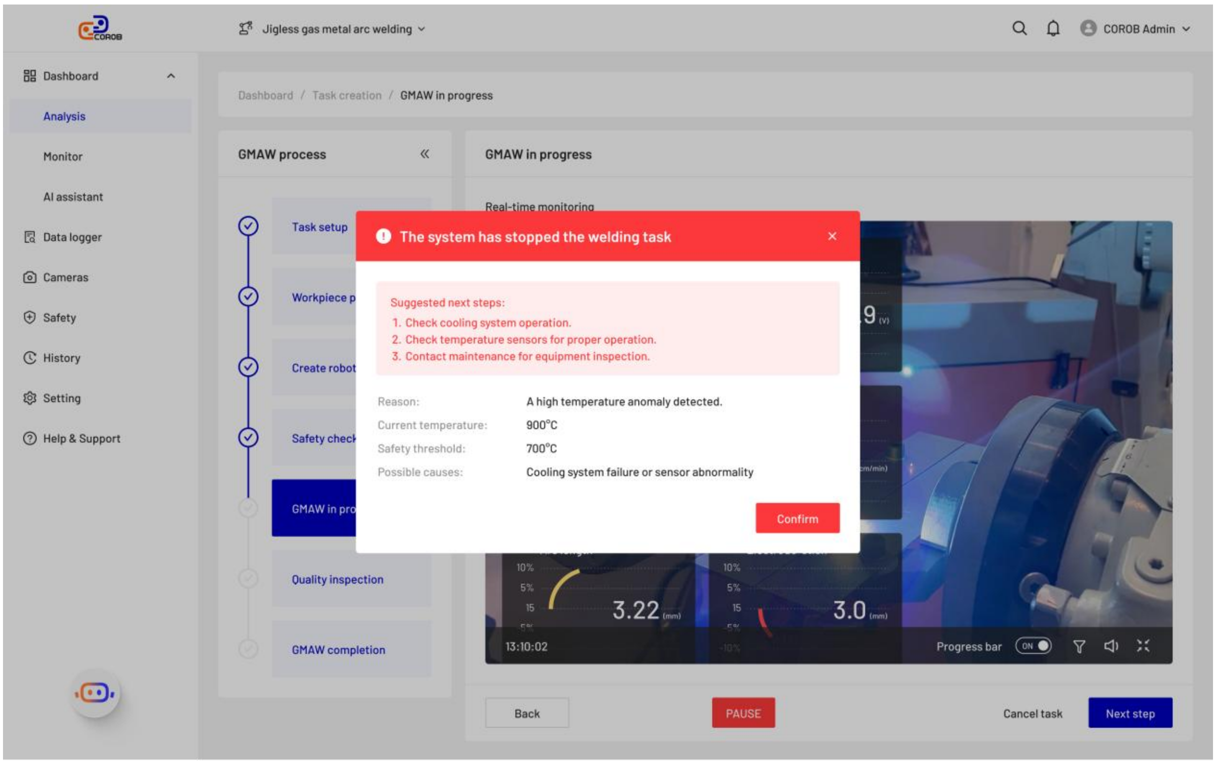


Figure 28: COROB Digital Platform UI - Workplace module – GMAW – Actionable feedback for resolution of system errors in line with positivistic principles

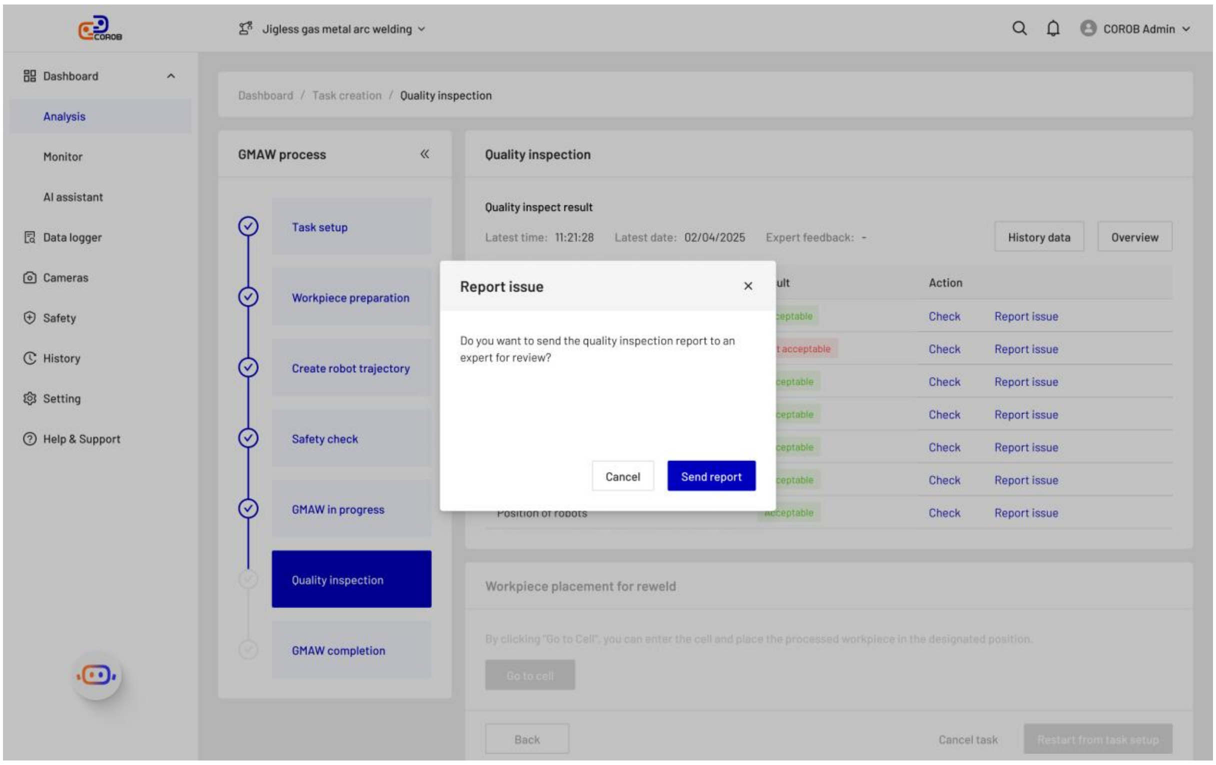


Figure 29: COROB Digital Platform UI - Workplace module – GMAW – Report of quality inspection results for expert review

5.3.2 WAAM UI screens

In the case of WAAM, operators have to follow a different workflow that requires more frequent intervention and input from the user side and closer supervision, compared to jigless GMAW.

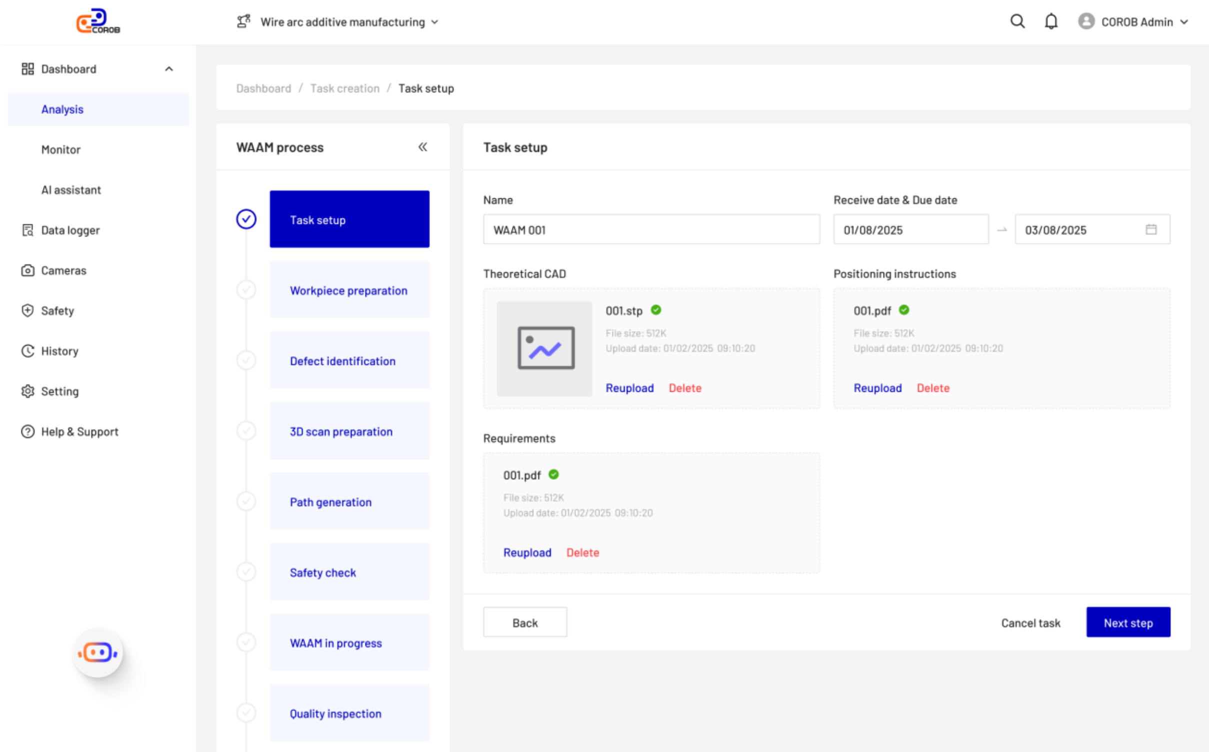


Figure 30: COROB Digital Platform UI - Workplace module – WAAM – Completed task setup

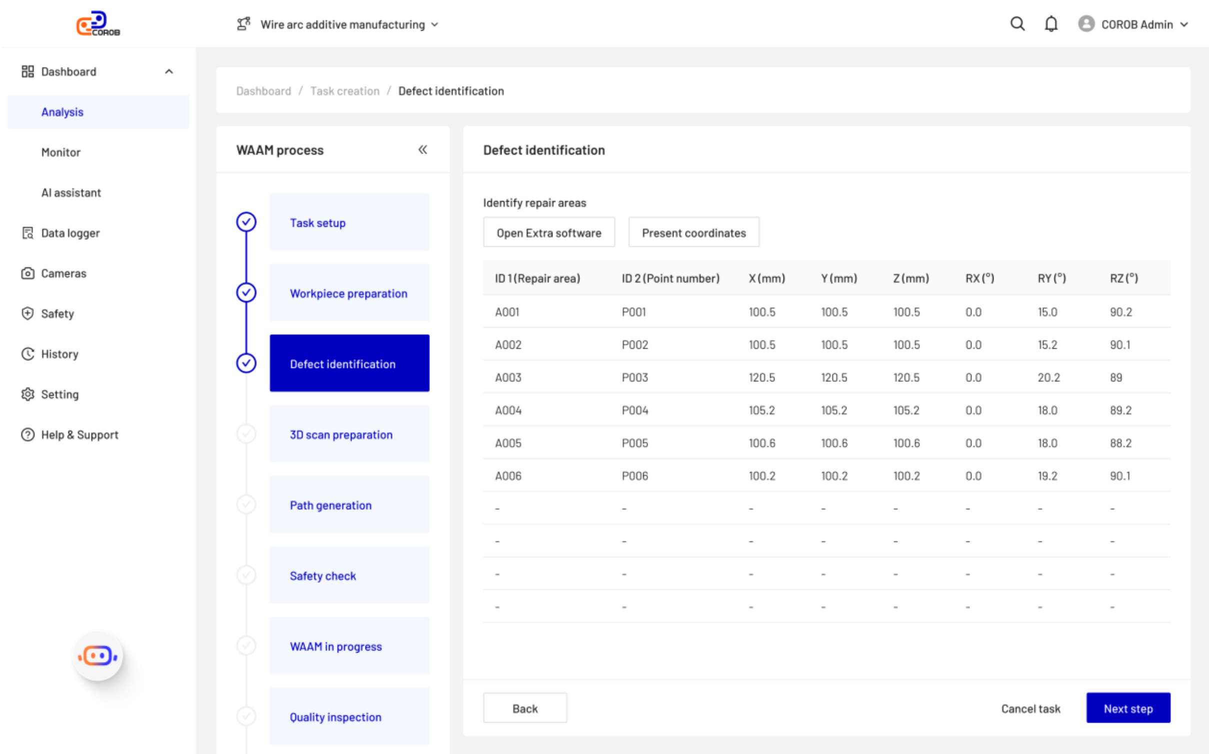


Figure 31: COROB Digital Platform UI - Workplace module – WAAM – Identification and localization of defects to be repaired

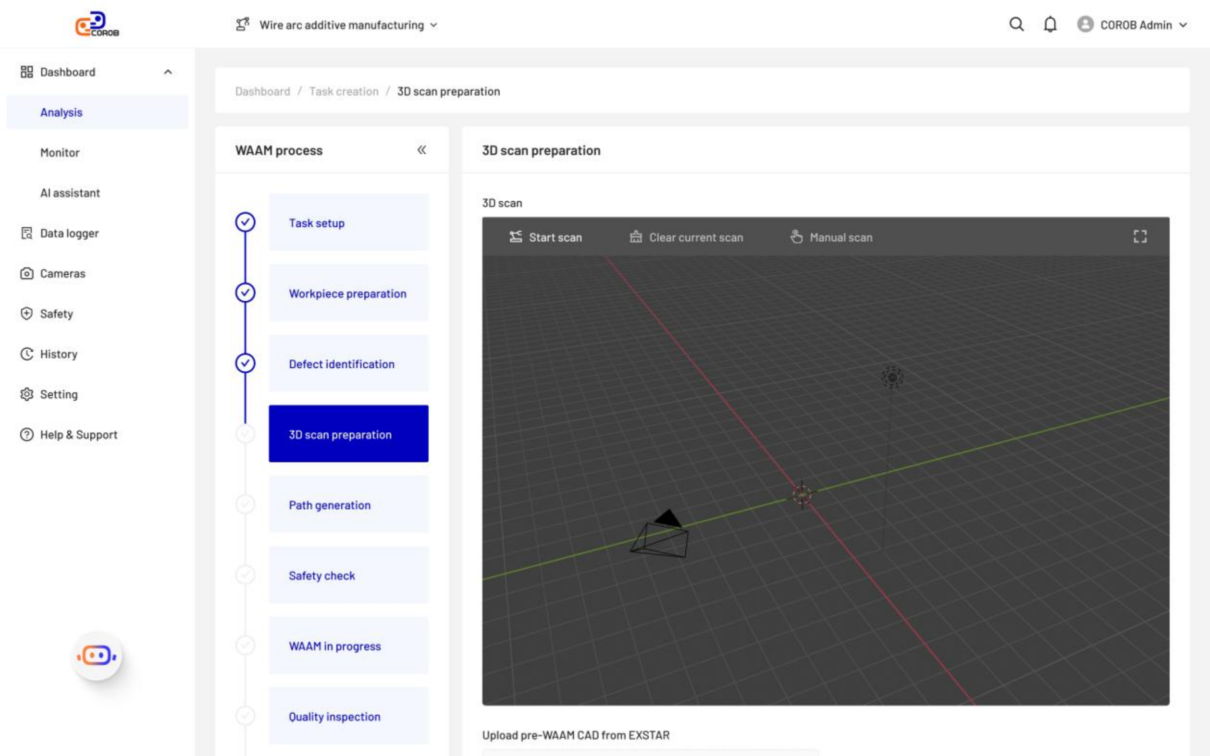


Figure 32: COROB Digital Platform UI - Workplace module – WAAM – Manual 3D scan of workpiece via external software EXSTAR

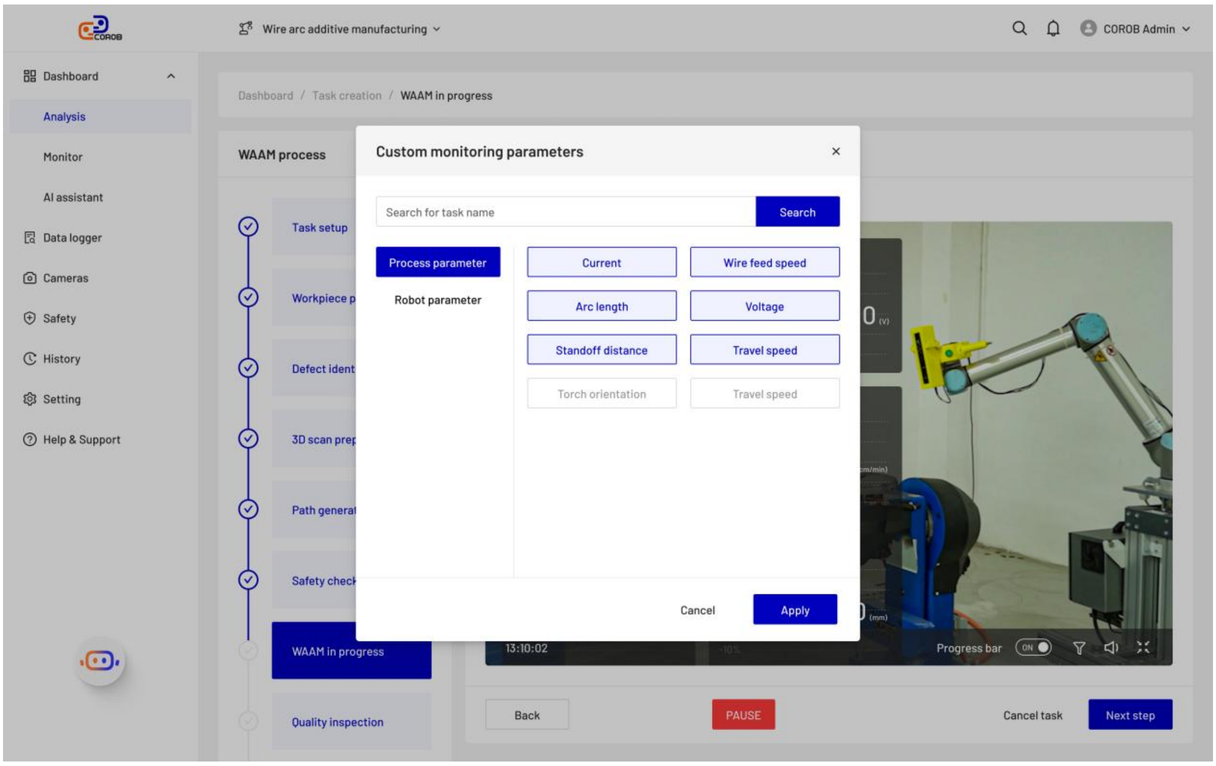


Figure 33: COROB Digital Platform UI - Workplace module – WAAM – Customization of parameters

6 CONCLUSIONS

This report provides an overview of all activities within T3.3 on the design of the user interface of the COROB platform.

Moreover, an overview of two user research studies that investigate the perception of the future users of COROB multi-robotic cells for GMAW and WAAM has been provided (focus group, questionnaires). Such initial findings indicate a general positive reception of the proposed technological solutions, although further investigation of how multiple stakeholders experience the COROB solutions and the COROB UI mock-up with larger and more diverse sample and in a more realistic setting would be needed to ensure a successful adoption of the technology in the real production environment.

In terms of supporting novice users to learn, gamification as a concept was evaluated in a user study. Based on the rather limited acceptance of gamification a set of principles to support learning were developed and evaluated. These principles can be a guideline for all applications and developments within the COROB project to support learning.

Based on an iterative design process with three major iterations and a series of heuristic evaluations a user interface design was developed and described.

The current mock-up of the COROB digital platform UI has been designed to faithfully reproduce the working process of the COROB multi-cooperative robotic cells and, at the same time, to empower users with minor tech-savviness and limited knowledge of welding processes. In the next months, the design will be taken up by the beneficiaries and these solutions will be continuously evaluated and validated. For this next step clear usability goals and metrics will be defined in collaboration with COROB partners and beneficiaries to test and validate future iterations of the COROB digital platform UI.

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