Co-Design Process for Upskilling the Workforce in the Factories of the Future

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Abstract—The digital transformation that the world is facing has a strong impact in the professional occupations and job profiles in the factories of the future context, requiring the need of upskilling and re-qualification of the workforce. Taking this into account, an Industrial Collaborative Educational Design (ICoED) is presented comprising three stages and eight steps, and considering a democratic and collaborative participation of the different stakeholders, namely the managers, educators and learners, each one providing its own perspective on the design of the training programme. In this co-design process, the analysis of the skills' gap is a crucial task to prepare the initial stage of the process, particularly identifying the needs in terms of soft and hard skills. The proposed ICoED process was applied to solve an upskilling problem of an industrial metal stamping company, with the participants performing three workshops to execute the eight steps, reaching a training programme with five modules, each one settled with proper activities, resources and infrastructures.

I. INTRODUCTION

The world is facing a digital transformation, known as the 4th Industrial revolution, that is based on the use of cyber-physical systems (CPS) [1] to enable the increasing level of automation and digitization and to transform the way factories operate to improve their responsiveness and reconfigurability [2]. CPS act as a backbone infra-structure to develop smart processes, machines and products, being complemented with the use of emergent digital technologies, e.g., Internet of Things (IoT), Big data, cloud computing, Artificial Intelligence, and Virtual/Augmented Reality. The resulting systems exhibit important innovative characteristics, e.g., intelligence, modularity, reconfigurability, agility, robustness, flexibility and responsiveness, which are demanding industrial requirements.

The availability of this set of new digital technologies and means of communication has a strong impact in the professional occupations and job profiles, with several projections and surveys estimating a significant need of upskilling and requalification of the workforce, especially focusing the factories of the future. In particular, the Mckinsey report estimates that *"75 to 375 million people around the world may change their professional category by 2030 due to the new job market scenario"* [3], and the World Economic Forum predicts that *"133 million new jobs will be created over the*

period 2018-2022" [4], the *"professions of the future will account for 6.1 million opportunities globally in 2020-2022"* [4], and that *"at least 54% of all employees will need reskilling and upskilling by 2022"* [5]. As a result, millions of people may need to acquire new digital skills, and others will need to change careers and improve their skills to be adapted to the new job market reality. The appearance of the COVID-19 pandemic in the last year has accelerated this need.

This challenge requires the development of new methods and tools to identify upskilling needs and particularly skills' gaps that affect the different companies' workforce groups. In the same manner, a co-design process is required to design innovative training programmes that addresses the identified needs, in a systematic manner and involving the different stakeholders, i.e. managers, learners, and educators. These topics are being addressed in the EU FIT4FoF (Making our Workforce Fit for the Factory of the Future) project (www.fit4fof.eu/) that analyses the current skills initiatives to better understand how to address the workers' needs and proposes a new upskilling framework that places workers at the centre of a co-design process and recognises their upskilling needs. For this purpose, technological trends are analysed across six industrial areas, namely robotics, additive manufacturing, mechatronics, data analytics, cybersecurity and human machine interaction, to define new job profiles that will determine education and training requirements.

Having this in mind, this paper describes the principles of a co-design process for upskilling the workforce in the factories of the future, aiming to design training programmes that fit the needs of a particular upskilling problem. The main contribution of the proposed co-design process is to facilitate the democratic and collaborative participation of these different actors, i.e. managers, educators, and learners, each one providing its perspective on the upskilling problem, as well as, to consider a skills gap analysis methodology that allows to understand the upskilling needs. The application of the proposed co-design process is illustrated in the upksilling problem of an industrial company devoted to produce metal stamping components for the automotive industry.

The rest of the paper is organised as follows: Section II

presents the co-design process to elaborate innovative training programmes focusing on the identified upskilling needs and Section III describes the methodology and developed web tool to identify the upskilling needs. Section IV describes the application of the proposed co-design process to an industrial case study, and Section V discusses the lessons learnt by performing this process. Finally, Section VI rounds up the paper with the conclusions and points out the future work.

II. Co-Design Process for Upskilling

Managers, educational providers and workers have a direct impact on an upskilling programme. Even though they have the same goal at upskilling the workforce, they see the upskilling problem from different perspectives. Moreover, they have little or no insight into the others' views on the upskilling problem. Consequently, this creates a subjectively and ambiguous view of the problem, where the discourse is paradoxical, where all the views on the upskilling problem are valid in their own perspective, but cannot be combined directly [6].

In the user centred design, problems are perceived as subjectively and ambiguous [6], which are comparable with the upskilling problem found in the industrial company with new technologies. In contrast to the traditional user-centered design, where the role of the designer is the translator that translates the insights of users' needs into solutions, the designers in a co-design process become facilitators and the users become designers [7]. This moves the design decision closer to the stakeholders that experience the problems from their own expertise view. The learning design methodology enables teachers to make more informed decisions about the learning activities, where a key principle is to make tacit knowledge more explicit and shared [8], [9].

The ICoED (Industrial Collaborative Educational Design), derived from the learning design method CoED [8], aims to facilitate the democratic discussion in a particular industrial company, where the learning design of upskilling the workforce is an objective. By the democratic discussion, all actors have a voice in the learning design, providing an explicit insight into each stakeholder's view on the upskilling problem, becoming a shared understanding. Decisions in the learning design are made by the different actors to create a common scope of the upskilling programme and to reduce the ambiguous and paradoxical upskilling problem.

The proposed ICoED method consists of three stages, comprising eight steps, to facilitate the decisions in the learning design of the upskilling programme, as illustrated in Fig. 1.

Before starting the ICoED process, a comprehensive analysis of skills gaps should take place. The result of the analysis creates the basis for the first stage, where throughout 3 steps, the decisions are made accordingly to the learning objectives. In this stage, the preconditions (step 1), list of hard skills (step 2) and list of soft skills (step 3) are determined for the target upskilling problem.

The learning approach is the main objective in the second stage, where the results from the first stage are discussed as ideal learning accordingly to the different views of the actors
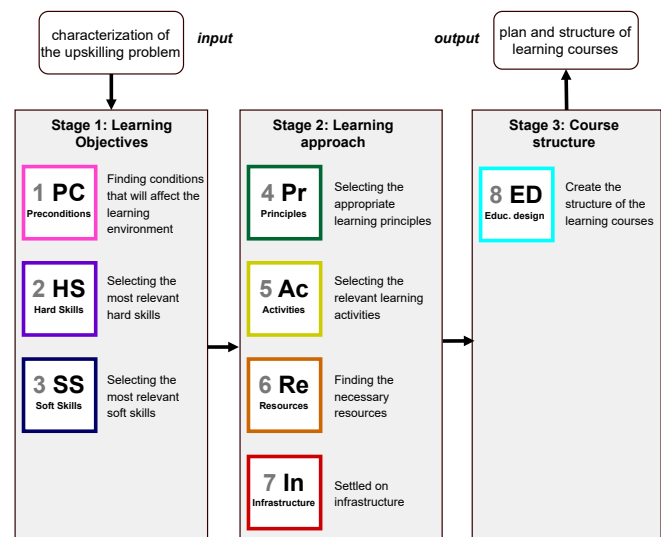

Fig. 1. The ICoED process.

of the upskilling problem in the four different learning topics. The steps included in this stage comprise the definition of:

- Principles (step 4), aiming to select the appropriate learning principles.
- Activities (step 5), aiming to select the learning activities.
- Resources (step 6), aiming to find the resources necessary to the training programme.
- Infrastructures (step 7), aiming to settle the infrastructure that will be used in the training programme.

In the third and final stage, all decisions performed in the previous stages are consolidated into the structure of the training course of the upskilling programme (step 8). The final outcomes of the ICoED process create a more informed foundation for the further decisions to be made in the specific planning and creation of the learning course.

As previously referred, to ensure a high-quality result in the decision made during the learning design, the participation of the different actors is crucial. The democratic approach in the discussions is important to ensure the voice of the actors' impact on the learning design. In this way, some stages in the ICoED process require the higher representation of participants than others, e.g., the second stage.

The ICoED methodology can be performed both as remote facilitation using an online collaborative tool and through the presential facilitation (i.e. face-to-face). In spite of the last approach is the recommended one, the former can take place, e.g., by using the online platform Miro (www.miro.com), supporting the remote participation of actors geographically distributed. This is crucial due to the COVID-19 pandemic restrictions to travel across borders and gathering in larger groups. Furthermore, facilitating the ICoED in a digital environment gives better opportunities to track and log discussions and mappings of the decisions made in the learning design.

III. ANALYSIS OF THE SKILLS GAPS AND IMPACT

An important aspect in the ICoED process is the identification of the upskilling needs for a target workforce group, which constitutes the input for the steps 2 and 3. To identify the gap and impact of future skills, three questions should be in mind: what kind of skills matter to employers, what are the existing gaps between employer's needs and employees skills, and what is the impact of each identified skill.

For this purpose, the methodology proposed in [10] considers the analysis of the association among technological trends, target job profiles, and skills' gaps and impact to determine the upskilling needs, as illustrated in Fig. 2. This methodology can be used by distinct users, each one having different perspectives:

- The learner that wants to identify its individual upskilling needs to achieve a particular target job profile.
- The manager or human resources director that wants to identify the upskilling needs for a particular workforce group.
- The educator or training provider that aims to identify opportunities to setup innovative training programmes.

Initially, the user that has an upskilling problem selects the technological trends that are affecting its business, e.g., the value of data and the power of connectivity, and selects the technological areas where the upskilling will be analysed, e.g., robotics, data analytics and human-machine interaction. A text mining technique based on natural language processing [11] is used to correlate these two sets of objects with the catalogue of identified new job profiles, identifying those that are affected by the selected trends.

After analysing the retrieved job profiles, the user should select those that are relevant for its business to proceed with the identification of the upskilling needs. Since each new job profile has associated a list of hard and soft skills that should be possessed by the employee to perform the job, the automatic engine correlates the required hard and soft skills with the previously determined skills gap analysis, stored in the database. This skills gap analysis was performed by using an iterative and continuous procedure, described in [12], that includes the analysis of the feedback from experts and an exhaustive analysis of scientific papers and recruitment repositories by using advanced data analytics techniques.

The data obtained from these sources were analysed and the skills were ranked according to their gap and impact, reflecting the need to upskilling the workforce to accomplish with the new job profiles in the factories of the future context. As example, Fig. 3 illustrates some relevant skills for the data analytics area, positioned according to their gap and impact. In this example, "Artificial Intelligence", "Machine Learning" and "Cloud Computing" skills present higher values of gap, which means that they will be relevant in the future and require an upskilling process. On the other hand, "Artificial Intelligence", "Data visualisation" and "Programming" present an higher impact, which means that they will affect a large number of people (note that, e.g., "Programming" presents a high impact but a moderate gap, which means that this skill is currently well dominated by employees in data analytics technological area but is impacting a high number of people).

According to the identified relevant (hard and soft) skills to the target upskilling problem, it is possible to search for recommended training programmes and in case of nonexistence of one that fits the user needs, it is possible to start an ICoED process. In this case, the hard and soft skills data is exported as a csv file, e.g., to the Miro platform, and used as playing cards to feed the steps 2 and 3 of the ICoED process.

A web tool, available at http://fit4fof.estig.ipb.pt/Home, has been developed by following the described methodology to perform the upksilling analysis, and may assist the different users to analyse their upskilling needs.

IV. APPLICATION OF ICoED TO THE CASE STUDY

The described ICoED process was applied to the Catraport, Lda pilot aiming to design training programmes to address the upskilling and requalification needs of its workforce to face the digital transformation.

A. Description of the Case Study

Catraport, Lda is part of the P&C Automotive group, an Italian multinational group with plants in Italy, Germany, Romania, Bulgaria and Portugal. The company was founded in 2015 and started the production in 2017 in its metal stamping factory, located in Bragança, Portugal, producing components for automotive industry. Since the beginning, the company is continuously expanding, even in the recent pandemic conditions, with consistent investments in technology and human resources, comprising at the moment more than 50 workers.

The reasons that brought Catraport to identify the need for the upskilling of its workforce are mainly linked to the fact that the company realised that the winning factors to remain competitive in the future cannot be just linked to the low costs but instead the need to be redirected to technological innovation, lean manufacturing, Industry 4.0 and eco-friendly business model. In fact, the automotive sector is moving fast to Industry 4.0 and to remain competitive, it is necessary to adapt the digital technical skills associated to production, quality and maintenance areas, which are deeply impacted by Industry 4.0 technologies.

Additionally, the company strongly believes that the 4th Industrial Revolution is centred on the human factor, which means an upskilling of the workforce also in terms of soft skills. Today, the company has a young and motivated team, with a very good technical background but lacking on specific digital technologies associated to Industry 4.0 and lean manufacturing, as well as specific soft skills, e.g., two ways of communication, leadership and team work.

B. Application of the ICoED Method

The application of the ICoED process in the company involved the realisation of three workshops, one for each stage of the co-design process, and following the previously described sequence of eight steps.
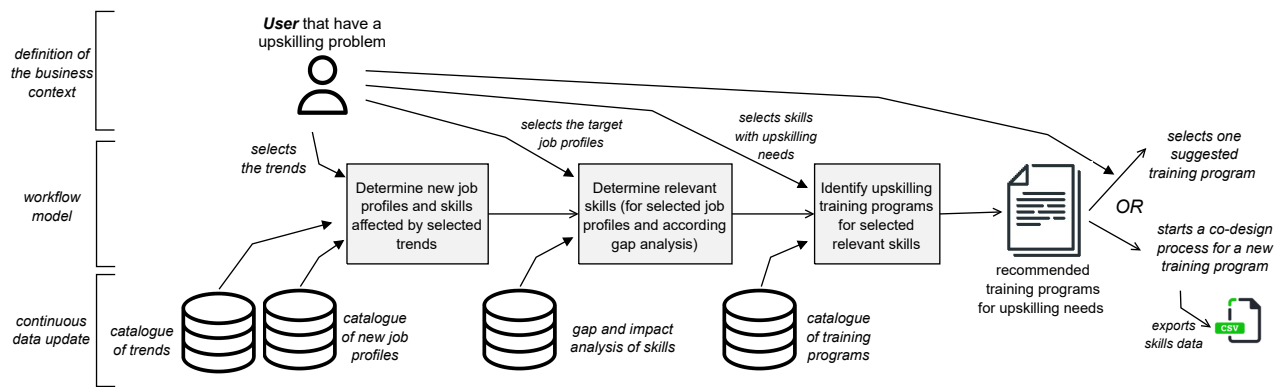
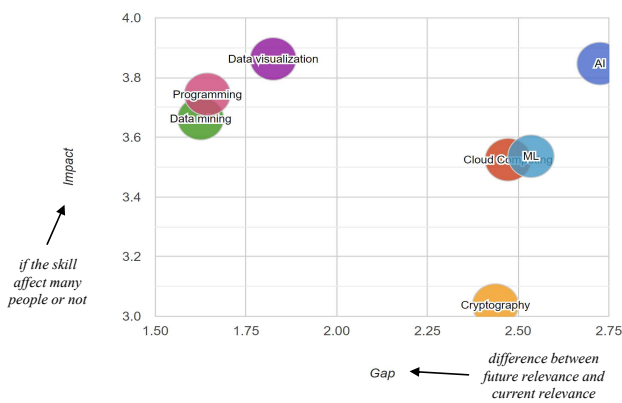Fig. 2. Methodology to identify the upskilling needs [10].

Fig. 3. Skills' gap and impact analysis.

1) Stage 1 (Steps 1 - 3): The first workshop, that took place on 10/03/21 with the presence of the company's manager and educators from the University College of Northern Denmark and Instituto Politecnico de Bragança, addressed the discussion of the first three steps of the ICoED process. At the beginning, in the step 1, the main preconditions for the upskilling training programme were established as follows:

- Qualification level: technician.
- Current digital maturity: very mixed.
- Language: Portuguese.
- Gender: mostly male.
- Time frame: 1 hour a week for long time.
- Learning type: blended learning.
- Educational level of workforce: secondary school to master degree.
- Age of workforce: mainly 30's.
- Group size for training: 10 to 20 workers.
- Location/physical setup: in-factory.

The defined preconditions allow to characterise the upskilling problem and define the boundaries for the design of the training programme.

In terms of steps 2 and 3, related to the definition of the hard and soft skills, the starting point was the current human resources gap analysis at the company. For this purpose, a quite traditional approach was considered, with upskilling needs being collected for each function and then looking for predefined training programmes to close the identified gaps. Complementary, the upskilling analysis web tool, described in the previous section, was used to identify the gaps from a set of new job profiles, retrieving the relevant hard and soft skills that need to be upskilled to reach the target new job profiles.

The identified hard and soft skills, as results of playing with the upskilling analysis tool, were exported to the Miro platform and considered as additional cards to be played in the ICoED process by the different actors, joining to the default cards suggested in the ICoED process. Fig. 4 summarises the sets of identified hard and soft skills needs as result of this workshop.

Fig. 4. Hard and soft skills identified as required during the ICoED process.

2) Stage 2 (Steps 4 - 7): The second workshop, that took place on 8/04/21, addressed the discussion of the steps 4 to 7 of the ICoED process. In this workshop, the participants were the same as in the previous workshop. This approach was followed since the workers have difficulties of communication using the English language and normally in companies the training needs are defined "top-down". In this case, an internal brainstorming was performed, involving the manager, department directors and workers, to address the "talents growth" through the collection of the training needs and the identification of skills gaps of each worker. In this way, indirectly, the manager

also brought to the workshop the workers' point of view regarding the upskilling problem.

Regarding the step 4, the participants have defined the following as the main principles that should regulate the training programme: professional and personal development, lifelong learning, interdisciplinary, informal learning, problem based learning, measurable results, workplace learning, technology centred and learning by doing. The established principles clearly link important aspects regarding the lifelong learning of the workforce, focusing the learning at the worker place and addressing concrete problems that the worker faces daily.

The activities foreseen for the training program (step 5) include the case study, gaming, collaboration, other companies visits, counselling, multiple choice, meeting, discussion, project, portfolio. Also, the resources identified as necessary for this training programme (step 6) include the teacher/expert, facilitator, video-chat, video, simulation, manual, forum, demonstration, portfolio, tutorial, course module and game. The identified resources are related with the selected principles and activities for this training programme, considering the use of different strategies. In fact, the use of digital technologies will be important to complement the role teachers and facilitators, enhancing the self-learning attitude of the learner.

Finally, the execution of a certain training programme requires the availability of a set of infra-structures (step 7). In this ICoED process, communication devices, digital platform, face to face meeting room (university/company), laboratories, learning management system, Internet connection and classroom onsite (quite), were identified as the necessary infrastructures for the training programme. The infrastructures were selected according to the principles, resources and activities previously defined, and besides considering classrooms and laboratories at education providers' facilities, it also establish the need to use remote sessions, virtual platforms and physical spaces in on-site work.

3) Stage 3 (Step 8): The third workshop, that took place on 29/04/21, addressed the conclusion of the ICoED process by discussing the step 8 related to the consolidation of the results of the previous steps and the elaboration of the structure of the training programme. This step results are illustrated in Fig. 5.
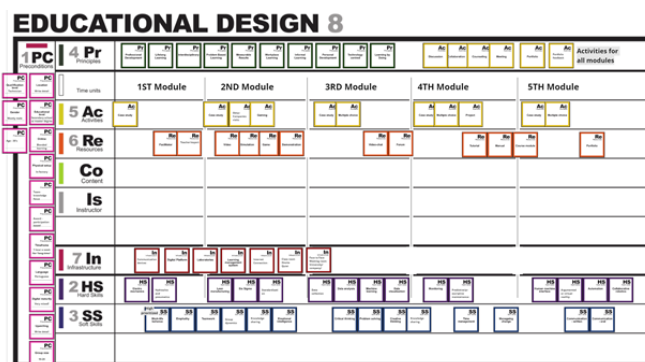

Fig. 5. Results of the step 8 of the ICoED process.

Briefly, at the end of the ICoED process, a training programme was designed to face the upskilling needs identified in steps 2 and 3 and addressing the established preconditions and principles, identified in steps 1 and 4 respectively. The designed training programme includes five training modules, each one comprising 20 working hours:

- *Electromechanics*, focusing the upskilling of hydraulics, pneumatics and electromechanics hard skills.
- *Lean Manufacturing*, focusing the upskilling of lean manufacturing, six sigma and standardisation hard skills.
- *Internet of Things*, focusing the upskilling of data collection, data analysis and data visualisation hard skills.
- *Predictive Maintenance*, focusing the upskilling of monitoring and predictive/prescriptive maintenance, data analysis and machine learning hard skills.
- *Human-machine interaction* focusing the upskilling of human machine interface, augmented or virtual reality, automation, and collaborative robotics hard skills.

These training modules use the resources and infrastructures identified in stage 2 of the ICoED process and follow the activities defined in the same stage. An important assumption is that the activities included in each module should promote the acquisition of competences related to the list of soft skills identified in the first stage.

V. DISCUSSION AND LESSONS LEARNED

At the end of applying the proposed ICoED process to the company's upskilling problem, some lessons learned can be discussed.

First, before the application of the ICoED process, no new job profiles were identified by the company since they believe that Industry 4.0 will live with "traditional manufacturing" for some years and the organisation will evolve slowly adapting to the new conditions, and the "traditional job profiles" will naturally grow into the new job profiles.

At the moment, the company recognises the need to adapt in some ways to the new needs from Industry 4.0; therefore adopting upskilling programmes for its workforce will facilitate this evolution from the "traditional job profiles" to new job profiles that incorporate new responsibilities in the area of AI, moving the technician focus to monitor and control the production. As example, the first contact of workers with a collaborative robot (cobot) generated some kind of fear on safety but also on the fact it could put at risk some work positions inside the plant. Then the curiosity and interest to learn made the transition soft and the workers realised that the cobot will help them in some tasks, e.g., involving ergonomic risks or high production volumes, but at the same time their role will remain essential, e.g., to supervise, feed, programme and maintain the activity of the cobot.

From the participants feedback about the execution of the ICoED process for the upskilling problem, several take away messages can be analysed. Indeed, during the workshops, participants had strong opinions and the ICoED process created opportunities for everyone to express their views and perspectives on the design of the training programme, contributing to

the development of shared knowledge. Additionally, the advantage of knowing each other before the workshops allowed a more open and out-of-the-box discussion.

In terms of the ICoED process itself, the steps and the purpose of each step were easily understood by the participants. The implementation of the ICoED process requires the execution of workshops for each stage; in the described case study, one workshop was performed for each stage, but in other cases, e.g., where the number of participants is high, more than one workshop for each stage may be required.

In this case study, learners were not directly involved in the workshops, but indirectly through the manager that brought their perspectives after internal and preparatory brainstorming meetings. However, it was clear the importance of having the learners in some workshops. Additionally, it will be very useful to collect the feedback from the workers after the execution of the designed training programme in order to have also their contribution to improve continuously the co-design model.

Finally, during this ICoED process, it became clear how universities can play an essential role to continuously upskill the workforce and how changes will be needed on the teaching paradigms to accommodate the fact that workers are not anymore students, and therefore also coaching and teamwork need to be associated to the classical teaching approaches. This means that companies and universities, and particularly workers and educators, can work together during the ICoED process, complementing each other to create a training programme that fits exactly the upskilling needs.

VI. CONCLUSION

Digital technologies are having a huge impact in the professional occupations and job profiles, particularly in the factories of the future context, with several projections referring the need of re-qualification of the workers. Consequently, the development of new training programmes are required to fill the existent gaps of the actual offer, addressing the upskilling needs. This challenge requires the development of innovative processes to address the identified needs, in a co-design environment involving the main actors, e.g., managers, learners and educators, each one providing its own perspective on the learning programme.

Along this work, an innovative industrial co-design process aiming to design new training programmes to fit the needs of a specific upskilling problem is described. A major contribution of the presented co-design process is to promote a democratic participation of the different actors as well as consider a skills gap analysis methodology to better understand and identify the upskilling needs.

Furthermore, to better understand the presented co-design process, its application to solve an upskilling problem in an industrial case study was considered. The use of this case study illustrates the rationale of each stage and step considered in the process, as well as analyses the feedback from the participants in the exercise. In general, the ICoED process was easy to implement and to be understood by the participants. Moreover, all the participants considered that it creates opportunities

to express opinions and perspectives regarding the design of training programmes that fit the upskilling needs, contributing to create a shared knowledge. Another point that it is worth to mention is the fact that the process can be implemented remotely or in a face-to-face environment.

Regarding the outputs of the ICoED process, at the moment, some training modules were already executed with the participation of the company's workers, e.g., one related to the development of IoT applications that addresses the data collection, analysis and visualisation. However, future work will be devoted to prepare and execute the other modules of the training programme designed during this ICoED process, and particularly to make an assessment of the workforce upskilling at the end of this process.

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