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Assessing the skills gap for industrial operators in Industry 5.0

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Abstract. The following paper presents a study that investigates the existence of a skill gap for operators of Industry 5.0. This study is part of the CONVERGING project, a project that aims to develop and deploy smart-production systems for different industrial use cases. In each use case, a manually performed task is being redesigned as a smart-production system that leverages collaboration between human operators and smart machines such as collaborative robots. The current study's aim is twofold – firstly, to identify the current skill set of the operators and the skills expected from them to perform the future roles in the smart-production systems. This was achieved through a literature review, hierarchical task analysis and task decomposition. The second aim is to assess whether there is a gap between operators' current skills and the skills expected from them for performing roles in the future systems. To meet the second aim, an online survey was developed using the list of skills already identified for the first aim, and the survey was administered to use case supervisors and managers. The following paper details the methodology for skill identification and survey development and the results from the survey are discussed.

Keywords: skills, soft skills, technological skills, technical skills, Industry 5.0, smart technologies.

1 Introduction

The cyber-physical technological advancements that characterized Industry 4.0, such as big data, artificial intelligence (AI), cloud computing, augmented reality (AR) and collaborative robots [1], are continuing to be developed in Industry 5.0. However, Industry 5.0 is characterized by a human-centric aim to prioritize the experience and well-being of the operator working in these cyber-physical or smart-production systems. This is not simply achieved through centralizing the operator's role in the industrial process but also through empowering operators to perform these roles. This empowerment entails identifying the skills required by operators to perform their tasks in future smart production systems and addressing methods to bridge a skill gap if it exists.

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Typically, studies that have explored the skills and competencies that are needed for future smart-production systems do so within a broad scope of Industry 4.0 and 5.0's developments. These studies recognize that new smart-production systems being developed across industries, which bring changes to organizational structures and functioning, and job roles of operators, thereby necessitating new competencies and skills for the future of Industry 4.0 and 5.0 [2–4]. Some papers narrow down the focus from the overarching Industry 4.0 and 5.0 context to specific sectors and investigate the skills and competencies required for the future of industries such as automotive, additive manufacturing, mechatronics, and renewable energy [1,5,6]. Research on skills for Industry 5.0 also includes the development of methodologies to investigate skills for specific job profiles within a company, wherein a company can formulate a job profile and then investigate skills required [7,8].

The current study differs from the existing studies on the skills gap for Industry 5.0, as it specifically approaches the assessment of skill requirements in consideration of the manual industrial tasks being redesigned into smart-production tasks. This study is part of the CONVERGING project, an EU-funded project that aims to develop and deploy smart-production systems for industrial use cases in the automotive and white-goods industries. The project is designing and developing smart-production systems for the specific task of sanding and polishing draw dies (automotive industry) and electric hob assembly (white-goods industry). Both these tasks are currently being performed manually, and the project is working on solutions to transform the task into a smart-production task that leverages the collaboration between human operators and smart technologies like collaborative robots, AR devices, smartwatches, smart pens, AI-enabled cognition and human-machine interfaces. The aims of the current study are therefore very focused on the future industrial task redesigns that the project is developing rather than a general enquiry about the future of industry. Additionally, the current study also differs from other studies by incorporating hierarchical task analysis and task decomposition in its methodology to determine skills required from the task being performed manually and the future redesign of the task. Previous research on skills for Industry 5.0 typically only involves capturing the opinions of industrial experts and/or systematic literature reviews on skills studies. The aim of the current study is twofold. Firstly, to identify the current skill set of the operators and the skills expected from them to perform the future roles in the smart-production systems, and secondly, to assess whether there is a gap between operators' current skills and the skills expected from them for performing roles in the future systems.

2 Method

2.1 Skill Identification

An initial review of the literature on skills for the industrial workforce demonstrated that a skills analysis necessitates the categorization of skills into soft skills and technical skills. Soft skills are intrapersonal and interpersonal skills which relate to cognitive and

self-management abilities, and the ability to work with others [9]. Technical skills refer to the abilities required to perform specific processes, procedures or techniques to complete a task [1].

The soft skills were determined through an analytical review of the literature using the key words 'Industry 4.0', 'Industry 5.0', 'non-technical skills', 'soft skills', 'digital skills', 'transversal skills', 'competencies', 'factory operators', 'industrial operators', 'smart factory'. A list of soft skills was finalized by identifying those skills that were repeatedly mentioned across studies. Table 1 presents the shortlisted soft skills operators would need currently and for the future.

Table 1. Soft skills for Industry 5.0

	Soft skills
1.	Team working skills: cooperation and coordination
2.	Problem-solving abilities
3.	Openness: adaptability and flexibility to new ideas and information
4.	Conflict resolution and negotiation
5.	Communication skills: interacting and sharing information with co-workers and clients, making speeches and presentations.
6.	Creativity
7.	Decision making
8.	Mindset for lifelong learning and development
9.	Leadership abilities
10.	Self-confidence
11.	Emotional intelligence
12.	People management: Supporting group cohesion and motivating other people
13.	Organization skills: Planning and time-management
14.	Analytical thinking
15.	Managing responsibilities and acting responsibly for one's work

The identification of technical skills is use case dependent, since technical skills relate to the abilities required to perform the industrial task. Thus, a hierarchical task analysis (HTA) with task decomposition (TD) of the current manual task and the proposed future task was conducted for each use case.

HTA is a human factors technique employed for the systematic deconstruction of a manual task activity into a hierarchy of operations and sub-processes. This deconstruction aims to present the step-by-step sequence from the base level of operation to complete the task. TD is an approach used in HTA that breaks down the task into its lowest levels of operations and then analyses each operation through categories such as the related purpose, cues, decision, and skills required for that task operation. By revealing each step of the task, the HTA and TD breakdown provides a step-by-step requirement of skills needed to successfully perform the overall task [10].

The HTA and TD helped identify the technical skills required for operators to perform their current manual task and the proposed future task. These skills were sent to the respective use case leaders, who reviewed the list of skills and validated them. Table 2 shows the list of technical skills specific to each use case.

Table 2. Technical skills for each use case

Use case and task	Technical skills
Automotive Industry: Sanding and polishing of draw dies	1. Identifying fault areas on dies that require sanding and polishing 2. Knowledge of the different types of sanding tools and polishing tools required 3. Manual sanding with grinding stones 4. Manual sanding with sandpaper
White-goods Industry: Assembly of electric cooking hobs	1. Familiarity with steps in the assembly process 2. Manual handling of the various components (cables, plugs, connectors, etc.) 3. Operational use of manual tools 4. Operational use of electric tools

The literature review revealed a consensus that the skill set for future industry 4.0 and 5.0 operators includes skills related to digital literacy and use of various smart machines characteristic of cyber-physical industrial systems. Some papers included these skills under technical skills, while others had a separate category of these skills under digital or core competencies, or ICT literacy skills. Several papers mentioned the importance of skills related to the use of technologies such as tablets, autonomous robots and vehicles, wearable devices such as headsets and any related software installed into these devices [3,4,6,7,11–13]. Skills related to data management and data collection, and analysis were also cited in multiple papers, alongside skills regarding cybersecurity and technological troubleshooting [4,5,13,14]. The findings from the HTA conducted the future process aligned with the literature. The HTA showed that operators will need certain skills for their future roles to operate the new CONVERGING smart technologies under development, such as tablets, smart pens, AR/VR headsets, and robots.

For the current study, these skills related to the use of using new technologies and devices that were obtained from the literature review and HTA, were together categorized under a third category of "technological skills". The final list of technological skills is presented in Table 3.

Table 3. Technological Skills for Industry 4.0 and 5.0

	Technological Skills
1.	Basic technological troubleshooting (identifying and resolving minor errors that arise in the basic functions of the software)
2.	Comprehension of the industrial process

3.	Ability to interact with different kinds of technology to obtain and communicate information
4.	Understanding machine to machine communication
5.	Data collection
6.	Understanding and evaluating data
7.	Visualizing data
8.	Knowledge of the importance of cyber-security
9.	Awareness on maintaining cyber-security
10.	Operational use of a smart pen
11.	Operational use of a smart watch
12.	Operational use of an AR headset
13.	Teleoperation of robots through touch screen tablet
14.	Using hand gestures to teach robots industrial tasks
15.	Operational use of a touch screen tablet

2.2 Survey development

The next stage in the skills gap analysis involved the development of an online survey from the skills finalized in the skills identification stage. The survey aimed to capture the gaps between the operators' current skill level and the skill level expected of them.

Survey design. The online survey had two sections. In the first section, the respondents were asked to rate each skill on the operators' current skill level from 0 to 100 where 0 = Skill level a lot lower than required, 50 = Skill level matched to requirement, and 100 = Skill level a lot higher than required. In the second section, the operators were presented with a detailed description of the proposed future smart-production redesign of the task and were asked to rate how important each skill would be for the operator's future role in these systems. The rating scale was 0 to 100, where 0 = Skill is not at all important, 50 = Skill is moderately important, and 100 = Skill is essential. Therefore, the survey would render two scores for each skill, one score indicating the operators' current expertise in the skill and one score indicating the future requirement of the skill. By subtracting the former from the latter, we arrived at a score from 0 -100 indicating the gap in the skill. This method of arriving at a skill gap was inspired by the study conducted by [1]. Additionally, the respondents also had the option to select a box indicating the skill was not applicable to the role. After each list of skills, in both sections, the respondents were asked if they thought any skills were missing from the list, and they could enter text for their answer. All respondents were presented with the same list of soft and technological skills. The list of technical skills presented to a respondent was specific to the use case they worked in.

Participants. The link to the survey was sent to the use case leaders, who were requested to circulate the link to employees in positions related to management and supervision of factory operators, who were requested to fill in the survey. 5 responses were received from the automotive industry use case and 3 from the white-goods

assembly use case. All respondents from the former were employees working in the role of a process engineer, and the respondents from the former were an automation manager and two engineers.

Ethics. This study was approved by the Cranfield University Research Ethics Committee and conducted in accordance with the Cranfield Research Integrity Policy, the British Psychological Society's Code of Human Research Ethics, and the General Data Protection Regulation 2018.

3 Results

3.1 Technical skills

Technical skills for automotive industry. From the four technical skills investigated, the skill "Knowledge of different types of sanding and polishing tools" showed the highest gap with a score of 18.6, followed by the skill "Identifying fault areas on dies that require sanding/polishing" with 4.8. The skills of "Manual sanding with sandpaper" and "Manual sanding with grinding stones" had negative scores (-21.2, and -20.6 respectively) (Figure 1). In the question that asked if any skills were missing, one respondent stated that in the future, the skill to identify the reason for unsuccessful sanding and change required parameters, should be included.

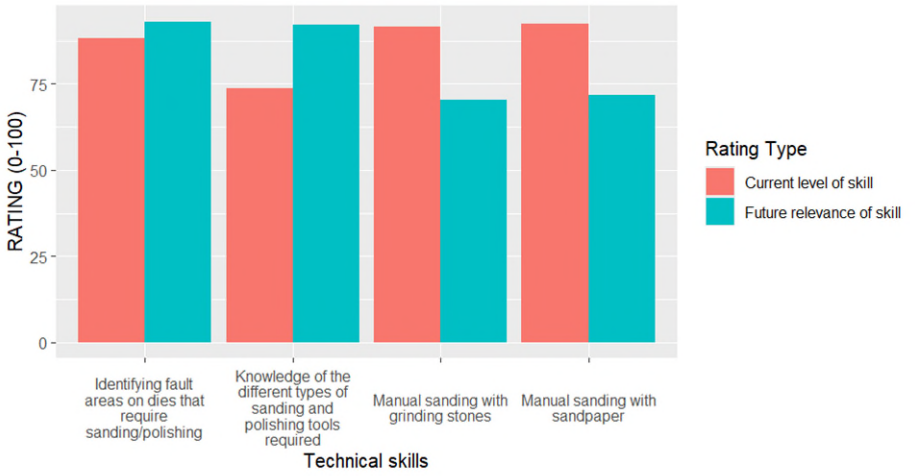


Fig. 1. Technical skills gap for automotive industry (n = 5)

Technical Skills for white goods assembly. From the four technical skills investigated, the skill "Manual handling of the various components (cables, plugs, connectors, etc.)" and "Familiarity with steps in the assembly process" showed the highest gaps

with scores of 20 and 19.67 respectively. The skill of "Operational use of electric tools" had a negligible gap of 2.34 and "Operational use of manual tools" showed a negative score (-9.33) (Figure 2). One respondent gave feedback about skills that were missed and mentioned that the ability to read the bill of materials (BoM), understand variants in the product range and assemble components following the BoM are technical skills that should be included.

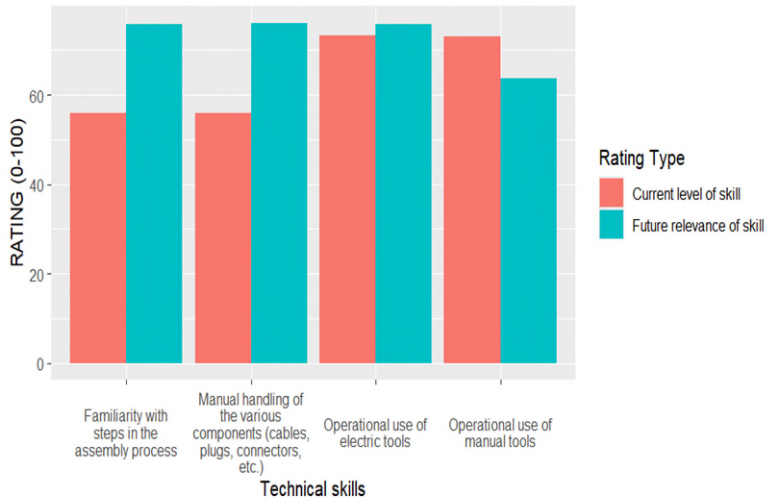


Fig. 2. Technical skills gap for white-goods assembly (n = 3)

3.2 Soft skills

The soft skill with the highest gap was "Conflict-resolution and negotiation" with a gap of 19.57, followed by "Mindset for lifelong learning and development" (gap = 16.71) and "Openness: Adaptability and Flexibility to new ideas and information" (gap = 16). The skills of "Self-confidence", "Emotional intelligence", "Creativity", "Team-working" and "People management" all yielded negative scores indicating that there were no gaps for these skills (Figure 3).

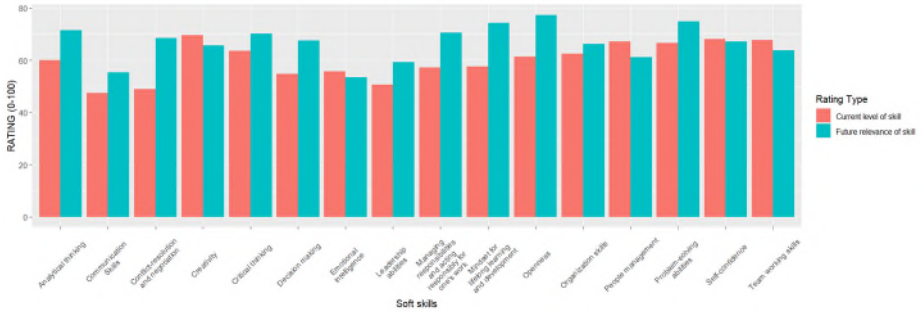


Fig. 3. Soft skills gap

3.3 Technological skills

The highest gaps were found for the skills "Operational use of a smart pen" (45.18), "Teleoperation of robots through touch screen tablets" (43.57), "Operational use of an AR headset" (42.96), "Operational use of a smart watch" (39.40), "Using hand-gestures to teach robots industrial tasks" (39). No technological skill was found to have a negative score, implying a gap existing for all skills. The skill with the lowest gap was found to be "Knowledge of the importance of cyber-security" (8.63). Figure 4. presents the results for technological skills.

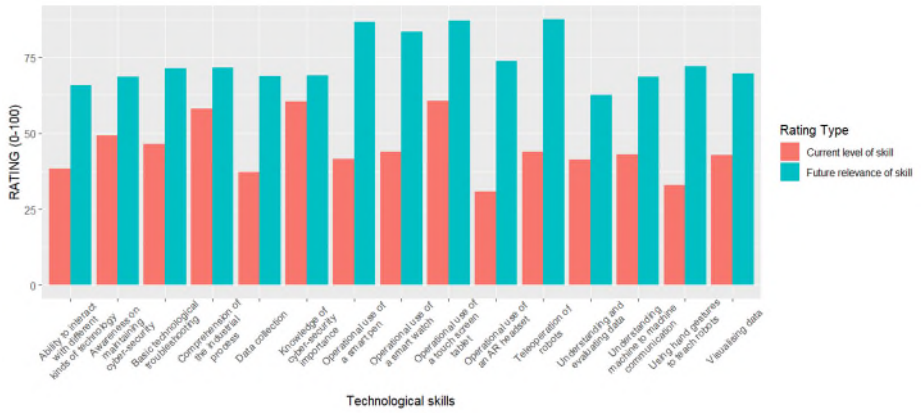


Fig. 4. Technological skills (n = 8)

4 Discussion

From the analysis of the ratings for each skill, the highest gaps were found in the list of technological skills. Most technical skills had small gaps or no gaps (negative scores). The negative scores for the skills "Manual sanding with sandpaper", "Manual sanding with grinding stones" (automotive industry) and "Operational use of manual tools"

(white-goods industry) implies that the need for these skills may die out in the future. This could be due to the CONVERGING project developing solutions that attempt to replace certain manual steps with automation, but with a cautious consideration of only automating steps that are unergonomic, dangerous or cause physical discomfort (such as movements with repetitive action).
The soft skills with the highest gaps are related to conflict-resolution, lifelong learning and openness. The increased relevance of skills like openness, and mindset for lifelong learning in the future Industry 5.0 systems can be attributed to the dynamic, reconfigurable nature of these systems which would entail operators to be more open and adaptable, and keen to learn new roles and use new machines. A high skill gap for conflict resolution can be seen as a recognition for the ability to mitigate hurdles to collaboration. Collaboration is often cited as a feature of the future Industry 5.0 systems, and therefore the ability to resolve conflict can help maintain collaboration. However, if this is the case, the skill of "Team working: cooperation and coordination" should have also shown a gap since the skill should increase in relevance for the future, nevertheless, this gap was negative. The skills of "Self-confidence", "Emotional intelligence", "Creativity", and "People management" also all yielded negative scores indicating that these skills are considered unnecessary or unimportant for the future. Further investigation into the reason for the skill gaps or the lack thereof for these soft skills, is necessary to understand the impact of each skill in future industrial job roles.

From a categorical perspective, the results from the skills gap survey revealed that technological skills should be the primary focus of any upskilling measures for these industrial tasks. The skills with the highest gaps were those related to the ability to use and interact with smart technologies in the future smart-production solutions, such the AR headset, smart pen, smart watch, touch screen tablet and robot. These findings suggest that training for Industry 5.0 solutions must focus on helping operators build skills to effectively use and work with robots and other smart technologies. These findings from the skills gap survey align with the insights captured from previous group discussions with industrial operators [15], wherein operators spoke of a lack of trust and uncertainty towards the robots and new smart machine solutions. During these discussions, the operators mentioned that they would need structured, in-person training opportunities to learn how to use and interact with the robots and smart-machines, and the training sessions should be opportunities for operators to build familiarity, comfort and effective comprehension of the new smart technologies. In these workshops, the feedback from operators reflected that they do not have adequate confidence in using new smart-machines. This survey shows that the factory line managers and supervisors also share this belief that operators need to be upskilled for the use of future smart technologies.

5 Limitations and Future Directions

This study was a feasibility study to test the skills shortlisted from the literature review and HTA, and test if the survey functions well to identify the gaps. The biggest limitation of this study is the low number of respondents for the survey. While the results

from the few respondents did grant use case specific insights specifically in the case of technical skills, the results cannot be considered as generalizable to the target population of all industrial operators. This will be a primary limitation to address in a re-administration of the survey after it has been reviewed and developed further.

One of the respondents for the white-goods survey mentioned in the skills feedback section that the survey should distinguish between technical skills for operators and technical skills for the support maintenance team, as the respondent felt some of the skills were more relevant to support maintenance rather than the operators who work on the task. This was insightful feedback and indicates a need to develop a more rigorous approach to shortlist and validate an exhaustive list of technical skills for different aspects of the industrial task.

In terms of future directions, the findings from this survey should be discussed with factory line managers/supervisors, during future in-person workshops. This will enable an understanding of the reason behind these skill gaps, and a better assessment of why certain skills are more relevant than others, specifically in the case of soft skills. As technological skills have shown the highest gaps, discussions should be held with operators to understand how they would like to be trained and upskilled for working with new smart-technologies for future production systems.

6 Conclusion

This feasibility study demonstrates a novel methodology to identify the skills that industrial operators currently possess for their tasks, the skills they will need for the future redesigns of the task in a smart-production system, and whether a skill gap exists. With the use of HTA and TD in addition to a literature review, skills which are task-specific can be identified and the skill gap was assessed through a survey. The survey results show that the largest gaps exist for skills related to the use of new smart technologies such as collaborative robots and smart devices, while certain technical skills and soft skills may become redundant in the future. The next step is to review and develop the survey based on feedback received and discuss the findings with industrial operators to understand the reasons behind the gaps for certain skills and the lack of gaps for others.

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