Uniting Man, Machine, and Work

Competences for the 4th industrial revolution

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Abstract

The fourth industrial revolution will rapidly and drastically change the content of work within the technical sector. This requires new competences from technical staff, which through research so far have only been described in very abstract ways. In the first study, we asked employers in the technical sector to indicate which competences they believe to be the most important for the technician of the future. Extending on this in the second study we asked technicians to materialize these competences and explain what they require from employers to show these competences.

The results show that employers are searching for technicians that are extraordinarily talented in expert knowledge, remarkably focused towards accuracy and take a proactive approach to their work. The technicians describe aspects of the competencies that are related to functioning in an increasingly ambiguous environment with ever changing priorities. Technicians therefore need a work environment and work content that constantly challenges them to learn.

Keywords: Smart Industry; Competences; 21 century skills

The employee of the future

The fourth industrial revolution - also known as 'Smart Manufacturing' or 'Smart Industry' - can be described as the second machine age, in which machines not only supply muscle, but also brain power in the form of robots, internet, and artificial intelligence (Brynjolfsson & McAfee, 2014). The fourth industrial revolution is usually interpreted as a merger of three types of technological developments: (1) extensive digitization of product and process information by sensors and information technology; (2) new technologies that are used in manufacturing areas, such as 3D printing and robots; (3) technology that connects production equipment and all value chain partners in the production process on all levels (Roadmap Smart Industry, 2014). Due to this, it is expected that the fourth industrial revolution will entail a demand for technicians to possess new competences in numerous ways, if they want to preserve their value.

Firstly, routine tasks are expected to disappear at an increasing pace, due to automation and robitization. The remaining work is consequently more complex beyond what the current range of technicians can handle (Van Est & Kool, 2015). Thus, it requires a highly skilled workforce, which will be able to design, implement and use the innovative technologies (HCSS & TNO, 2013).

Secondly, recent technological developments demonstrate that technology does not only affect routine tasks, but also non-routine tasks. For example, in 2005 Levy & Murnane stated that a car driver could not be substituted by a computer. However, in 2010 Google introduced a self-driving car that could function in an equally reliable manner as the average car driver. Moreover, even cognitive routine tasks are now taken over by smart machines,

such as the creation of a design for a heat exchanger by the means of ‘generative design software’. This is a process in which work is carried out 100% autonomously by software (Brynjolfsson & McAfee, 2017). Meaning tasks can and are constantly being executed by machines.

Thirdly, businesses are discovering new ways of organizing and consequently adopting their business models. For example, some high-tech enterprises already allow their clients to operate the manufacturing technology of their suppliers over the internet, enabling same-day delivery of their orders. There is hardly any need for operator intervention. The technical employees are in permanent contact with the client and require an extensive insight into the supply chain and methods of data analysis. Goos (2013) infers that such innovative ways of organizing will go hand in hand with developments regarding self-managing teams, staff rotation and ongoing training of competences such as cooperation and information sharing.

The aforementioned changes in work lead to an increasing need for new competences of employees, which are often described as 21st century skills, 'lifelong competences', or 'key skills' (Voogt & Roblin, 2012). They allow technical employees to function in an environment, which is heavily influenced by technological developments and subsequently allows them to successfully work with newly involved robots and machines. Examples of such skills are: creativity, the ability to innovate, adapting and collaborating with other disciplines and flexibility (Voogt & Roblin, 2012). However, publications about ‘21st century skills’ often display abstract descriptions of the competences incorporated and have not yet been operationalized for the technicians, making them a valid study, but not directly practical for the technical sector. The purpose of this paper is therefore to describe and operationalize the ‘21st century skills’, in order to create a more graspable concept, which can be used as a

reference point by companies and technicians. In order to achieve this, two studies have been conducted. In the first study, we asked employers in the technical sector which competences they believe to be most important for the technician of the future and in the second study we asked technicians to concretize these competences. Finally, to come to practical recommendations for employers, we asked which work (environment) characteristics technicians require from employers to show these competences in terms of work context and content factor.

Study 1

Method

Population. A questionnaire was distributed among 236 directors and HR managers from companies within the technical sector. Among these companies 91 were small enterprises (<50 employees), 113 medium enterprises (50 to 250 employees) and 32 large enterprises (250+ employees). A wide range of companies in the technical sector have been approached as heterogeneously as possible: from metal and electrical companies to more high-tech process technology and ICT companies.

Procedure The questionnaire measured how important employers considered certain competences for a technical employee in the future (five years from now), divided among three domains: knowledge, skills and attitude. The questionnaire consisted of twelve competences (Corporaal, Vos & Geusendam, 2016): (1) expert knowledge, (2) multidisciplinary knowledge and (3) business knowledge, (4) adaptability, (5) commercial skills, (6) accuracy, (7) analytical skills, (8) communication skills, (9) cooperation, (10) proactivity, (11) creativity / innovation and (12) dealing with uncertainty. Each competence is

questioned with three to six questions, which were derived from previous qualitative research about the competences of technical employees for the future (Corporaal, Vos & Geusendam, 2016). Respondents were asked how important they considered the competency for technical employees in five years from now, using a five-point Likert scale (1 = very unimportant, 5 = very important).

The scales from the questionnaire were tested for reliability, using Cronbach's Alpha with a test criterion of $\alpha > .70$. Based on this criterion, four questions were omitted from the data analysis, while the other 8 were considered. The following competences were measured with a reduced number of questions: business knowledge, creativity/innovation, commercial skills and adaptability. Table 1 gives an overview of the number of questions, after omission, per competence and the associated reliability. Despite the insufficient reliability for the competence creativity/innovation ($\alpha = .68$), the decision has been made to include the competence in the study as the test criterion of $\alpha > .70$ is nearly met.

Table 1: Overview Cronbach's Alpha after omission

Domain	**Competences of the technician of the future**	**Number of questions**	**α**
Knowledge	Expert knowledge	6	.91
	Multidisciplinary knowledge	4	.76
	Business knowledge	4	.70
Skills	Analytical skills	5	.83
	Accuracy	6	.72
	Communication skills	6	.74
	Collaboration	5	.90
	Creativity/Innovation	5	.68
	Commercial skills	4	.78
Attitude	Proactivity	3	.78
	Dealing with uncertainty	4	.72
	Adaptability	4	.77

Findings

When it comes to knowledge competences, employers describe that expert knowledge and business knowledge are the most important. They value this more than having multidisciplinary knowledge. It is notable that this finding applies to all companies, regardless of the size.

Accuracy and creativity/innovation are emphasized as more important competences, than analytical skills, communication skills, collaboration and commercial skills. However, differences between the responses and size of company are visible here. Larger companies value analytical skills, communication skills and collaboration skills than more than Small - Medium Enterprises (SME). Overall, it seems that larger companies set higher demands on the technical employee of the future, compared to the smaller companies.

When it comes to attitude, the companies indicate that adaptability is particularly important, followed by a proactivity and dealing with uncertainty as a close runner-up. Similar to the previous domain, differences between company sizes are visible. In particular, proactivity and being able to deal with uncertainty is more important for large companies than for SMEs. Generally, the case seems to be that larger companies place higher demands on the technical employee of the future when it comes to their attitude. The above findings are illustrated in the table below.

Table 2. Differences between size of companies regarding the importance of knowledge, skills and attitude

		Importance of the competence (1-5)			
Domain	**Competences of the technician of the future**	**Total group**	**Small companies (<50)**	**Medium companies (<250)**	**Large companies (>250)**
		(N=236)	**(N=91)**	**(N=113)**	**(N=32)**
Knowledge	Expert knowledge	3.97	3.86	4.02	4,10
	Multidisciplinary knowledge	3.50	3.50	3.43	3,73
	Business knowledge	4.11	4.14	4.07	4,11
Skills	Analytical skills	3.48	3.44	3.41	3.88
	Accuracy	3.83	3.86	3.77	4.00
	Communication skills	3.45	3.35	3.49	3.66
	Collaboration	3.55	3.47	3.48	4.04
	Creativity/innovation	3.76	3.68	3.79	3.91
	Commercial skills	3.50	3.41	3.63	3.27
Attitude	Proactivity	3.62	3.63	3,53	3,93
	Dealing with uncertainty	3.49	3.47	3,37	4,01
	Adaptability	3.86	3.75	3,93	3,92

Study 2

Method

Population In order to explore and describe the relevant aspects of the competences as defined in study 1, semi structured interviews were held with 31 technical employees from different companies in central Europe. The approached employees were described by their direct supervisor as ‘future-proof’ and ‘ready for the fourth industrial reality’. The sample group included technicians from the high-tech industry, manufacturing industry, and the IT sector.

Procedure The first goal of the interviews was to explore the relevant aspects of the competences of described in study 1. The focus here is only placed on the eight competencies that employers consider to be the most important for the technical employee of the future to embody. Therefore, the interviewees were firstly asked to describe a work situation they were most proud of. Following this, the interviewee was asked to describe the competences that

were required in the described work situation and to further clarify on the competences with the use of examples. Subsequently, the competences from study 1 were presented to the technical employee, in the form of cards. By asking the interviewee to describe work-related examples per competency, relevant aspects of the competences could be explored.

The second goal of the interviews was to determine what technicians need from companies to demonstrate these competences. Therefore, technicians were once again asked to describe the same work situation where they are most proud of and which competences were required in this situation. Based on that, the interviewee was asked to describe which work (environment) characteristics supported them in showing these competences.

At the end of the interview, space was given to the technicians to appoint any competences and/or work context and content factors that had not been discussed yet, but which they consider to be vital for their work.

Analysis After importing all interview transcripts into ATLASTI, the transcripts were independently coded by three researchers. The codes have been agreed upon prior to this process so that all were aware of the requirements.

Findings

In this section, we firstly describe the specifications of the eight highest scored competences from study 1, which were defined by the technicians. Expert knowledge has consciously not been included, because it is so divergent that it cannot be operationalized into one description. Secondly, we present the work context and content factors, which the technicians defined as needed to demonstrate these competences.

Competences

Multidisciplinary Knowledge comprises of two factors. Technicians describe that (1) communicating with other disciplines is crucial when working on a project with a group of multiple professions. The technicians state that *"people (from different disciplines) do not speak the same language"* but that you *"need to have some knowledge about other processes"* in order to be able to *"start working together"*. Furthermore, the technicians state that (2) knowledge about the customer is always at key of all processes, as the customer is the ultimate user of the creations. For example, technicians state that *"you do this (creating the process or product) by talking to the customer about what they want"* and that they need to *"extract the relevant parts"*, in order *"to be able to communicate that to other parties"* and ultimately create something that fits the needs of the customer.

Business Knowledge is made up out of two factors. Technicians find the (1) knowledge about other disciplines essential. This is because it helps them to view products from different perspectives, which provides them with new insights. For example, they advocate: *"if you want to think of new things, you have to know what already happened"* and figuratively state *"if you have eye patches on, you will just continue drawing the same circle"*. Furthermore, technicians find that the (2) knowledge about processes helps to deepen their skills and promote innovation. They value this because it supports the creation of more complex and expert-driven products. Technicians describe this factor as: *"when you have expert knowledge, you are capable of going deeper into something"* and they think that this *"is more important than knowing (...) a little bit about a lot of things."* Lastly, it was noted that the technicians describe that their tasks do not require knowledge about finance and that they therefore do not need this knowledge. They advocate *"as long as I keep them (Finance*

Department) updated (...), the financial side is less important to me", because then they can *"focus on the things in which I am good at"* instead.

Accuracy consists of two factors. (1) Awareness about the importance of precision engineering important in the implementation phase, but not as pivotal in the creation phase. They describe that precision can prevent innovation from arising while trying to mentally create a new product, however, when it has to be concretized, they advocate that preciseness is key in order to create a technically functioning product. For example, one part of the technicians' state that *"it is very important that a product is precise"* as *"if they find out later that it is not good, then everything needs to be done again"*, while another group advocates that *"if you think about innovation"* and try to be precise as the same time, then *"you lose the ability to come up with these new solutions"*, since they then go *"into too much detail"*. The description of (2) the ability to conduct the job precisely and accurately likewise also differs, depending on the stage that the innovation is taking place in. One part of the technicians describes that *"you do not have to be accurate to be more creative (...) in order to think of it"*, while the other group advocates that they *"do not even want to start with it"* when everything is not *"worked out precisely"*.

Collaboration is comprised of four factors. Firstly, (1) contributing to the joint solution has been described by technicians are working together to create that whole innovate product. This is highly advocated by technicians as crucial for them in order create new and innovative products. As illustrated, *"Eventually you want one product that is going to work, not multiple different parts. It's important to work on it together and communicate well to input the joint energy into the result"*. Moreover, (2) offering constructive feedback to

colleagues was described as a feeling of mutual understanding and engagement, which is considered fundamental in allowing technicians to produce innovative results and create special products. For example, technicians advocated that *"People give you real feedback and you can work with that, that makes good collaboration".* Thirdly, (3) open-mindedness was acknowledged by technicians as being vital for them, as they acknowledge that to see other great things you need to learn from other people. As illustrated, *"Understanding people is really very important. You will always need other people, you need to search for people".* Lastly, (4) taking responsibility for collective results is promoted as an important competency to embody in order to produce innovation as a result. For example, *"In the end you are jointly responsible for the product, as a team to build something creative".*

Creativity & Innovation is comprised of three factors. (1) thinking outside the box to create innovative products is considered a very relevant competency to embody by technicians as they describe this to be where the innovation lies. As illustrated, *"It's the out of the box part that is important, I like to keep an open mind as well, and be creative to sketch out my ideas and just draw things."* Moreover, (2) generating unconventional ideas has been described and advocated by technicians as a factor that is essential. For example, "*the proudest moment is when you think of something, that hasn't been thought of earlier and that it then works brilliantly"*. Lastly, (3) creating new ideas through existing knowledge is considered to be vitiable to display. For example, *"when you see a problem in the actual work and pick it up and combine things which are seemingly unrelated and convert it into something else, connecting them, that is innovation."*

Proactivity is comprised of four factors. Firstly, (1) the attitude to constantly improve themselves and develop oneself was described by technicians as crucial to sustain innovative

ability. As explained by a technician *"you have to continuously keep up with the world and the changes (...) specifically in your industry sector"*. Secondly, to (2) taking initiative, is considered to be the root of productivity by technicians. They described that in their eyes taking initiative is that *"you have to be a bit like a very enthusiastic Labrador, who continuously comes back and is very enthusiastic."* Further illustrated by technicians taking initiative is about dedicating *"your own time and sometimes on your own costs to experiment and create something innovative"*. Moreover, (3) voicing own opinion is likewise considered fundamental by technicians. For example, technicians express that *"it is important to communicate your opinions and ideas, and notify others about (...) your own point of view (...) if you don't do this, the quality of the work will not be right, and definitely not (...) innovative"*. Lastly, (4) resilience was described by technicians as being fundamental for them to transform ideas into action. As illustrated *"You have to have this drive, an inner flame to do more"*. Subsequently one needs to stand his ground *"when I am being retained, I am looking for alternative routes to get it done"* through *"rules are there to bend, but you cannot break them"*.

Dealing with uncertainty is comprised of three factors. Technicians find that to (1) dealing with conflicting interests and tight deadlines can be intimidating, but is very important in their daily work. The technicians describe that it *"is a bit in between. It is something that you can halfway get comfortable with and halfway actively seek"* and that *"you need to deal with the uncertainty"* as it is *"paired with creativity"*. Technicians also find it crucial to be able to (2) switch quickly between changing expectations. They value this, as they find that the technician should be able to change as quickly as the technology. For example: *"You should be able to work on one thing first and then move to another thing,*

just as the world changes, you need to change too and move with the change." Lastly, technicians find that (3) dealing with an uncertain outcome / goal is a critical skill to possess when wanting to be innovative. To illustrate: *"You can't be worried or afraid of uncertainty"*, because ultimately, *"the whole process of innovation is uncertainty (...). In fact, I think that the ability to deal with uncertainty is even more important than being creative or innovative"*.

Adaptability is comprised of three factors. Firstly, technicians describe the (1) ability to adapt to various roles as a crucial baseline. They think this is pivotal in order to be innovative and therefore something which must be embraced. For example, as expressed *"if you can't adapt then all of this, the innovation becomes obsolete"*. Secondly, (2) working effectively in a climate of constant change is described by the technicians as resilience to deal with a climate of constant change and ambiguity. For example: *"You should be able to work on one thing first and then move to another thing. As the world changes, you need to be able to change with it. Technicians still need to be effective, so they must adapt"*. Lastly, (3) taking over the work from colleagues has been described by the technicians as the ability to perform various functions in the width of adjacent technical functions. They think this is necessary in the field of work to be cross functional. A technician explained that *"I am definitely all rounded, I wasn't specialized in each area but I knew how different functions worked"*.

Work (environment) characteristics that stimulate the competences

Autonomy is constructed of three factors. Firstly, (1) freedom to set own goals, which is essential for technicians to innovate. As an illustration technicians emphasize that *"if I make my own decisions then I become more innovative and find more joy in my work"*.

Moreover (2) freedom in choosing own work methods is also decisive in allowing technicians to be innovative, as advocated: *"there was no dictating which tools should be used",* but instead "*how and in which way I get there is up to me"* which demands innovation. Lastly, failure is described by the technicians as an atmosphere wherein (3) freedom to make mistakes is guaranteed and is seen as a learning opportunity. They think this is pivotal because it promotes the generation of new ideas, the pursuance of the realization and provides an opportunity to learn from it if it goes wrong. For example, *"you learn from then, because you know then from experience why an idea did not work or was a bad idea"* and *"if you learn something from it then it is more valuable"* and *"it is not a bad thing when innovation fails."*

Leadership consists out of two factors. Technicians describe that (1) support in the form of trust of the leader is highly valued and contributes to their motivation. One technician for instance states: *"If I am not getting the trust, then I am not going to be too invested either"* and "*if my manager eliminates all my ideas then nothing will happen.*" On the other hand, technicians also state that support could arise from oneself, rather than from a leader. For example, it is advocated that *"the leader as a person maybe does not have to be there, but it is important to have a lead"* and that technicians were *"not innovative because of good leadership".* Technicians describe that the (2) leadership style should provide them with freedom, and should be steering if necessary. This is because they value that a leader has faith in them to do the right thing, but to be a sparring partner at the same time if needed. It has for example been stated that they would like a leader *"who provides freedom"* and who is able to *"give someone good directions, but also to call back if someone thought of something that is not possible at all"* and to be their *"sparring partner".*

Challenge is comprised of three factors. Firstly, (1) challenge in solving and dealing with new or difficult problems, which is vital according to technicians in order to keep them motivated. For example, technicians advocate that *"when there is no challenge in your work, you lose the enthusiasm*" and "*excitement of not knowing"* is needed *"as that is when you have to start being creative"*. Secondly, (2) challenge in problem solving, has been described as *"constantly having to try out new processes, and new ways of coming to solutions"* which does provide technicians with a challenge, that they consider to be *"the baseline"* for innovation. Lastly, (3) challenge in job complexity is crucial according to technicians in order to keep the work interesting and encourage innovation. For example, technicians express that "*job complexity is needed in the workplace to keep the excitement and commitment level up"*.

Organization climate is made up of two aspects. Firstly, (1) technicians describe that certitude is pivotal what is characterized by a feeling of trust among co-workers. They think this is important because it lays the foundation to share ideas and to concretize the content. One technician for instance states: *"If someone feels strong within his profession it is easier for him to take things into perspective and to determine which works and what not"*. Secondly, (2) an interactive meeting place, is described by the technicians as spot in which they can have mutual entertainment with each other (e.g. a football table). They stress the importance of this because it empowers the mutual collegial ties and serves as a platform for brainstorms. For example: *"you transform your organization into a ... breeding ground wherein mushrooms arise from the ground"*.

Variety is made up of two aspects. The (1) variety in the range of tasks of the technician, is described by the technicians as crucial in order to use these insights to generate innovation. For example, it was stated that: *"if I would have to always do the same, (...) it*

would be very difficult to innovate." and that the differentiation in tasks helps to *"come to something new"*, as it enables them to *"look at it from different angles"*. Concerning the (2) variety in the skills and talents, which the job of the technician appeals to, the technicians describe it bipartite: it can both foster and break innovation. Technicians for instance advocate that is useful, because *"then I can use what I learn in the different ones (projects)"*, while others say that this even should be avoided, as *"you have to restrict people to innovate in the right space"*.

Discussion

Through this paper, we aim to specify the competences that the technicians need in order to successfully function in the new industrial revolution.

The first contribution observed from this paper is the identification of these competences When considering the competences that are required in the new industrial revolution it can be summarized that employers are searching for technicians that are extraordinarily talented in expert knowledge, remarkably focused towards accuracy and take a proactive approach to their work. Knowledge is overall seen as the most crucial competence by employers, as they describe they search for technicians with both expert knowledge and business knowledge. In addition, the ability for technicians to deliver work accurately is also illustrated as crucial, as well as their proactive attitude. Remarkably, employers rank competences such a creativity and collaboration as less important, which is contradictory to previous research that expected that cognitive skills will become more important (Westlake, 2014) to survive the fast ever changing environment (Meel, 2015).

In the second study, we explored the relevant aspects of the competences to establish

which aspects of the competences the technicians themselves find important to work in the fourth industrial reality. Firstly, taking initiative and having resilience are key factors to possess according to technicians. This arises from the fact that the technicians need to succeed in an increasingly ambiguous environment with ever changing priorities and they believe that this can only be achieved through resilience. To deal with this constantly changing climate, the technicians emphasize the importance for them to deal with all kinds of uncertainty, by being able to change at the same pace as the technological developments. The technicians must offer solutions for unstructured problems through generating unorthodox ideas and solutions. In the search for these solutions, the technician must work together with other disciplines, in which it is crucial to 'speak each other's language'. A remarkable difference is that employers state that knowledge is the most important for technicians, while the technicians themselves state that they need skills that enable them to cope with the constant technical developments, which they face in their daily work.

Additionally, to the competences required for the technician of the future, this study identified the work (environment) characteristics that technicians consider important to allow them to display the earlier mentioned competences. Technicians want to be well prepared for continuous changes by performing challenging tasks in which they work together with colleagues (from other disciplines) and have the necessary freedom for implementation of projects. The technicians must be supported (by colleagues and / or supervisor) in open and constructive cooperation with each other, as they hold the feeling of security as very important. The technicians find variety and development very important: so they must be prevented from continuously carrying out the same work.

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