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PROMOTING INNOVATIVE TRAINING & PERFORMANCE SUPPORT AT THE MANUFACTURING WORKPLACE. THE MAN.TR.A™ MODEL FOR LACE PROJECT

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Abstract

Manufacturing is going through what many call the 4th industrial revolution with new technologies coming into place to disrupt the way we produce, distribute and sell goods in contemporary markets.

This paper presents an EU support action for Learning Analytics Community Exchange (LACE) which includes a specific work package dedicated to the study and promotion of innovative learning analytics approaches in the manufacturing work place. It presents an innovative training process based on maturity modelling called MAN.TR.A. which will be used in the LACE 30 months life cycle to detect, classify and analyze best practices in manufacturing training aimed at identifying process models and appraisal paths for those seeking excellence in the manufacturing training sector.

Europe's Smart Manufacturing challenge: from the Internet of Bits to the Internet of Things

After changing the service and content industry in the last decade, the web is now passing from the 'Internet of Bits' to the 'Internet of Things'. New disruptive technologies such as 3d Printing, Advanced Robotics and Cyber Physical Manufacturing are appearing that will revolutionize the way we produce, distribute and purchase goods in contemporary markets. Technology is not only about to change production plants and infrastructures.

When it comes to its workforce, Manufacturing is currently undergoing what many have called the 'Big Crew Change' which has already affected other skill intensive sectors such as Oil & Gas in the recent past (Cardinali, 2010). New processes and skillsets will need to evolve in synch in the quest towards a holistic transformation of how businesses conceive, design, produce and distribute artefacts in contemporary, digital, marketplaces. New production processes and models, such as *Produce on Demand* and *Make to individual*, matched with innovative business and financial models such as *Crowd funding*, are rapidly reshaping the way contemporary plants might plan and optimize their supply chains from the provision of raw materials and resources to final product distribution and sales.

In a nutshell, it is now clear that another '*webificatio*n' wave is about to hit industry. This time it will address the roots of goods fabrication and distribution, an economical space potentially with a much higher likely impact than that reported for the digitization of the content and service industry, with manufacturing still retaining a 17% share of the world's overall GDP, (Europe reported at 15.1% in 2012), despite the massive off shoring and de-industrialization forces influencing western economies in the recent past (Figure 1).

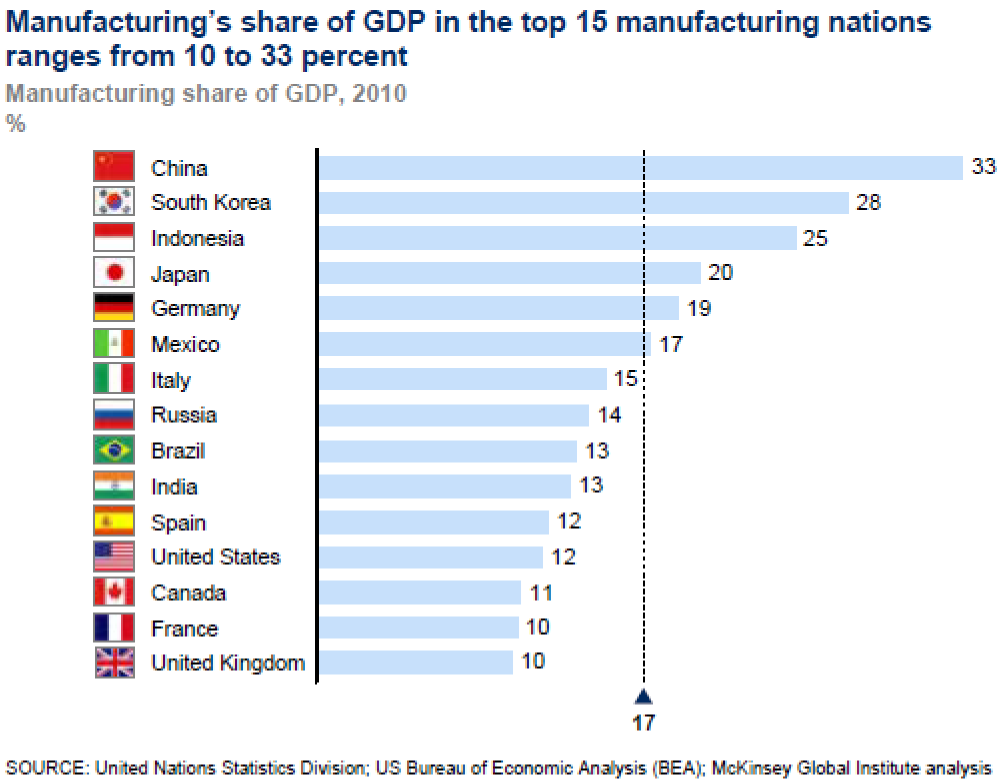

Figure 1. Manufacturing Share of GDP – Top 15 manufacturing nations by GDP % (Manyika et al. 2012. p.22)

What many call the '4th industrial revolution' is most likely to happen within the next decade and with the potential to completely change world trade balances, rewarding those who picked up on the change and invested in the training and support of their workforces at the right time, re-insourcing jobs and competences. Luckily Europe, along with other western economies, hasn't completely de-industrialised and today the challenge for Manufacturing leadership is still an open question (Figure 2). It is also well known that manufacturing has a strong spill-over effect on the rest of the economy and especially on overall productivity. Each euro of added final demand in European manufacturing generates around 50 cent of additional final demand in other sectors of the economy. Regaining Europe's manufacturing leadership will revitalize the knowledge and technology base of the whole European economy, which is crucial for achieving sustainable development.

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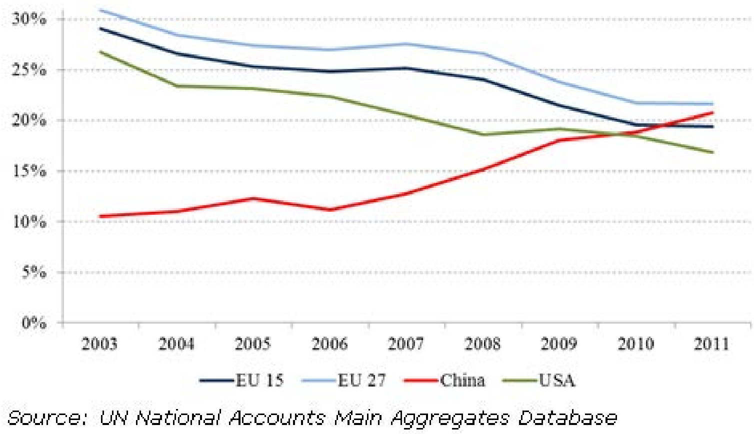

Figure 2. Europe's Manufacturing Share of GDP – EU 2013 competitiveness report (European Commission, 2013)

Smarter Training for Smarter Manufacturing

With the pace of change affecting manufacturing today, accelerating the pace and quality of STEM (Science, Technology, Engineering, Math) teaching directly within the curriculum plans in secondary and higher education of its future managers is as urgent as improving process and technology skills directly at the workplace of its current workforce.

Despite the evidence that supports these claims the majority of research currently under development in manufacturing is about technology implementation. It directs little attention to the users and how they master this technology (Aiman-Smith & Green, 2002). This is becoming an important issue whilst manufacturing is changing fast, and engineers need to learn new types of skills and to keep pace with change and new trends (O'Sullivan et al., 2011).Industrial training has its own pedagogical and cognitive perspectives and should be addressed within dedicated research projects in a different manner than other types of educational provision. Additionally, the typology of knowledge found in the workplace differs from what is found in educational settings, since it depends heavily on the experience of working contexts and conditions (Eraut, 2009).

Improving the skills of people at the necessary speed and level may be achieved only by the massive use of learning technologies. A survey in 2005 in a variety of industrial settings confirmed that many workplace environments already were using technology-aided learning methods, and had a strategic plan for e-learning. However, only a small number indicated that this plan was efficient and that they could measure the return from their investment on training (Bonk et al., 2005). Despite its historical inclination to measure and assess performance, neither analytics nor performance indicators were linked to those processes adopting technologies for educational purposes

As a result although manufacturing systems have done valuable labour on staying up-to-date with the big changes affecting their market today, the need for proper personnel training and

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appraisal has been highly under-estimated, mostly passive and inadequate, lagging behind the pace and quality of improvements to the other pillars usually addressed during manufacturing transformation initiatives, namely Plants, Infrastructures and Processes.

The LACE Project – Promoting learning analytics for better training and performance support at the workplace

The LACE Initiative (Learning Analytics Community Exchange, www.laceproject.eu) began its work in January 2014. This project funded by the European Commission, brings together a group of leading academic, industrial and governmental stakeholders[1] with the aim to promote the adoption of learning analytics and improve education and industrial training. Within the next 30 months the nine LACE partners will be promoting knowledge creation and exchange on Learning Analytics (LA) and Educational Data Mining (EDM); increasing the evidence base; contributing to the definition of future directions; and building consensus on interoperability and data sharing.

From the very beginning the activities of the Lace project will be directed towards three main investigation axis, those of primary and secondary education, further and higher education and industrial training involving broader communities. The area of industrial training will be analyzed in a dedicated Work Package by partner Infinity Technology Solutions (short name ITS, www.itsinfinity.com) an innovative Italian SME active in Manufacturing IT recently acquired by a new Public Private industrial investment group named sedApta™ (www.sedapta.com), first of a series of M&A actions targeting the acquisition of leading EU SMEs to merge them and create a stronger EU player in the emerging global marketplace for Smart Manufacturing IT solutions.

With a long experience in the use and standardization of analytics and key performance indicators (KPI) for process monitoring and appraisal, Manufacturing is a very capable industry case to benchmark the level of analytics maturity for training and the potentials of their adoption within workflow based training and performance support initiatives.

Promoting Analytics for Manufacturing Training & Performance Support

The Manufacturing industry and its enlarged supply chain eco system have been using advanced analytics and data mining techniques for more than a decade to support process measurement, monitoring and improvement. Today the area of manufacturing intelligence and analytics is one of the fastest growing sectors of the Business Intelligence world. Manufacturing organizations use Key performance indicators to evaluate their success, or to

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[1] Open Universiteit Nederland, NL; Cetis, the Centre for Educational Technology and Interoperability Standards at the University of Bolton, UK; Institute for Educational Technology at the Open University, UK; Infinity Technology Solutions, sedApta Group, IT; Skolverket, the Swedish National Agency for Education, SE; Høgskolen i Oslo og Akershus, NO; ATiT, Audiovisual Technologies, Informatics and Telecommunications, BE; EDEN, the European Distance Education Network, UK

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evaluate the success of a particular activity in which they are engaged (Fraser et al., 2012; Fitz-Gibbon, 1990). Sometimes success is defined in terms of making progress toward strategic goals but often success is simply the repeated, periodic achievement of some level of operational goal (e.g. zero defects, 10/10 customer satisfaction, etc.).

Using KPIs within process modelling and improvement has gone a long way in manufacturing. ANSI/ISA-95, or ISA-95 as it is more commonly called, is an international standard developed by and for global manufacturers defining a five layer abstract reference model (Figure 3) describing the plant environment and its operations from low level 'machine to machine' automation to high level 'business to manufacturing' transactions. It was developed to describe and standardise performance analytics and indicators to be applied in all industries, and in all sorts of processes, like batch processes, continuous and repetitive processes.

The underpinning value of a model like ISA95 has been that to create a 'process standardisation culture' within the industry, with the aim to unify definition and measurement of performance indicators, in a continuous drive towards persistent improvement and appraisal of processes, usually called 'maturity modelling'.

As a consequence 'Maturity Modelling' has recently become a very hot topic due to the rapid 'transformation' forces running through the manufacturing world with high end analysts such as Gartner™, Atos™, McKinsey™ and the like rallying plants to analyse, measure and monitor the degree of formality and optimization of processes, from *ad hoc* practices, to formally defined steps, to managed result metrics, to achieve active optimization of the overall production effort for their clients.

With such a background it is highly likely that industrial stakeholders when approached with new training solutions promising improvement for their workforce by using analytics will want to 'observe and measure' such metrics using the same approach and wave length used for the other processes in their work space. This is especially true if they will need to justify investments into new scenarios to their IT and Finance departments, require the integration of solutions in the cockpit and, last but least, need to report results up through their decision chains used to decide upon increased data aggregation levels and decision support dashboards.

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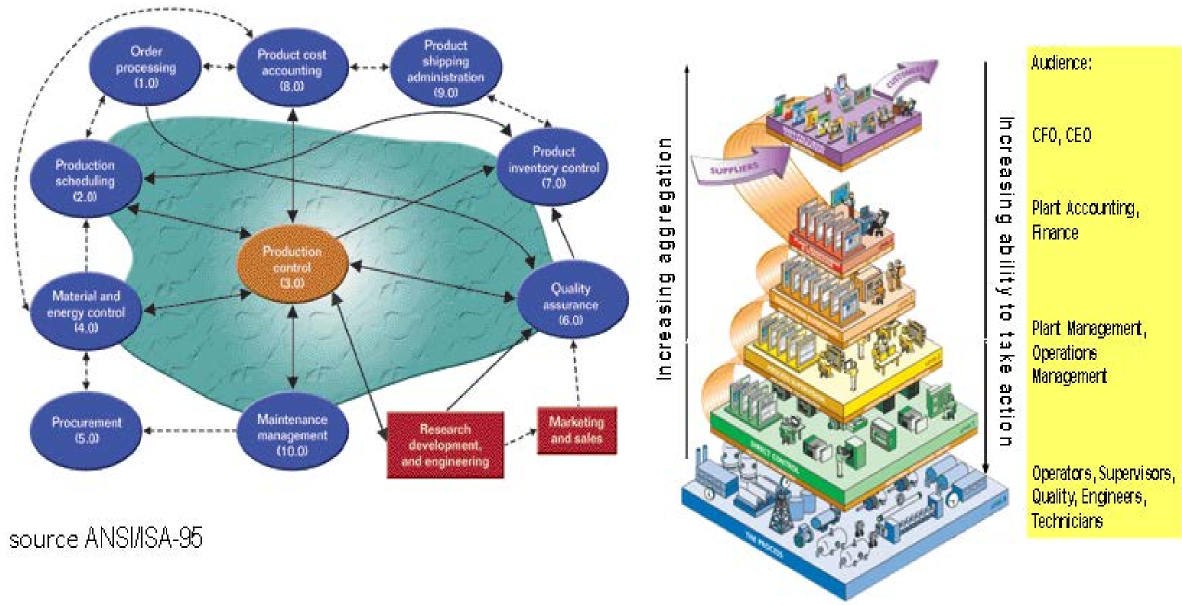

Figure 3. The ISA 95 Manufacturing Abstract Model by ANSI (DBpedia, 1995)

Reporting will be another key request, possibly available through an approved management framework such as the balanced scorecard (Cobbold & Lawrie, 2002), which is a semi-standard structured report, supported by design methods and automation tools that can be used by managers to keep track of the execution of activities by the staff within their control and to monitor consequences arising from these actions.

In conclusion proposing learning analytics to manufacturing executives will always imply assessment of the changes applied to the underpinned training processes, in order to detect successes and pitfalls, and above all the ROI of performed changes. If we want to promote analytics at the manufacturing workplace, we will need to abstract the training processes underpinned, choose the right KPIs for measuring and monitoring and assess improvements introduced by the suggested changes with KPIs relying upon a good understanding of what is important to the organization and always considering which department will be responsible for measuring the performance.

Using the MAN.TR.A ™ Maturity Model for the LACE analysis

Studying and promoting learning analytics in the manufacturing workplace in order to identify good learning experiences will be at the heart of LACE WP5 activities throughout the 30 months lifecycle of the project. In particular a new study methodology will be used, the MAN.TR.A™ maturity level model, developed by sedApta Group companies involved in the Italian National Cluster for Intelligent Factory, or IIF (Figure 4).

The IIF Project is Italy's leading technological cluster recently awarded by the Italian Ministry of Universities & Research (MIUR) to a consortium of 22 core partners and 76 associated partners coming from leading Manufacturers, Universities and Research centres representing Italy's manufacturing scene. With an overall planned investments of more than 48 ML Euros

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of which 11 ML Euros is co-funded by MIUR, the project aims to preserve and re-launch the Italian manufacturing context, taking into account the distinctive features of the Italian manufacturing system and the evolution of European and Global industry according to H2020 agendas as defined by the European Commission and the European Factory of the Future Association EFFRA.

One of the drivers behind the engagement of the sedApta Group of companies in the IIS initiative is the definition of a Manufacturing Training Analytics maturity modelling device (The MAN.TR.A cube™, short name MAN.TR.A^3), that will be used within LACE case study and reporting activities.

The MAN.TR.A^3 model (Figure 5) is intended as a way to help the analysis, classification and monitoring of training processes within 3 axis meant to discover their level of maturity in terms of well defined, observable and repeatable workflows, with measurable KPIs to be monitored within an overall (training) improvement and appraisal strategy.

To achieve this, the MAN.TR.A^3 model blends achievements coming from many years of development in the areas of Competency, Process and Maturity modelling and is developed around 3 main classification axis defining respectively:

1. Training Outcomes. Being the entry point under which to start classifying the incoming training experiences under analysis and expressing the target training outcomes expected
2. Training Processes. Representing the process workflow under which the training experience takes place, during delivery
3. Training Maturity. Representing the scale of maturity of the training process under observation, ideally implying at its highest levels the use of repeatable processes and KPI analytics for performance monitoring and continuous appraisal

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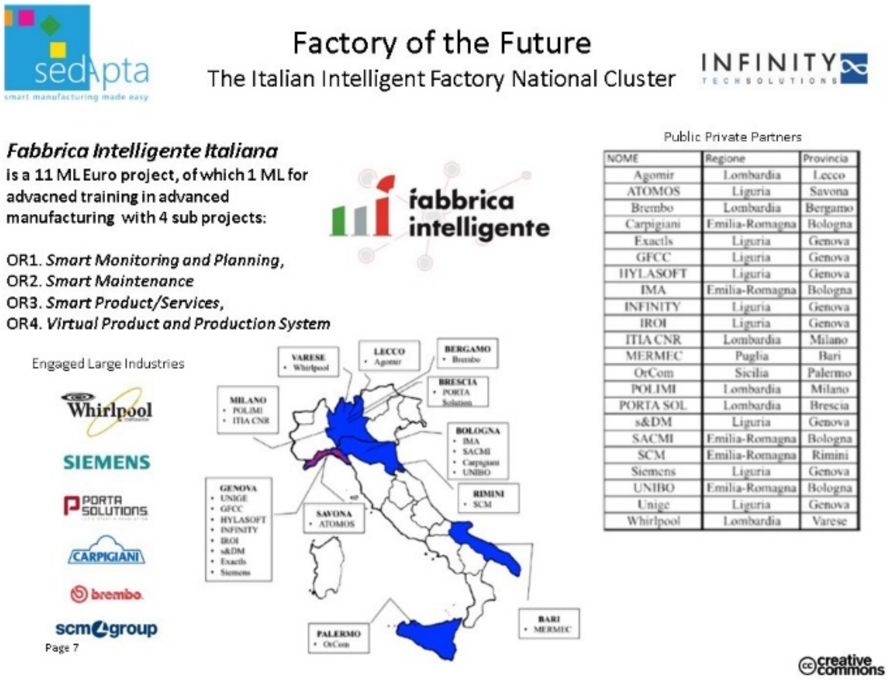

Figure 4. The Italian Intelligent Factory (IIF) initiative

For each axis several different scales and approaches were investigated and verified models selected in order to show that they were well understood and appreciated by the stakeholders of the sector under investigation.

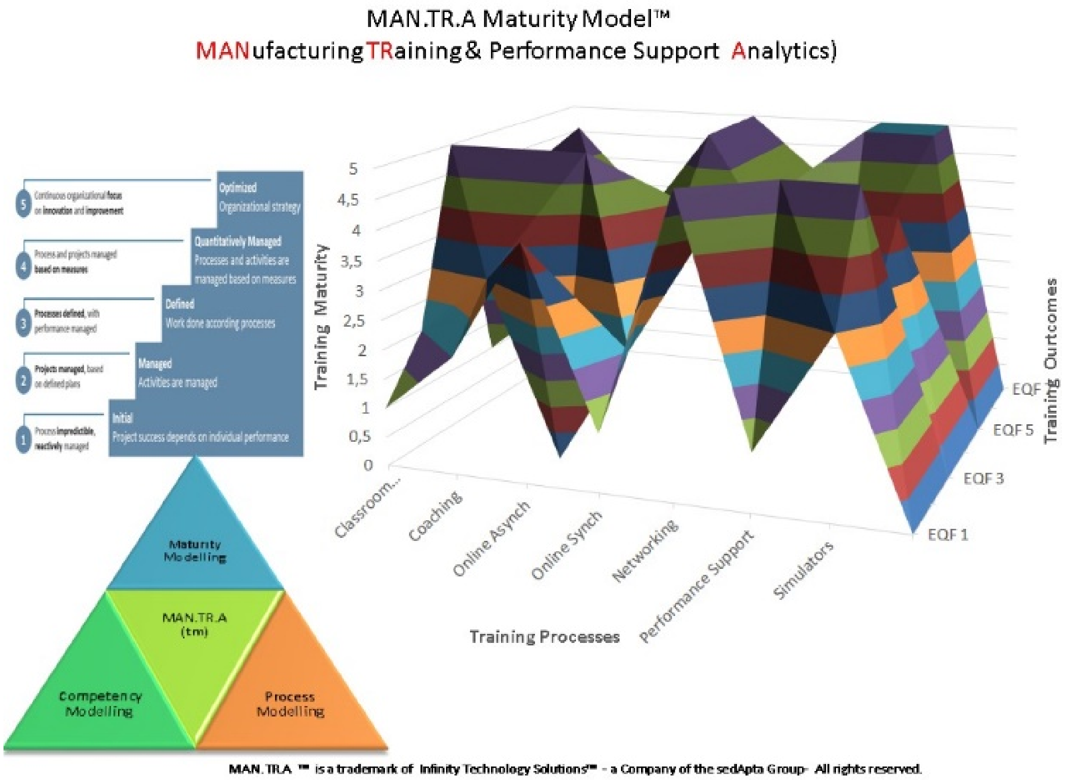

Figure 5. The Manufacturing Training Analytics Maturity Model – MAN,TR.A ™

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In particular for Axis 1 of the MAN.TR.A^3 (Training Outcomes) an independent skills classification translation and alignment meta-model was searched given the many areas and regions expected to enter the analysis, possibly with different skills vocabularies, taxonomies and curricula. The selected model was that of the European Qualification Framework (EQF – http://ec.europa.eu/eqf/home_en.htm) due to its popularity in the European vocational space and training agencies (Figure 6).

The second axis of the MAN.TR.A^3 space (Training Processes) is then meant to describe which training strategy is used to achieve the predefined training outcome. This axis scale had several options to define training strategies, from those more appropriate to a pedagogy oriented model, something highly volatile in the industry sector, to those enabling a formal classification of the procedures and flows of processes used when delivering the training experience. The latter was selected because it enables analysts to combine workflow notations within each entry describing not only the 'as is' process used in the case but possibly also its 'to be' optimization.

Level	Knowledge	Skills	Competence	Example
Level 1	Basic general knowledge	basic skills required to carry out simple tasks	work or study under direct supervision in a structured context	
Level 2	Basic factual knowledge of a field of work or study	basic cognitive and practical skills required to use relevant information in order to carry out tasks and to solve routine problems using simple rules and tools	work or study under supervision with some autonomy	lower secondary school (FI)
Level 3	Knowledge of facts, principles, processes and general concepts, in a field of work or study	a range of cognitive and practical skills required to accomplish tasks and solve problems by selecting and applying basic methods, tools, materials and information	take responsibility for completion of tasks in work or study; adapt own behaviour to circumstances in solving problems	(GCSE Grades A*-C UK)
Level 4	Factual and theoretical knowledge in broad contexts within a field of work or study	a range of cognitive and practical skills required to generate solutions to specific problems in a field of work or study	exercise self-management within the guidelines of work or study contexts that are usually predictable, but are subject to change; supervise the routine work of others, taking some responsibility for the evaluation and improvement of work or study activities	Abitur, vocational school
Level 5[1]	Comprehensive, specialised, factual and theoretical knowledge within a field of work or study and an awareness of the boundaries of that knowledge	a comprehensive range of cognitive and practical skills required to develop creative solutions to abstract problems	exercise management and supervision in contexts of work or study activities where there is unpredictable change; review and develop performance of self and others	HND
Level 6[2]	Advanced knowledge of a field of work or study, involving a critical understanding of theories and principles	advanced skills, demonstrating mastery and innovation, required to solve complex and unpredictable problems in a specialised field of work or study	manage complex technical or professional activities or projects, taking responsibility for decision-making in unpredictable work or study contexts; take responsibility for managing professional development of individuals and groups	Honours Bachelor Degree, vocational university German State-certified Engineer, Business Manager and Designer (Fachhochschule) Bachelor, City and Guilds Graduateship (GCGI), German Fachwirt, German Operative Professional
Level 7[3]	• Highly specialised knowledge, some of which is at the forefront of knowledge in a field of work or study, as the basis for original thinking and/or research • Critical awareness of knowledge issues in a field and at the interface between different fields	specialised problem-solving skills required in research and/or innovation in order to develop new knowledge and procedures and to integrate knowledge from different fields	manage and transform work or study contexts that are complex, unpredictable and require new strategic approaches; take responsibility for contributing to professional knowledge and practice and/or for reviewing the strategic performance of teams	Masters, vocational university (Fachhochschule) Masters, City and Guilds (MCGI)
Level 8[4]	Knowledge at the most advanced frontier of a field of work or study and at the interface between fields	the most advanced and specialised skills and techniques, including synthesis and evaluation, required to solve critical problems in research and/or innovation and to extend and redefine existing knowledge or professional practice	demonstrate substantial authority, innovation, autonomy, scholarly and professional integrity and sustained commitment to the development of new ideas or processes at the forefront of work or study contexts including research	Doctorate City and Guilds Senior Awards - Fellowship

1. ^ The descriptor for the higher education short cycle (within or linked to the first cycle), developed by the Joint Quality Initiative as part of the Bologna process, corresponds to the learning outcomes for EQF level 5.
2. ^ The descriptor for the first cycle in the Framework for Qualifications of the European Higher Education Area agreed by the ministers responsible for higher education at their meeting in Bergen in May 2005 in the framework of the Bologna process corresponds to the learning outcomes for EQF level 6.
3. ^ The descriptor for the second cycle in the Framework for Qualifications of the European Higher Education Area agreed by the ministers responsible for higher education at their meeting in Bergen in May 2005 in the framework of the Bologna process corresponds to the learning outcomes for EQF level 7.
4. ^ The descriptor for the third cycle in the Framework for Qualifications of the European Higher Education Area agreed by the ministers responsible for higher education at their meeting in Bergen in May 2005 in the framework of the Bologna process corresponds to the learning outcomes for EQF level 8.

Figure 6. The European Qualification Framework used for Axis 1 of the MAN.TR.A^3 classification device
(source: http://ec.europa.eu/eqf/documentation_en.htm, http://en.wikipedia.org/wiki/European_Qualifications_Framework)

The Training Processes workflows listed in axis 2 may be further detailed using a BPM (Business Process Management) notational device such as that made available by the Object Management Group (OMG – http://www.omg.org) for describing workflow activities and

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roles, already well known and accepted by industry analysts and stakeholders when detailing working processes in the manufacturing industry (Figure 7).

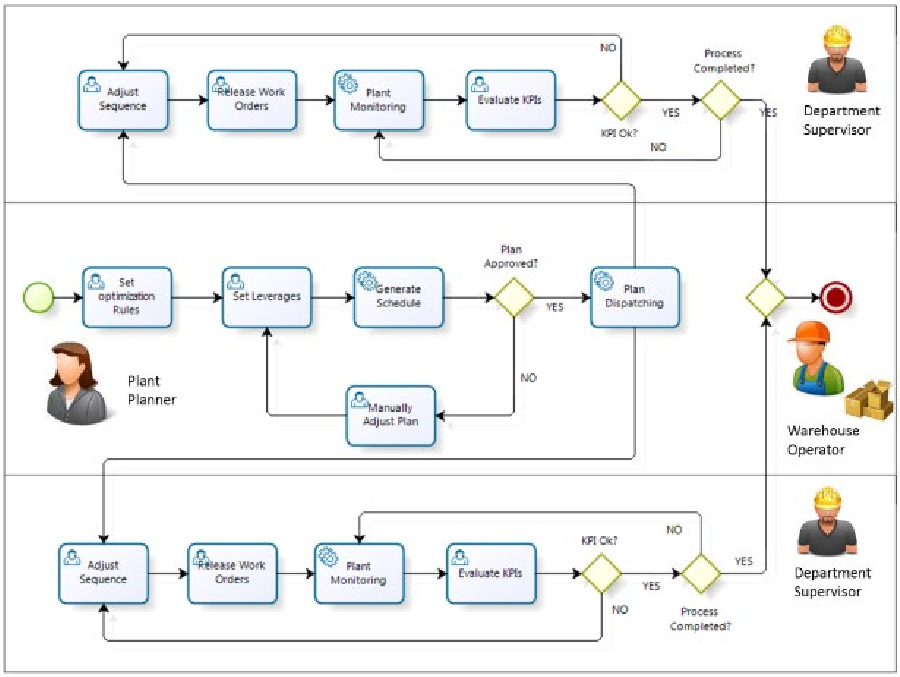

Figure 7. Example of a BPMN 2.0 workflow used by sedApta analysts for describing manufacturing processes

The third and final classification axis of the MAN.TR.A[3] space is that expressing the Training Process Maturity level.. For such an axis many maturity model samples are available on the market. From those developed for the Software Engineering Industry (e.g. the Capability Maturity Model Integration, CMMI; from Carnegie Mellon University) to those more recently designed to support process analysis and improvement in the manufacturing sector (e.g. the Manufacturing Maturity Model, MMM, by ATOS origin) and their supply chains (e.g. the Supply Chain Operations Reference, SCOR, model by PricewaterhouseCoopers). Each of these maturity modelling approaches come with the goal of bringing processes to higher levels of standardization with predictable performances measurable by means of well-defined and agreed KPIs. Many KPIs have been designed and circulated for such purposes such as those directly included in the ISA and SCOR models or the independent library from American Productivity & Quality Center (i.e. AQPC Process Definitions and Key Measures) and ISO (i.e. the ISO22400 key performance indicators for manufacturing operations management). All KPIs, from wherever they come, need a high level of maturity to be identified, measured and reported within standard and reusable processes, together with the capability of their continuous assessment and reporting by means of scorecards in order to abstract, at the needed decision levels, data to support decision-making regarding new actions and process improvement. Finally each model comes with its compendium of more or less formal appraisal strategies delivered through specialized consulting services and training (e.g. the Standard CMMI Appraisal Method for Process Improvement, SCAMPI).

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For the third axis of the MAN.TR.A^3 space (maturity level) a scale of 5 has been chosen shortlisting the de facto maturity levels usually used for defining process maturity in the manufacturing industry, to help understand their value to sector decision takers.

Conclusions and further work

The effort of studying and promoting learning analytics in the manufacturing workplace in search of good learning experiences, has not been underestimated at the start of the LACE Project. Prior to approaching manufacturing stakeholders to collect and report cases during the 30 months lifecycle of the project, the project has equipped itself with a sound study and reporting methodology named MAN.TR.A^3 which will guide the identification, analysis and positioning of industrial cases using analytics within workplace based training and performance support presenting adequate RIAD (*Reusability, Interoperability, Accountability and Durability*) levels within adopted processes.

Further work will include the development of a MAN.TR.A abstract reference architecture for optimized training and performance support processes at each of the MAN.TR.A cube levels and a MAN.TR.A appraisal methodology to guide Manufacturers towards 'to be' processes with improved training maturity levels and efficiency.

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