



White paper for IO1:
Theoretical Industry 4.0
PSM Skills Framework and
Gamification Overview in
PSM Education

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Introduction

In the modern network economy, more than half of the entire income of a firm is directly routed through to its suppliers. Hence, not only from the perspective of an individual firm, but from the perspective of European competitiveness the management of the buyer-supplier interface, i.e. professional Purchasing and Supply Management (PSM), is crucial. In order to achieve these aims, world class training and education of purchasers are necessary. Since the beginning of the fourth industrial revolution (I4.0), cyber-physical systems with autonomous machine-to-machine communication are re-shaping parts of our economy and PSM is one of the areas that is most strongly affected. Therefore, the skill set purchasers need to manage and organise such systems and to efficiently prevail in an I4.0 world is also changing.

Project PERSIST was introduced to address the changes brought on by I4.0, with the following aims:

- a) identifying those skills which are likely to prevail and those which are newly added to the profile of a European purchaser to develop an I4.0 PSM Skill framework,
- b) developing a module-based course for higher education to teach these skills,
- c) to develop new, gamification and playful interaction oriented didactical elements for purpose student-centered teaching approach, including a gamified MOOC.

Although the fourth industrial revolution or Industry 4.0 (I4.0) is frequently used term, the challenge is that there is currently very little knowledge available on how to react to the I4.0 induced change from an educational perspective. The following questions arise:

- How will the purchaser in the I4.0 have to act?
- Which skills and knowledge are purchasers likely to need in I4.0?
- How to train current students as purchasers of the future in an efficient, modern way (i.e. student-centred), i.e. already reflecting the new technologies?

PERSIST uses a set of methods, including expert interviews and Delphi studies for the generation and verification of knowledge. For the practical application of a novel and student-centered teaching format, a module-based course using gamification elements and playful

interaction concepts will be designed and created to train individuals to deal with I4.0 changes. To design the module-based course the project PERSIST follows the didactic approach of Constructive Alignment for the design of competence-oriented lectures in academic contexts, starting with the definition of competence-oriented learning outcomes.

Upon completion of PERSIST the following will be available:

1. Providing a framework for PSM Skills in I4.0 for academics and practitioners (knowledge, skills and traits)
2. Description of a multi-perspective approach to the collection of future competence requirements for PSM managers in the context of I4.0 (best practice world café, expert interviews and Delphi study)
3. Describing a procedure for using gamification elements and playful interaction concepts in teaching courses (accessible tool-set using modern didactical tools such as online digital learning elements, gamification, MOOC)
4. Developing a module-based course with digital and gamification elements for I4.0 PSM Skills
5. Developing and providing open-source learning material to prepare students and professionals for the changes in PSM in the era of I4.0, e.g. gamified MOOC

PERSIST will support Europe in seizing the changes that I4.0 presents, at a crucial time in its development. I4.0 is a significant opportunity for the industrialised economies of Europe, but they need to be enabled to take full advantage of these opportunities. In the long term, PERSIST provides an exceptionally strong lever for the European economy with a competitive advantage through being prepared for and embracing this inevitable change. Via new learning and teaching methods in I4.0 PSM, students will form the future workforce in PSM in the I4.0 era and will lead to a better communication and understanding in strategic buyer – supplier relations.

The work is divided into five scientific project activities together with additional project activity for the management of the consortium, communication and dissemination and exploitation of results. Each of the five main activities leads to a set of intellectual outputs (IOs) as presented in Table 1.

ID	Name of the output/description of activity
PM	Project management, coordination and promotion
IO1	Theoretical Industry 4.0 PSM Skills Framework and Gamification Overview in PSM Education
IO2	Qualitative Prestudy by conducting World Cafe Sessions and Expert Interviews as a Starting Point for the Delphi Studies
IO3	Conducting Delphi Studies on future PSM-competencies in the era of Industry 4.0 and the use of Gamification in Higher Education
IO4	Design of module-based course concept for PSM with Gamification elements based on the outcomes of the Delphi studies
IO5	Designing of templates and content for the format of learning material

Table 1 Overview of PERSITS's Intellectual Outputs.

The evaluation and exploitation of project results is considered a crucial issue. Therefore, an Advisory Board (AB) has been created to ensure that an independent body can accompany the project and support its dissemination. It includes experts in the fields of PSM education and practice, whose task is to advise and guide PERSIST on promising directions and the long-term vision of the project, based on both their knowledge of the current state and global trends in their fields and also their practical experience. The AB will also comment on the implementation of the project's activities regarding the research, mobility, networking of researchers, dissemination of information, and exploitation/dissemination of results.

1. Intellectual Output 1: Theoretical Industry 4.0 PSM Skills Framework and Gamification Overview in PSM Education

1.1. Aims

In order to gain a comprehensive overview of future competence requirements of managers in PSM, PERSIST starts with an analysis of the scientific literature, accompanied by other more practice-oriented sources, such as job advertisements. The focus of this analysis is on the competences (a construct of knowledge, skills and traits) that are needed in the field of purchasing and supply management, in combination with a high involvement of the implications of Industry 4.0.

At the same time, PERSIST maps developments in the use of gamification and serious games in higher education and especially in business administration and purchasing and supply management. Literature reviews on existing initiatives in education (academic and industry), which offer PSM courses dealing with the digital transformation (learning programs, modules, courses) are conducted.

1.2. Research Questions

To support the overall aim, the following research questions were formulated:

Research questions related to PSM skills:

1. What are the PSM skills that have been identified in the Industry 4.0 oriented academic literature as being necessary for modern PSM practitioners?
2. What are the domains (digital, social) of Industry 4.0 oriented academic literature dealing PSM related skills?
3. What PSM skills have been identified in the Industry 4.0 oriented academic literature for specific areas of Industry 4.0 purchasing?

Research questions related to gamification overview:

1. How has gamification been used in Purchasing & Supply Management education?
2. What are the characteristics of gamified education?
3. What are the underlying principles/techniques of gamified education?
4. What are the processes and the stages to implement gamified education?

1.3. Structure of the white paper

The structure of the IO1 white paper is determined by the research questions and has two parts. The first part is focused on the identification of PSM skills based on Industry 4.0 oriented scientific literature. In addition, the identification of the required types of PSM skills based on job description advertisements describing current PSM environment is provided. The second part of the white paper focuses on gamification approaches which can support PSM teaching and learning. In order to deal with the research questions and to provide some order to a complex discussion, the project team have used an interrelated inputs-outputs model, which uses 2 different sets of input data to produce several key outputs and the paper is structured to deal with each of these in turn. The inputs are as follows:

NUMBER	INPUT NAME	DESCRIPTION	WHITE PAPER CHAPTER
1	PSM Industry 4.0 Skills from the academic literature	A systematic review of PSM and Industry 4.0 related academic literature to identify what skills are needed for PSM professionals in their workplace	2
2	Gamification PSM literature review	A systematic review of PSM and gamification related academic literature to identify approaches which support PSM teaching and learning	3

Table 2 IO 1 Inputs

Using several different approaches, a detailed analysis of the inputs shown above leads to the following outputs:

NUMBER	OUTPUT NAME	DESCRIPTION	WHITE PAPER CHAPTER
1	PSM Industry domain overview	Overview of main domains connecting Industry 4.0 and PSM skills	2.2
2	Overview of PSM Skills required in Industry 4.0 oriented scientific literature	List of PSM skills together with their importance which are recognized in Industry 4.0 oriented scientific literature	2.3.2
3	Overview of PSM Skills for Industry 4.0 core purchasing technologies	List of PSM skills together with their importance which are recognized by scientific literature focused specifically on Industry 4.0 core purchasing solutions	2.3.3
4	Overview of PSM Skills for Industry 4.0 maturing purchasing technologies	List of PSM skills together with their importance which are recognized by scientific literature focused specifically on Industry 4.0 maturing purchasing solutions	2.3.3
5	Overview of PSM Skills for Industry 4.0 emerging purchasing technologies	List of PSM skills together with their importance which are recognized by scientific literature focused specifically on Industry 4.0 emerging purchasing solutions	2.3.3
7	Overview of gamification approaches that support PSM teaching and learning	A systematic review of PSM and gamification related academic literature to identify approaches which support PSM teaching and learning	3.3

Table 3 IO 1 Outputs

2. Industry 4.0 PSM Skills Framework

The European parliament define Industry 4.0 as “the comprehensive transformation of the whole sphere of industrial production through the merging of digital technology and the internet with conventional industry. In short, everything in and around a manufacturing operation (suppliers, the plant, distributors, even the product itself) is digitally connected, providing a highly integrated value chain.” (Davies, 2015). The identification of future requirements for jobs and skills, which can ensure the successful implementation of Industry 4.0 is becoming a more and more important task for researchers (Gehrke et al., 2015), policy makers (Smit et al., 2016) and corporate managers (Lorenz et al., 2015). The implementation of automation and digital technologies, such as Cyber-Physical Systems, the Internet of Things, cloud computing and Big Data in manufacturing significantly affect work processes and the work environment (Chryssolouris et al., 2013). The content and nature of jobs is changing and new kinds of job are being introduced. These changes also impact Purchasing and Supply Management (PSM). Although there is an increase in the attention being paid to the changing role of PSM professionals, research on the changes in the jobs and skills required by Industry 4.0 is still emerging. Furthermore, the majority of Industry 4.0 and skills-oriented research (e.g., Gehrke et al., 2015; Hecklaue et al., 2016) is mostly theoretical and tends to provide only a general overview of Industry 4.0 related competencies, without any specification for the different organizational areas where technologies are being implemented (Pinzone et al., 2017). Such approaches make it difficult to identify how specific job profiles should evolve and what types of skills will be required and needed in specific positions after Industry 4.0 is implemented (Dworschak & Zaiser, 2014). To mitigate these shortcomings in the area of Purchasing and Supply management, a detailed literature review focused on PSM skills within Industry 4.0 was conducted.

2.1. Methodology for Industry 4.0 PSM Skills literature review

The Industry 4.0 PSM skills literature review is focused on the identification of future procurement skills within industry 4.0 oriented scientific literature. It starts with the creation of a relevant search syntax.

2.1.1. Syntax creation

The purpose of the syntax creation step is to propose suitable search syntax (string) which can identify those articles which identify and describe future procurement skills. Because the aim of this review is to identify procurement skills connected to Industry 4.0. the project team decided to divide the search string into three segments:

- **Procurement segment:** include all synonyms and keywords connected with procurement, such as: PSM, supply chain, etc.
- **Industry 4.0 segment:** include all synonyms and keywords connected with Industry 4.0. such as industrial revolution, 4th, smart, IoT, IoE, digitization, digitization, future, trends, big data, automation, robotisation, robotization, artificial intelligence, autonomous
- **Skills segment:** include all synonyms and keywords connected with skills, such as: Competencies, training, education

The conjunction “AND” was used to connect different segments and conjunction “OR” was used to connect keywords within the segments.

In order to be confident that all main search terms and their synonyms are included in the search string, the IO1 lead developed a table in which every partner of PERSIST project added terms into the specific segments. The terms included in the search string are presented in following table (Table 4):

Procurement segment:	Industry 4.0 segment:	Skills segment:
PSM	industrial revolution	competencies
supply chain	4th	training
purchasing	smart	education
procurement	IoT	skill
buying	IoE	knowledge
sourcing	digitisation	competency
contract management	digitization	competence
supplier management	future	digital literacy
supply management	big data	task performance
outsourcing	automation	self-efficacy
supplier-buyer relationship	robotisation	capability
inter-organisational relationship	robotization	
buyer-supplier relationship	intelligent robotics	
supplier selection	artificial intelligence	
supplier evaluation	autonomous	
vendor selection	Industry 4.0	
vendor evaluation	Lights out	
	machine dominant	
	cooperating machine	
	learning machine	
	interoperability	
	virtualisation	
	virtualization	
	virtual manufacturing	
	interconnect	
	cyber physical	
	cloud	
	machine to machine	
	smart factory	
	intelligent factory	
	real time factory	
	factory of things	
	data mining	
	ERP	
	augmented reality	
	digital industrial age	
	data processing	
	data economy	
	industrial internet of things	
	IIoT	
	CPS platform	
	networked manufacturing	

	Digital Manufacturing	
	data security	
	data analytics	

Table 4 Terms included in the search string

As per previous related projects (e.g. PERFECT), these keywords were also translated into the German language and a literature review of German scientific literature was also conducted.

After the selection of proper phrases, the next step was to select the segments to be searched in which part of the articles. The distribution presented in Table 5 was agreed by project partners.

	Procurement segment:	Industry 4.0 segment:	Skills segment:
Title	x		x
Abstract	x		x
Keywords	x		x
Fulltext		x	

Table 5 Distribution of search terms between parts of articles.

Based on the distribution presented in table 5, all articles which mention Industry 4.0 or synonyms and also mention procurement skills or synonyms were therefore identified.

2.1.2. Database selection, time frame and selection criteria:

The literature review was done using the SCOPUS database. The time frame was determined by the year that term Industry 4.0 was first used. The term Industrie 4.0, shortened to I4.0 or simply I4, originated in 2011 from a project in the high-tech strategy of the German government, which promotes the computerization of manufacturing. Therefore, the literature review includes only peer-reviewed articles, conference papers and book chapters indexed in SCOPUS database and published after 2011.

The search string used for searching in the SCOPUS database has the following structure (English version):

TITLE-ABS-KEY ("industrial revolution" OR "4th" OR "smart" OR "IoT" OR "IoE" OR "digitisation" OR "digitization" OR "future" OR "big data" OR "automation" OR "robotisation" OR "robotization" OR "intelligent robotics" OR "artificial intelligence" OR "autonomous" OR "Industry 4.0" OR "lights out" OR "machine dominant" OR "cooperating machine" OR "learning machine" OR "interoperability" OR "virtualisation" OR "virtualization" OR "virtual manufacturing" OR "interconnect" OR "cyber physical" OR "cloud" OR "machine to machine" OR "smart factory" OR "intelligent factory" OR "real time factory" OR "factory of things" OR "data mining" OR "ERP" OR "augmented reality" OR "digital industrial age" OR "data processing" OR "data economy" OR "industrial internet of things" OR "IIoT" OR "CPS platform" OR "networked manufacturing" OR "Digital Manufacturing" OR "data security" OR "data analytics") AND TITLE-ABS-KEY ("PSM" OR "supply chain" OR "purchasing" OR "procurement" OR "buying" OR "sourcing" OR "contract management" OR "supplier management" OR "supply management" OR "outsourcing" OR "supplier-buyer relationship" OR "inter-organisational relationship" OR "buyer-supplier relationship" OR "supplier selection" OR "supplier evaluation" OR "vendor selection" OR "vendor evaluation") AND TITLE-ABS-KEY ("competencies" OR "training" OR "education" OR "skill" OR "knowledge" OR "competency" OR "competence" OR "digital literacy" OR "task performance" OR "self-efficacy" OR "capability") PUBYEAR > 2011 AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "cp") OR LIMIT-TO (DOCTYPE , "ch"))

2.1.3. Definition of inclusion and exclusion rules

Based on our previous experiences with systematic reviews, inclusion and exclusion rules were established in order to determine which articles should go forward for a more detailed review. These are shown in Table 6 and were proposed and validated by the PERSIST project partners.

Inclusion rules	Exclusion rules
Abstract written in English or German	Research conducted before 2011
Scientific peer-reviewed articles	Scientific poster or conference abstracts
Papers mentioning concrete skills	

Table 6 Inclusion and exclusion criteria

2.1.4. The selection procedure

The database of articles identified by the search string were divided among PERSIST project partners. The first part of the screening process was to review the abstracts and allowed each partner to identify articles, conference papers or book chapters suitable for full text analysis. Then the selection based on full text analysis were performed. Distribution of reviewed articles based on the year of their publication is presented in the next table (Table 7):

	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Articles identified by search string	335	381	436	419	482	460	580	558	20*	3671
Selected articles	0	4	3	2	1	6	22	11	1	50

*One article that was approved but not published yet in SCOPUS journal was added by project partner into review and selection

Table 7 Distribution of selected articles per year

The basic overview of articles selected for the review is presented below in table 8.

ID	Title	Author	Journal/ Conference	Country	Sector	Research Method
2013-01	An empirical examination of strategic sourcing dominant logic: Strategic sourcing centrality	Eltantawy R.A & Giunipero L.	Journal of Purchasing and Supply Management	Global	Cross sectoral	Survey
2013-02	Supply chain professionals: A study of competencies, use of technologies, and future challenges	Prajogo D. & Sohal A.	International Journal of Operations & Production Management	Australia	Cross sectoral	Survey
2013-03	Developing competencies of supply chain professionals in Australia: Collaboration between businesses, universities and industry associations	Sohal A.S.	Supply Chain Management	Australia	Cross sectoral	Survey
2013-04	Data science, predictive analytics, and big data: A revolution that will transform supply chain design and management	Waller M.A. & Fawcett S.E.	Journal of Business Logistics	Not specified	Not specified	Conceptual paper
2014-01	Integrating skills profiling and purchasing portfolio management: An opportunity for building purchasing capability	Knight, L. et al.	International Journal of Production Economics	Taiwan,	Cross sectoral	Survey
2014-02	An exploration of knowledge-based factors affecting procurement compliance	Hawkins T. G. & Muir W. A.	Journal of Public Procurement	United States	Defense	Survey
2014-03	Best Practices for Procurement and Management of Professional Services Contracts	Bausman D. et al.	Journal of Professional Issues in Engineering Education and Practice	United States	Transportation	Survey

2015-01	Supply chain talent: the missing link in supply chain strategy	Dubey R. & Gunasekaran A.	Industrial and Commercial Training	Global	Supply chain management	Literature review
2015-02	Data Science, Predictive Analytics, and Big Data in Supply Chain Management: Current State and Future Potential	Schoenherr T. & Speier-Pero Ch.	Journal of Business Logistics	United States	Strategic supply chain research	Survey, experts interview
2016-01	Management Approaches for Industry 4.0	Shamim, S. et al.	IEEE Congress on Evolutionary Computation	UK	Human resources management	Conceptual paper
2017-01	Harnessing capabilities and practices for sourcing innovation: An exploratory study	Rajkumar C. & Stentoft J.	Logistics Research	Global	Manufacturing	Case study
2017-02	An empirical investigation of the effects of firm characteristics on the propensity to adopt cloud computing	Loukis E. et al.	Information Systems and e-Business Management	EU	Glass, ceramic and cement manufacturing	Survey
2017-03	Moral education for sustainable development: Exploring morally challenging business situations within the global supply chain context	Ha-Brookshire J. et al.	Sustainability	United States	Textile industry	Focus groups
2017-04	Project Quality: The Achilles Heel of Offshore Technology Projects?	Mishra A. et al.	IEEE Transactions on Engineering Management	United States	Technology firms	Survey
2017-05	Identifying key skill sets in humanitarian logistics: Developing a model for Sri Lanka	Rajakaruna S. et al.	International Journal of Disaster Risk Reduction	Sri Lanka	Humanitarian logistics	Survey
2017-06	Clashing institutional interests in skills between government and industry: An analysis of demand for technical and soft skills of graduates in the UK	Cacciolatti L. et al.	Technological Forecasting and Social Change	UK	Cross sectoral: engineering, food and drink, retailing	Content analysis of job advertisements
2018-01	Understanding big data analytics capabilities in supply chain management: Unravelling the issues, challenges and implications for practice	Arunachalam D. et al.	Transportation Research Part E: Logistics and Transportation Review	Not specified	Not specified	Literature Review
2018-02	Development of an Industry 4.0 maturity model for the delivery process in supply chains	Asdecker B. & Felch V.	Journal of Modelling in Management	Not specified	Not specified	Modelling
2018-03	Service Chain Logistics Management for Increasing Equipment Uptime	Bake J.S. et al.	Procedia CIRP	Not specified	Not specified	Literature Review
2018-04	Big data-driven fuzzy cognitive map for prioritising IT service procurement in the public sector	Choi Y. et al.	Big data analytics in operations & supply chain management	Russia	IT	Modelling
2018-05	The effect of "Internet of Things" on supply chain integration and performance: An organisational capability perspective	de Vass T. et al.	Australasian journal of information systems	Australia	Retail	Survey
2018-06	Pharma Industry 4.0: Literature review and research opportunities in sustainable pharmaceutical supply chains	Ding B.	Process Safety and Environmental Protection	Not specified	Pharmaceuticals	Literature Review
2018-07	An intelligent multi-agent based decision support system for refugee settlement siting	Drakaki M. et al.	International Journal of Disaster Risk Reduction	Greece	Humanitarian	Modelling

2018-08	Examining the role of big data and predictive analytics on collaborative performance in context to sustainable consumption and production behaviour	Dubey R. et al.	Journal of Cleaner Production	India	Auto-components manufacturing	Survey
2018-09	Big data analytics and demand forecasting in supply chains: a conceptual analysis	Hofmann E. & Rutschmann E.	The International Journal of Logistics Management	United States	Retail	Conceptual
2018-10	Impact of big data and predictive analytics capability on supply chain sustainability	Jebble S., et al.	The International Journal of Logistics Management	India	Auto-components manufacturing	Survey
2018-11	An examination of the importance of big data analytics in supply chain agility development: A dynamic capability perspective	Mandal S.	Management Research Review	Not specified	IT	Survey
2018-12	Smart process optimization and adaptive execution with semantic services in cloud manufacturing	Mazzola L. et al.	Information	Not specified	Not specified	Modelling
2018-13	Management approaches for industry 4.0 – The organizational culture perspective	Mohelska H. & Sokolova M.	Technological and Economic Development of Economy	Czech Republic	Cross sectoral	Survey
2018-14	Collaborative working architecture for IoT-based applications	Mora H. et al.	Sensors	Not specified	Education	Experiment
2018-15	The impact of big data analytics on firms' high value business performance	Popović A. et al.	Information Systems Frontiers	Not specified	Manufacturing	Interviews
2018-16	Optimization of dynamic data traceability mechanism in Internet of Things based on consortium blockchain	Qiao R. et al.	International Journal of Distributed Sensor Networks	Not specified	Not specified	Modelling
2018-17	Big data analytics in supply chain and logistics: an empirical approach	Queiroz M.M. & Telles R.	The International Journal of Logistics Management	Brazil	Multiple	Survey
2018-18	Effect of IoT capabilities and energy consumption behavior on green supply chain integration	Shafique M.N. et al.	Applied Sciences	Pakistan	Retail	Survey
2018-19	Technology disruptions: exploring the changing roles of designers, makers, and users in the fashion industry	Sun L. & Zhao L.	International Journal of Fashion Design	Not specified	Fashion	Interviews
2018-20	BeeKeeper 2.0: Confidential blockchain-enabled IoT system with fully homomorphic computation	Zhou L. et al.	Sensors	Not specified	Beekeeping	Modelling
2018-21	Data-driven supply chain capabilities and performance: A resource-based view	Yu W. et al.	Transportation Research Part E: Logistics and Transportation Review	China	Manufacturing	Survey
2018-22	Acknowledging knowledge: The perception of knowledge requirements for public procurement officials and their professional development.	Williams, A. M. et al.	Journal of Public Procurement	North america	Cross sectoral	Content analysis of job advertisements
2019-01	An investigation into talent shortages in the Australian procurement profession	Hopkins J. & Sohal A.	Higher Education, Skills and Work-based Learning	Australia	Cross sectoral	Survey
2019-02	The influence of big data analytics management capabilities on supply chain preparedness, alertness and agility	Mandal S.	Information Technology & People	Not specified	Cross sectoral	Survey

2019-03	AI in Supply & Procurement	Chopra A.	Amity International Conference on Artificial Intelligence (AICAI)	Not specified	Cross sectoral	Literature Review
2019-04	Managing Talent Loss in the Procurement Function: Insights from the Hospitality Industry	Daghfous A. & Belkhodja O.	Sustainability	United Arab Emirates	Hospitality	Case study
2019-05	Purchasing and supply management (PSM) competencies: Current and future requirements	Bals L. et al.	Journal of Purchasing and Supply Management	Not specified	Cross sectoral	Question
2019-06	You'll never walk alone: Why we need a supply chain practice view on digital procurement	Kosmol T. et al.	Journal of Purchasing and Supply Management	Germany	Cross sectoral, Automotive, Human resources management	Interview
2019-07	Emerging procurement technology: data analytics and cognitive analytics	Handfield R. et al.	International Journal of Physical Distribution & Logistics Management	United States	Cross sectoral	Survey
2019-08	Monitoring of Educational Programs for the Development of Professional Competencies by Procurement Specialists in Procurement Statistics	Sergeeva, S. A.	Academic Journal of Interdisciplinary Studies	Not specified	Not specified	Literature review
2019-09	Big data in procurement: The role of people behavior and organization alignment	Biazzin C. & Carvalho C. L.	Dimensión Empresarial	Spain	Cross sectoral	Survey
2019-10	Digitized Performance Management Along the Supply Chain	Dzbock Ch. et al.	Performance Management in Retail and the Consumer Goods Industry	Austria, Germany	Cross sectoral	Literature review
2019-11	Supply chain management and Industry 4.0: conducting research in the digital age	Hofmann, E. et al.	International Journal of Physical Distribution & Logistics Management	Not specified	Logistics, cross sectoral	Literature review
2020-01	Cyber-physical systems with autonomous machine-to-machine communication: Industry 4.0 and its particular potential for purchasing and supply management	Schiele H. & Torn R. J.	International Journal of Procurement Management	Switzerland, Austria, France, Germany and Finland.	Cross sectoral	Interviews

Table 8 Overview of articles selected for the review.

In addition to the literature review, the PERSIST team also tried to conduct an analysis of job descriptions and advertisements in order to specify current the competence requirements from enterprises that are needed in the field of purchasing and supply management, in combination with a high involvement of the implication of Industry 4.0; i.e. machine-to-machine communication. Unfortunately, the preliminary analysis showed that most of the job descriptions and advertisements for positions like Junior purchaser, Senior purchaser, Purchasing manager and their equivalents, only mention a general description of the skills like negotiation skills, computer skills, analytical skills etc. and fail to specify any Industry 4.0 areas or do not link the skills to Industry 4.0 areas. This mean that practitioners do not provide enough context to distinguish PSM Industry 4.0. related skills from other PSM

skills. Therefore, the project team decided to modify the initial research approach and address this issue and provides the link between Industry 4.0 technologies and needed purchasing and supply management competencies. Several studies focused on the future of procurement were analysed and the Deloitte study was selected to provide a classification of current and future Industry 4.0 purchasing technologies. The findings from the literature review was then linked to the required skills with proper technology. Despite not having relevant data from job descriptions and advertisements, the wide spread of scientific literature provides enough context to make robust connections.

2.2. Keywords analysis of Industry 4.0. articles dealing with PSM skills

As the first part of white paper is focused on understanding studies related to procurement skills needed soon in the future, the project team provides the analysis of key words describing the main topics of these studies. The main objective is to understand the perceived significance of main domains of related papers expressed as the key words suggested by authors and to classify higher/wider domains of related studies.

The significance of these main domains is expressed by the frequencies of key words calculated from reviewed papers related to Industry 4.0 and procurement skills and trends.

Competences were categorised according to the types listed below:

- Internal/External competence dealing with core business skills
- Future Digital Domains dealing with new future skills related to Industry 4.0
- Future Social Domains dealing with purchasing skills focused on social value
- Competences dealing with type of key words related to different types of skills related keywords

For the purpose of better categorisation, some of synonyms and expressions were processed into one term.

In the Table 9, the frequencies of how the domains occurred during the years 2013-2020 based on the categorisation are shown:

		Year							
		2013	2014	2015	2016	2017	2018	2019	2020
Internal/ External Competencie s	Total	14	5	11	2	21	84	25	4
	Administration	0	1	0	0	0	1	0	0
	Agile	0	0	0	0	1	1	0	0
	Business process management	0	0	0	0	0	1	1	0
	Business value	0	0	0	0	0	2	1	0
	Case analysis	0	1	0	1	1	1	1	0
	Collaboration	2	0	0	0	0	1	0	0
	Competition	0	0	0	0	1	0	0	0
	Consortium	0	0	0	0	0	1	0	0
	Contract	0	1	0	0	0	0	0	0
	Decision making	0	0	0	0	0	3	0	0
	Development	0	0	0	0	0	0	1	0
	Fault tolerance	0	0	0	0	0	1	0	0
	Logistics	1	0	0	0	1	3	0	0
	Maintenance	0	0	0	0	0	1	0	0
	Management	2	0	2	1	3	6	2	1
	Monitoring	0	0	0	0	0	0	1	0
	Negotiation	0	0	0	0	0	1	0	0
	Organisation	0	0	0	0	1	6	0	0
	Performance	1	0	0	0	2	4	1	0
	Procurement	0	5	0	0	0	2	11	2
	Quality	0	0	0	0	1	0	0	0
	Resource	1	0	0	0	0	2	1	0
	Retail	0	0	0	0	0	1	0	0
	Risk	0	0	0	0	1	0	0	0
	Roadmap	0	0	0	0	0	0	1	0
	Services	0	1	0	0	0	2	0	0
	Sourcing	1	0	0	0	3	0	0	0
	Strategic	1	0	0	0	2	0	0	0
	Structure	0	0	0	1	0	0	0	0
	Supply base	0	0	0	0	0	1	0	0
	Supply chain	4	0	3	0	1	16	5	1
	Value chain	0	0	0	0	0	1	0	0
Digital Future	Total	19	13	9	4	31	83	25	5
	Additive	0	0	0	0	0	1	0	0
	Adoption	0	0	0	0	0	0	1	0
	Analytics	1	0	1	0	0	7	2	0
	Artificial intelligence	0	0	0	0	0	0	3	0
	Automation	0	0	0	0	0	1	0	0
	Big data	1	0	1	0	0	7	3	0
	Blockchain	0	0	0	0	0	1	0	0

	Cloud	0	0	0	0	1	2	0	0
	Cognitive analytics	0	0	0	0	0	0	1	0
	Complexity	0	0	0	0	0	1	1	0
	Cyber physical	0	0	0	0	0	0	0	1
	Data analytics	0	0	0	0	0	0	1	0
	Data monitoring	0	0	0	0	0	0	1	0
	Data science	2	0	2	0	0	5	0	0
	Data sharing	0	0	0	0	0	1	0	0
	Digital	0	0	0	0	0	0	1	0
	Digital procurement	0	0	0	0	0	0	1	0
	Digital readiness	0	0	0	0	0	0	1	0
	Digitization	0	0	0	0	0	0	1	0
	Disruption	1	0	0	0	0	1	2	0
	ICT	1	0	0	0	0	6	1	0
	Industry 4.0	0	0	0	1	0	5	1	1
	Infrastructure	0	0	0	0	1	0	0	0
	Innovation	0	0	0	0	4	3	0	0
	Integration	1	0	0	0	0	1	0	0
	Internet of things	0	0	0	0	0	4	0	0
	Just in time	0	0	0	0	0	1	0	0
	Modelling	0	1	2	0	1	8	0	0
	Optimisation	0	0	0	0	0	1	0	0
	Prediction	1	0	1	0	0	0	1	0
	Sensors	0	0	0	0	0	1	0	1
	Simulation	0	0	0	0	0	1	0	0
	Statistics	0	0	0	0	0	0	1	0
	Technology	0	0	0	0	1	1	3	0
Social Future	Total	27	14	16	5	36	131	51	8
	Culture	0	0	0	0	0	3	0	0
	Ethics	0	0	0	0	2	0	0	0
	Green	0	0	0	0	0	2	0	0
	Sustainability	0	0	0	0	1	6	0	0
Competence	Total	22	10	12	4	30	129	43	7
	Competencies	3	4	2	1	6	9	3	1
	Education	2	0	1	0	2	3	1	0
	Knowledge	0	0	1	0	1	1	2	0
	Talent	0	0	0	0	0	0	2	0

Table 9 The Frequencies of key words identified within years 2013-2020 within categorised key words

As can be seen, the frequencies of occurrence of core and digital competences during this time period are relatively similar, but some of the skills emerge more often in the later period, for example those related with analytical and data competencies, which are highlighted in bold text. Those competencies are related to analytical thinking using data and

modelling techniques. Moreover, some specifics are emerging for example in automation which was identified in several white papers and visionary studies as one of the crucial pillars of future supply chain or procurement management. The automation was not identified within competences related papers till 2018. Although the mentioned paper was more manufacturing oriented than procurement process oriented, which shows a gap between competences vs future trends studies. On the other hand, as will be showed later, some of authors are emphasizing the general skills related to managerial competences to implement new technologies related to Industry 4.0 or digitisation into the procurement processes, including automation.

Within the key words analysis during the examined period, the most important key words in studies mentioning procurement related core competences are focusing on strategic and management competences presented by management, performance and organisation(al) domains.

2.2.1. Visualisation of competencies' importance according to category

The results of the previous table, which showed results of the keyword analysis are summarized and presented visualised in the next graphs. Each graph represents one of four categories described above. In terms of Internal/External competencies most of the studies mention key words such as Supply chain, Procurement and management (Figure 1). Results like these are not surprising because most of the purchasing-oriented papers use these key words to describe their main topics or orientation.

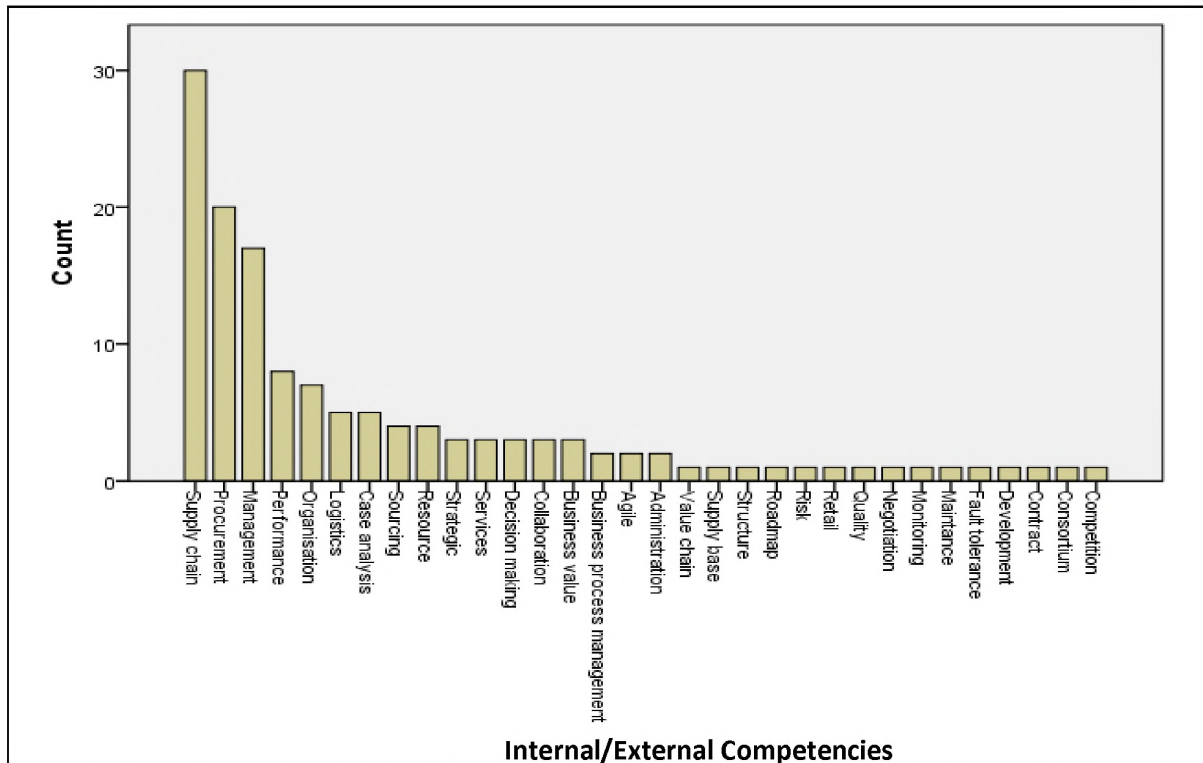


Figure 1 The Frequencies of key words identified within category Internal/External Competencies

On the other hand, according to next graph (Figure 2), during this period the main focus in digital competences shifted towards analytical skills and technology in general. It may emphasise the importance of analytical and innovative thinking requirements for managerial positions, as the main driving factor for change in a company.

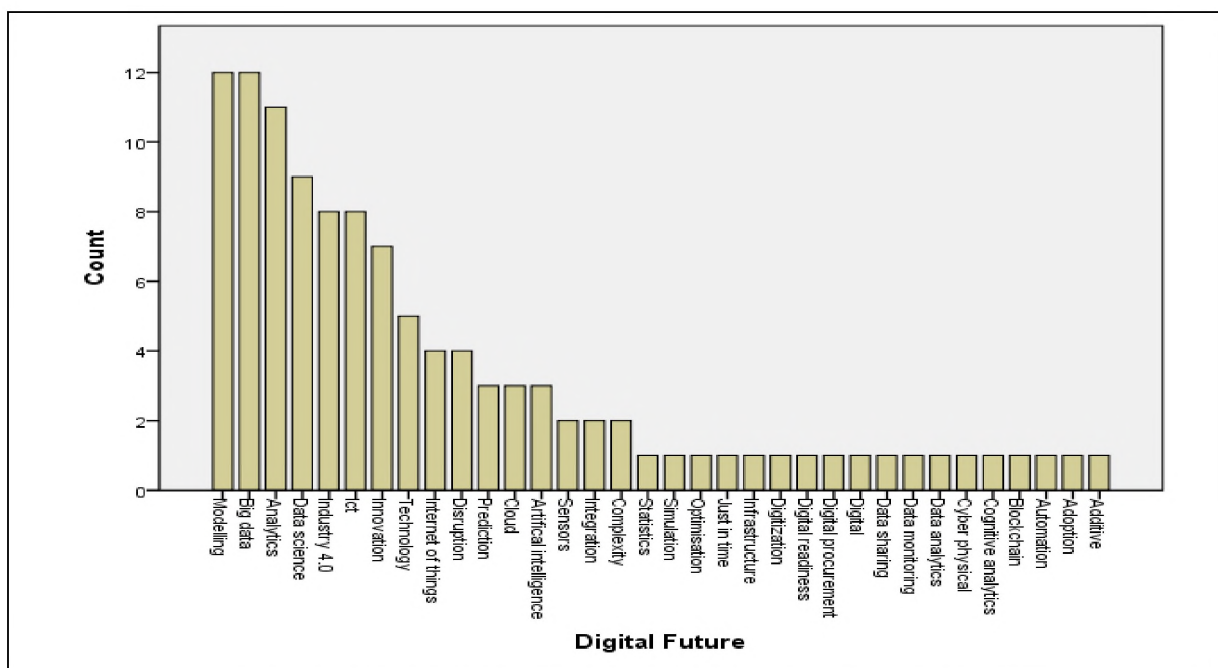


Figure 2 The Frequencies of key words identified within category Digital Future

Many policy paper studies, and also studies related to corporate social responsibilities deal with social and societal aspects of company behaviour, and procurement is no exception, as several papers dealt also with social responsibility and related competences. As can be seen in the next graph, the frequency of socially related procurement key words is not as frequent as those in the digital domain and their main focus is on sustainability. However, it should be noted that the key words used in this area are often similar, complementary and the terminology or more concrete definitions in this field are identified as still being a gap in scientific literature. Although several case studies in Europe, not only in public procurement, but also in commercial sector (e.g. ASAHI) are integrating corporate social responsibility into procurement objectives and priorities. As the PERSISTS consortium were only searching for papers related to skills and competences, on the basis of the key word analysis, this social aspect of procurement is still not so related to procurement skills. However, the rising interest in this field in the last four years, can signify its increasing importance.

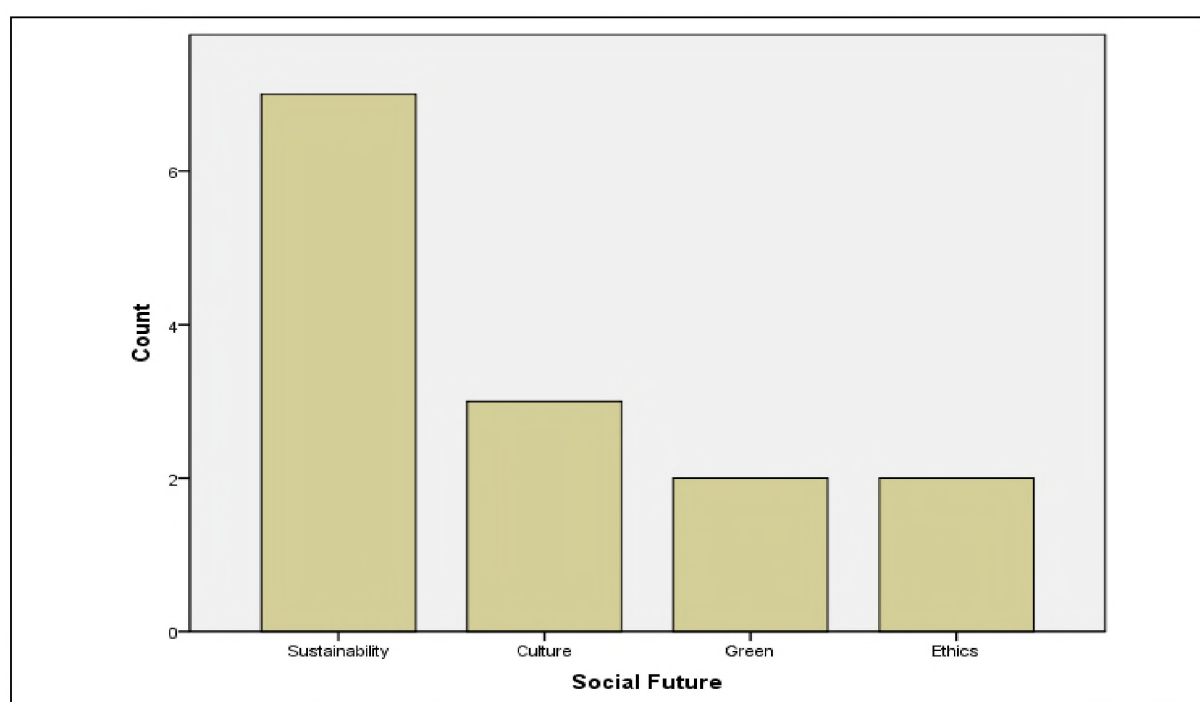


Figure 3 The Frequencies of key words identified within category Social Future

In the area of using skills, the related key words (Figure 4) mentioned in the papers, show that there are four key drivers focused on skills/competences, education (especially in needs identification or forms), knowledge required and talent. These results also suggest that most of the analysed studies focus on the identification of the skills. Education and knowledge-oriented papers present only a very small portion of the reviewed sample.

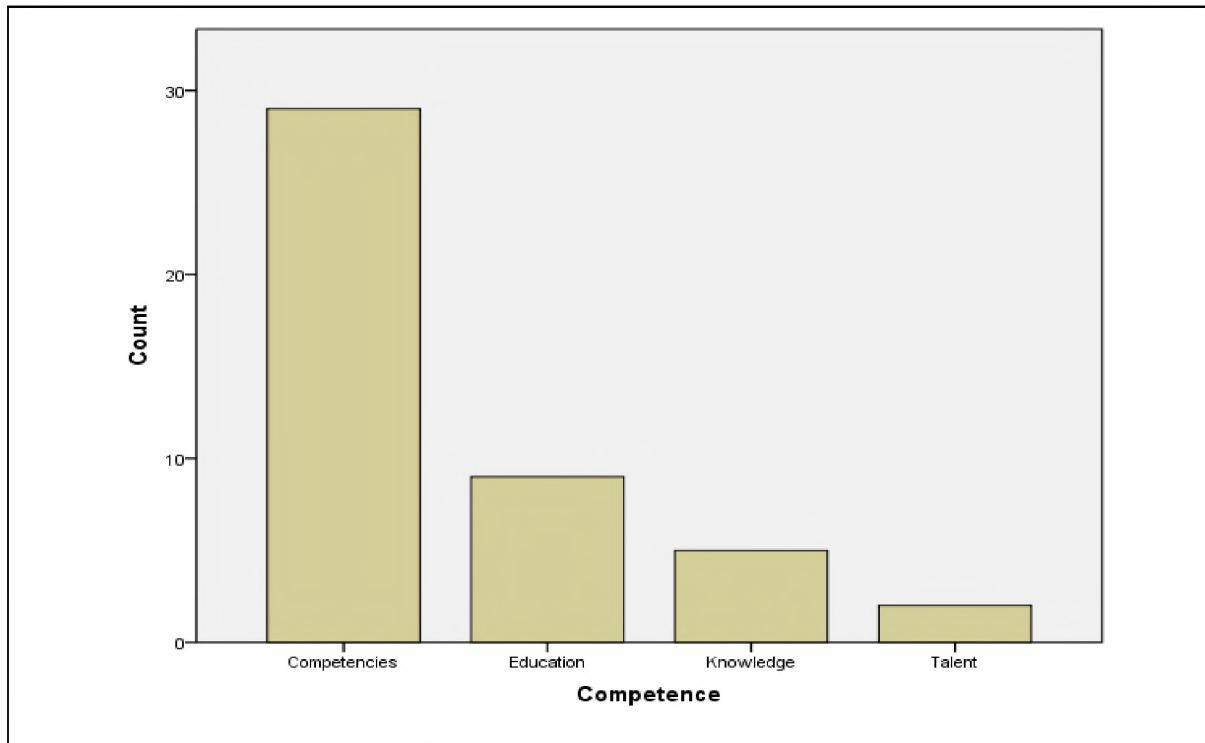


Figure 4 The Frequencies of key words identified within category Competence

2.3. Analysis of Industry 4.0 PSM Skills literature review

The skills were identified and classified based on the work of Bals et al. (2019), entitled *Purchasing and supply management (PSM) competencies: Current and future requirements*. According to the authors they follow the approach of Tassabehji and Moorhouse (2008), Derwik and Hellström (2017) and key works from the HRM literature (e.g. Delamare-Le Deist and Winterton, 2005) to obtain the widest possible view of competencies and enhance the understanding of what PSM professionals need to be able to do their jobs. Such holistic approach is also consistent with the United Nations Industrial Development Organisation (UNIDO, 2017) and the European Commission frameworks (see e.g. the customs competency framework: European Commission, 2014) and also reflects how competencies have been defined in a number of similar papers in other, but related, areas such as SCM (e.g. Briscoe et al., 2001; Derwik and Hellström, 2017; Flöthmann et al., 2018a,b; Gammelgaard and Larson, 2001; Giunipero et al., 2005; Giunipero et al., 2006; Kotzab et al., 2018; Mangan and Christopher, 2005; Prajogo and Sohal, 2013). The mentioned classification was used as basic

framework and was updated by project partners in order to include additional skills identified in the reviewed articles, but not listed in Bals et al. (2019).

The analysis of the Industry 4.0 PSM skills has two parts. The first part deals with an analysis of PSM skills in general. The motivation for this research is to identify the Industry 4.0 relevant PSM skills and show how frequently they are mentioned in articles dealing with Industry 4.0. The second part of Industry 4.0 PSM skills analysis tries to link the PSM skills with the particular area of Industry 4.0. The aim of such analysis is to identify the PSM skillsets needed for different areas of Industry 4.0.

2.3.1. General analysis of PSM Industry 4.0 oriented skills

In order to determine which PSM skills and how frequently a particular skill is mentioned in Industry 4.0 articles, the work of Bals et al. (2019) was used to divide skills into the four categories of: Technical Skills, Interpersonal Skills, Internal/External Enterprise Skills, Strategic Business Skills.

Based on the definition adapted from Tassabehji and Moorhouse (2008) the Technical skills represent “Fundamental and basic administrative skills necessary for any procurement professional in the 21st century”. They include product knowledge, computer literacy, total quality management and government legislation. The sub-category “Advanced procurement process skills (APP)” includes category management, project planning and e-procurement (Bals et al., 2019). Using the classification table mentioned in the methodology, the distribution of the technical skills within Industry 4.0 related academic literature is presented in Tab 10.

	Skills	2013	2014	2015	2016	2017	2018	2019	2020	N
Technical skills	Big Data Analytics	1	0	1	0	1	13	4	0	20
	Project Management	2	2	1	0	2	1	2	0	10
	Tools and Systems Implementation	2	0	1	0	0	3	1	0	7
	Negotiation	0	1	0	0	1	1	3	0	6
	Process optimization	0	1	1	0	0	3	1	0	6
	Database Management*	0	0	0	0	0	4	2	0	6
	Computer Literacy	0	0	1	0	0	2	2	0	5
	Basic knowledge on PSM role & processes	0	0	0	0	0	1	3	0	4
	Contract Management	0	1	0	0	0	1	2	0	4
	eProcurement Technology	0	0	1	0	0	0	3	0	4
	Product knowledge	0	1	0	0	0	2	1	0	4
	Strategic sourcing	0	1	1	0	0	0	2	0	4
	Innovative sourcing approaches	0	0	0	0	0	1	2	1	4
	Innovation sourcing	0	0	0	1	1	0	1	0	3
	Statistical Skills*	0	0	1	0	0	0	2	0	3
	Cost savings	0	1	0	0	0	0	1	0	2
	Skill for Artificial intelligence*	0	0	0	0	0	0	2	0	2
	Operations research*	0	0	2	0	0	0	0	0	2
	Skills for Blockchain*	0	0	0	0	0	1	1	0	2
	Skills for Machine Learning*	0	0	0	0	0	1	1	0	2
	Skills for Distributed Computing*	0	0	0	0	0	2	0	0	2
	Intellectual Property	0	0	0	0	0	0	1	0	1
	KPI Reporting Design	0	0	0	0	0	0	1	0	1
	Languages	0	0	0	0	0	0	1	0	1
	Quality assurance	0	0	0	0	0	0	1	0	1
	Automation	0	0	0	0	0	0	1	0	1
	Mathematical modelling*	0	0	1	0	0	0	0	0	1
	Skills for Solution development*	0	0	0	0	0	1	0	0	1
	Skills for 3D Printing*	0	0	0	0	0	1	0	0	1
	Skills for Cloud computing*	0	0	0	0	1	0	0	0	1
*Skills not listed in Bals et al. (2019)										

Table 10 List of technical skills recognised by literature review

As can be seen from previous table, big data analytics is the most frequently mentioned PSM technical skill. This is followed by those skills related to project management and Tools and system implementation and the top five list of technical skills is concluded by negotiation and process optimisation skills. From the skills that were not listed in Bals et al.

(2019), database management is mentioned quite often in the articles published more recently (i.e. after 2017).

The interpersonal skills represent the second group of identified skills. The list of interpersonal skills identified by review are presented in the table below (Table 11).

	Skills	2013	2014	2015	2016	2017	2018	2019	2020	N
Interpersonal skills	Analytical skills	2	1	1	0	2	4	3	0	13
	Decision making	0	1	1	0	0	4	3	0	9
	Teamwork-working in teams	2	1	1	1	1	0	3	0	9
	Interpersonal Communication	0	1	2	0	1	1	2	0	7
	Creativity	0	0	2	1	0	1	2	0	6
	Knowledge sharing	0	0	0	0	0	3	3	0	6
	Leadership	0	1	1	0	1	1	2	0	6
	Learning agility	1	0	0	1	0	1	2	1	6
	Problem solving*	0	1	0	1	0	1	2	0	5
	Conflict Resolution	0	1	2	0	0	0	1	0	4
	Integrity	0	0	0	0	2	0	1	0	3
	Results focus driving for results	0	0	0	1	1	0	1	0	3
	Openness, Open-minded,	0	0	0	1	0	0	2	0	3
	Passion	0	0	1	0	1	0	1	0	3
	Effective questioning techniques	0	0	1	0	0	0	1	0	2
	Curiosity	0	0	0	1	0	0	1	0	2
	Self-confidence	0	0	0	0	1	0	1	0	2
	Prioritization	0	0	0	0	0	0	1	0	1
	Remote Virtual Working	0	0	0	0	0	0	1	0	1
	Structured way of working	0	0	0	0	0	0	1	0	1
	Deal with ambiguity	0	0	0	0	0	0	1	0	1
	Humility	0	0	0	0	0	0	1	0	1
	Mobility	0	0	0	0	0	0	1	0	1
	Resilience	0	0	0	0	0	0	1	0	1
	Self-reflection	0	0	0	0	0	0	1	0	1
	Self-reliance	0	0	0	0	0	0	1	0	1
	Flexible thinking*	0	0	0	1	0	0	0	0	1
	Stress Management*	0	0	1	0	0	0	0	0	1
	Awareness of the needs of other*	0	0	1	0	0	0	0	0	1
*Skills not listed in Bals et al. (2019)										

Table 11 List of interpersonal skills recognised by literature review

The interpersonal skills can be determined as “necessary for interaction with people in teams and on an individual level including written and oral communication, conflict resolution, influencing and persuasion, group dynamics, leadership, problem solving and interpersonal and cultural awareness.” (Tassabehji and Moorhouse, 2008; Bals et al., 2019)

In terms of interpersonal skills, the results showed that analytical skills are the most mentioned in the Industry 4.0 oriented scientific literature. This is followed by decision making (2nd) and team working (3rd), interpersonal communication (4th) and creativity (5th). In addition to the skills listed in Bals et al. (2019), problem solving is the only skill mentioned more than once.

The third group of skills are Internal/External enterprise skills. The internal enterprise skills can be defined as “skills relate to the overall business and how the different functions interaction” (Tassabehji and Moorhouse, 2008; Bals et al., 2019), while external enterprise skills are “relate to the supply chain/network and its stakeholders”. (Tassabehji and Moorhouse, 2008; Bals et al., 2019). The skills identified within this category can be found in Table 12.

From all Internal/External enterprise skills identified by literature review, cross-functional abilities & knowledge are those mentioned most often in the Industry 4.0 oriented scientific literature. This is followed by logistic skills (2nd), communications skills (3rd), knowledge of change management (4th) and supply chain (5th). From the skills not listed in Bals et al. (2019), Business ethics and International regulations/Legal knowledge are mentioned more than once.

	Skills	2013	2014	2015	2016	2017	2018	2019	2020	N
Internal/External enterprise skills	Cross-functional abilities & knowledge	2	0	0	1	0	5	2	1	11
	Logistics	2	1	1	0	1	3	1	0	9
	Communication skills	2	0	1	0	1	1	3	0	8
	Change Management	2	1	0	0	0	0	3	0	6
	Supply Chain	2	0	2	0	0	1	1	0	6
	Supplier management	0	2	0	0	1	1	2	0	6
	Stakeholder Relationship Management	1	1	0	0	0	1	2	0	5
	Finance	0	0	1	0	0	1	2	0	4
	Marketing	2	0	1	0	0	0	1	0	4
	Customer Focus	0	1	0	0	1	0	2	0	4
	Manufacturing/Production	0	1	0	0	1	0	1	0	3
	Cultural awareness	0	0	0	0	0	0	3	0	3
	Business ethics*	0	0	1	0	0	1	1	0	3
	International regulations/Legal knowledge*	0	0	1	0	0	1	1	0	3
	Engineering	0	1	0	0	0	0	1	0	2
	Quality (QHSE)	0	0	1	0	0	0	1	0	2
	R&D	0	1	0	0	0	0	1	0	2
	Sales	0	0	0	0	0	1	1	0	2
	Operations management*	0	1	1	0	0	0	0	0	2
	Networking	0	0	0	0	0	0	1	0	1
	Customer relationship management*	0	0	1	0	0	0	0	0	1
	Warehousing and distribution*	0	0	1	0	0	0	0	0	1
	Warehouse management*	0	0	1	0	0	0	0	0	1
	Transportation management*	0	0	1	0	0	0	0	0	1
*Skills not listed in Bals et al. (2019)										

Table 12 List of Internal/External enterprise skills recognised by literature review

The final category is Strategic business skills and: “These skills relate to broader strategic issues and how procurement can impact on overall organisational value such as planning and managing strategic partnerships and alliances, risk management and adding value to the organisation” (Tassabehji and Moorhouse, 2008; Bals et al., 2019). The list of such skills recognised by the literature review is presented in the Table 13.

As shown in the table below, strategic thinking represents the most frequently mentioned Strategic business skill, with Business acumen in second and holistic supply chain thinking (3rd), risk management (4th) and financial acumen (5th). From the skills not listed in Bals et al. (2019), Future thinking/Innovativeness and planning are mentioned more than once.

	Skills	2013	2014	2015	2016	2017	2018	2019	2020	N
Strategic business skills	Strategic thinking	2	1	1	0	0	3	5	1	13
	Business Acumen	1	1	2	0	1	3	3	1	12
	Holistic Supply Chain Thinking	2	0	0	0	1	5	1	1	10
	Risk management	2	1	1	0	2	0	2	0	8
	Financial acumen	3	0	1	0	0	1	1	0	6
	PSM Best Practice Intelligence Scouting	0	1	0	0	0	1	1	1	4
	Sustainability	2	0	0	0	0	0	2	0	4
	Future thinking/Innovativeness*	0	0	0	0	0	4	0	0	4
	Critical thinking	0	0	0	0	1	0	2	0	3
	Planning*	1	0	1	0	0	1	0	0	3
	Technological trends*	0	0	0	0	0	1	0	0	1
*Skills not listed in Bals et al. (2019)										

Table 13 List of Strategic business skills recognised by literature review

To compare all groups together, table 14 shows the synthesised results.

Skills	2013	2014	2015	2016	2017	2018	2019	2020	Total	Top 10
Technical Skills	5	8	11	1	6	38	41	1	111	2
Interpersonal Skills	5	7	14	8	10	16	40	1	101	3
Internal/External Enterprise Skills	13	10	14	1	5	16	30	1	90	2
Strategic Business Skills	13	4	6	0	5	19	17	4	68	3

Table 14 Distribution of skills categories

In terms of frequency, the table above shows that technical skills are the most represented skill group, although only two technical skills occur in the Top 10 list of most frequently mentioned skills. However, it is worth mentioning that in Industry 4.0 oriented articles, the Interpersonal skills group is the second largest group and three skills from this group are in the TOP 10 list. Interestingly, the occurrence of strategic business skills was the smallest within the researched literature, yet three such skills are in the TOP 10 list.

2.3.2. Comparison of identified PSM Skills with research on Purchasing and supply management (PSM) competencies: Current and future requirements

In order to compare how PSM skillset determined by Industry 4.0 oriented articles differs from a general PSM one, we compared our results with list of current PSM competencies and future PSM competencies defined in Bals et al. 2019. The comparison is presented in Table 15.

Current PSM Competencies	Future PSM Competencies	Industry 4.0 oriented PSM Competencies
Analytical skills	Analytical Skills	Analytical skills
Strategic thinking	Strategic thinking	Strategic thinking
Basic knowledge on PSM role & processes	Big Data Analytics	Big Data Analytics
Communication skills	Holistic supply chain thinking	Holistic Supply Chain Thinking
Cross-functional abilities & knowledge	Automation	Cross-functional abilities & knowledge
Interpersonal Communication	Computer Literacy	Business Acumen
Negotiation	eProcurement Technology	Decision making
Stakeholder Relationship Management	Process optimisation	Logistics
Strategic sourcing	Strategic Sourcing	Project Management
Sustainability	Sustainability	Teamwork-working in teams

Table 15 Comparison of Top 10 current PSM competencies, Future PSM competencies and Industry oriented 4.0 PSM competencies

The comparison shows some areas where Industry 4.0 PSM oriented competencies align with the more general current and future PSM competencies. Analytical skills and Strategic thinking represent two types of skills where there is an alignment across the board. Big Data Analytics and Holistic Supply Chain thinking connect Industry 4.0 PSM oriented competencies with Future PSM competencies and Cross-functional abilities & knowledge match Current PSM competencies with the Industry 4.0 oriented PSM competencies.

2.3.3. Analysis of PSM skills based on Industry 4.0 area

The second part of literature review connects PSM skills with concrete areas of Industry 4.0. Industry 4.0 is a very broad concept and because of ongoing development of new technologies, in fields such as cyber-physical systems, automation and IoT etc. it is still growing. In order to grasp how the future of PSM within the Industry 4.0 framework will look like, the classification from Deloitte study named *Digital Procurement: New Capabilities from Disruptive Technologies*, which connects PSM with pillars of Industry 4.0, was used to provide an overview of how the Industry 4.0 technologies can be used in PSM. It should be mentioned that this classification seems to be sufficient enough for the purpose of the literature review because every concrete example of Industry 4.0 PSM used was found in reviewed articles and can be allocated into specific categories within the classification. This meant that no new categories had to be added.

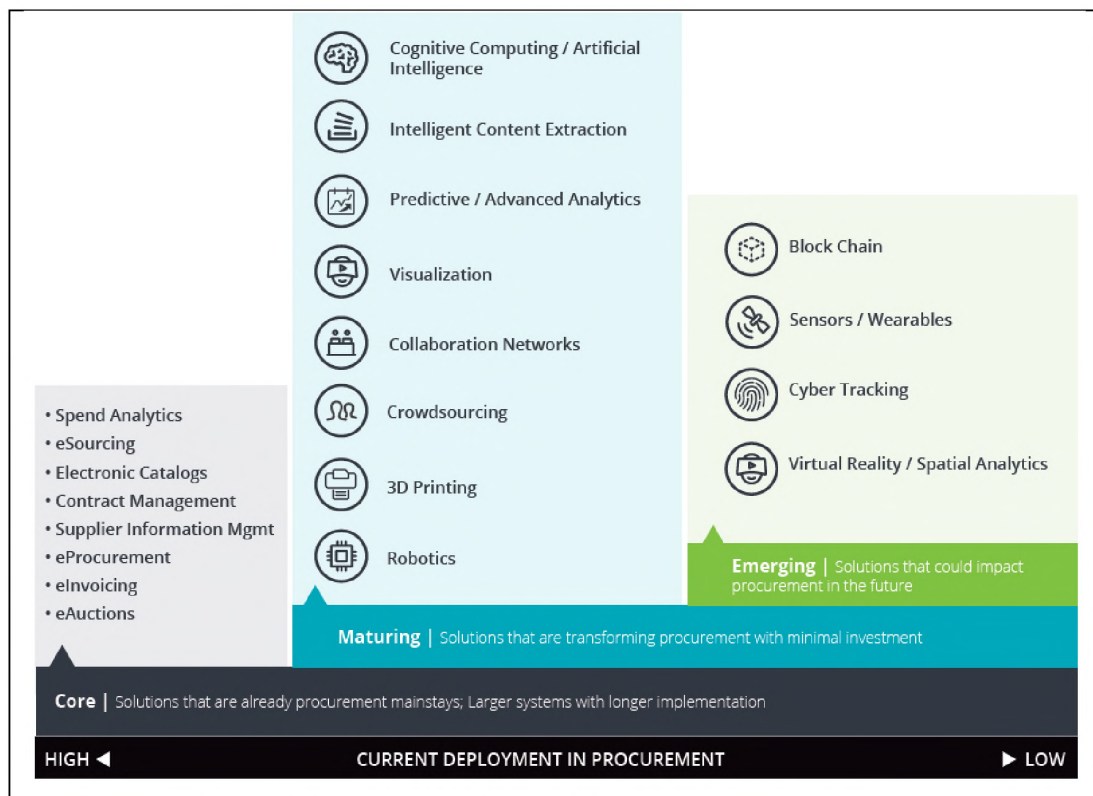


Figure 5 Classification of Industry 4.0 procurement technologies
Source: Deloitte (2017)

As can be seen on Figure 5, the Deloitte study divided procurement technologies into three categories. The first category represents Core solutions, which are defined as: “Solutions that are already procurement mainstays; Larger systems with longer implementation” (Deloitte, 2017). Procurement technologies such as eProcurement/eSourcing, Electronic Catalogs, Contract Management, Supplier Information Management belong to this category. The procurement technologies in the second group are known as Maturing solutions, which are the: “...solutions that are transforming procurement with minimal investment” (Deloitte, 2017). Solutions based on Predictive and advanced analytics, Collaborative networks, Robotics, Cognitive computing and artificial intelligence, Intelligent content extraction, Visualization, 3D printing are part of this group. The final group is represented by emerging solutions, which are defined as: “solutions that could impact procurement in the future”. (Deloitte, 2017). Procurement technologies based on the Cyber Tracking, Sensors, Blockchain, Virtual Reality / Spatial Analytics are part of this group. An overview, describing how many reviewed articles are dealing with particular Industry 4.0 procurement technology, is presented in the next table (Table 16).

Phase of procurement development	Area of Industry 4.0.	Count
Industry 4.0 in general (procurement technologies are not specified)		14
Core	eProcurement/eSourcing	9
	Electronic Catalogs	5
	Contract Management	4
	Supplier Information Management	2
Maturing	Predictive and advanced analytics	24
	Collaborative networks	10
	Robotics	7
	Cognitive computing and artificial intelligence	5
	Intelligent content extraction	4
	Visualization	2
	3D printing	2
Emerging	Cyber Tracking	24
	Sensors	13
	Blockchain	7
	Virtual Reality / Spatial Analytics	2

Table 16 Overview describing representation of Industry 4.0 procurement technologies in reviewed articles

A detailed analysis of the reviewed articles showed that there are several articles which cover Industry 4.0, but do not mention any purchasing technologies, but mention Industry 4.0 as a general term. The list of PSM skills which are mentioned in these articles is presented in the following table (Table 17).

Industry 4.0 in general			
Skills	n	Skills	n
Project Management	6	eProcurement Technology	1
Teamwork-working in teams	5	Process optimization	1
Logistics	5	Product knowledge	1
Risk management	5	Tools and Systems Implementation	1
Analytical skills	4	Innovative sourcing approaches	1
Interpersonal Communication	4	Statistical Skills	1
Communication skills	4	Operations research	1
Business Acumen	4	Creativity	1
Strategic thinking	4	Decision making	1
Negotiation	3	Knowledge sharing	1
Strategic sourcing	3	Results focus driving for results	1
Big Data Analytics	3	Openness, Open-minded,	1
Leadership	3	Passion	1
Problem solving	3	Self-confidence	1
Change Management	3	Stress Management	1
Customer Focus	3	Awareness of the needs of other	1
Stakeholder Relationship Management	3	Engineering	1
Supplier management	3	Marketing	1
Conflict Resolution	2	Quality (QHSE)	1
Integrity	2	R&D	1
Learning agility	2	Cultural awareness	1
Cross-functional abilities & knowledge	2	Customer relationship management	1
Finance	2	Operations management	1
Manufacturing/Production	2	Warehousing and distribution	1
Supply Chain	2	Warehouse management	1
Business ethics	2	Transportation management	1
International regulations/Legal knowledge	2	Financial acumen	1
Basic knowledge on PSM role & processes	1	Critical thinking	1
Computer Literacy	1	Holistic Supply Chain Thinking	1
Contract Management	1	Sustainability	1
Cost savings	1	Planning	1

Table 17 List of PSM skills which are mentioned in Articles oriented on Industry 4.0 in general

The previous table showed that in articles which deal with Industry 4.0 without mentioning concrete technologies, skills such as project management, team working, logistic and risk management are often mentioned.

However, a different selection of PSM skills can be found when only the articles which cover the core procurement technologies are analysed. A detailed overview of skills distribution in such articles can be found in table below (Table 18).

Core					
Skills	eProcurement/ eSourcing	Electronic Catalogs	Contract Mgmt	Supplier Information Mgmt	N
Strategic thinking	4	3	3	1	11
Holistic Supply Chain Thinking	4	3	2	1	10
Business Acumen	3	1	2	1	7
Cross-functional abilities & knowledge	3	2	1	1	7
Innovative sourcing approaches	3	1	2	1	7
PSM Best Practice Intelligence Scouting	3	1	2	1	7
Leadership	3	1	2		6
Database Management	3	1	2		6
Analytical skills	3	1	1		5
Change Management	2	2	1		5
Learning agility	2	1	1	1	5
Computer Literacy	3		2		5
Product knowledge	2	1	1		4
Cultural awareness	2	1	1		4
Financial acumen	2	1	1		4
Interpersonal Communication	2		1		3
Communication skills	1	2			3
Negotiation	2		1		3
Big Data Analytics	3				3
Supplier management	2		1		3
Finance	2		1		3
Basic knowledge on PSM role & processes	2		1		3
Contract Management	2		1		3
eProcurement Technology	2		1		3
Tools and Systems Implementation	1	2			3
Decision making	2		1		3
Knowledge sharing	2		1		3
Skill for Artificial intelligence	2	1			3

Project Management	1	1			2
Teamwork-working in teams	1	1			2
Logistics	1	1			2
Risk management	1	1			2
Supply Chain	1	1			2
Business ethics	1		1		2
International regulations/Legal knowledge	1		1		2
Marketing	1	1			2
Sustainability	1	1			2
Planning	1		1		2
Innovation sourcing	1			1	2
Skills for Machine Learning	2				2
Sales	1	1			2
Future thinking/Innovativeness	1		1		2
Strategic sourcing	1				1
Customer Focus	1				1
Stakeholder Relationship Management	1				1
Conflict Resolution	1				1
Integrity	1				1
Manufacturing/Production	1				1
Cost savings	1				1
Process optimization	1				1
Creativity	1				1
Results focus driving for results	1				1
Openness, Open-minded,	1				1
Passion	1				1
Self-confidence	1				1
Engineering	1				1
Quality (QHSE)	1				1
R&D	1				1
Critical thinking	1				1
Intellectual Property	1				1
KPI Reporting Design	1				1
Languages	1				1
Quality assurance	1				1
Automation	1				1
Skills for Blockchain	1				1
Skills for 3D Printing		1			1
Effective questioning techniques	1				1
Prioritization	1				1
Remote Virtual Working	1				1
Structured way of working	1				1
Curiosity	1				1

Deal with ambiguity	1				1
Humility	1				1
Mobility	1				1
Resilience	1				1
Self-reflection	1				1
Networking	1				1

Table 18 List of PSM skills which are mentioned in articles oriented on Industry 4.0 core purchasing technologies

The table shows that skills which are mostly mentioned in the articles covering mainstream procurement technologies, known as core, are strategic thinking, holistic supply chain thinking, business acumen, cross-functional abilities & knowledge, innovative sourcing approaches, PSM Best Practice Intelligence Scouting and Leadership.

Some of the skills mentioned previously are also often mentioned in the articles which are oriented to maturing procurement technologies. These technologies are not so expensive to implement, but they are supposed to transfer procurement environment. The complete list of PSM skills mentioned in connection with these technologies is displayed below (Table 19).

Maturing								
Skills	Cognitive computing and AI	Intelligent content extraction	Predictive and advanced analytics	Visualization	Collaborative networks	3D printing	Robotics	N
Big Data Analytics			15	1	3		2	21
Strategic thinking	2	2	7	1	2	1	3	18
Business Acumen	1	1	7		2	1	2	14
Analytical skills			8	1	3		2	14
Cross-functional abilities & knowledge	1	1	6		2	1	2	13
Database Management	2	1	5	2	1		1	12
Decision making	1		7	1	2		1	12
Holistic Supply Chain Thinking	2	1	4		1	1	2	11
PSM Best Practice Intelligence Scouting	1	2	3		1	1	3	11
Innovative sourcing approaches	1	1	3		1	1	2	9
Learning agility	1	1	3		1	1	2	9
Leadership	1	1	3	1			2	8
Computer Literacy	1		4	1	1		1	8
Knowledge sharing	1		4	1	1		1	8
Change Management	1	1	2	1			2	7

Cultural awareness	1	1	2	1			2	7
Tools and Systems Implementation	1		4		1		1	7
Skill for Artificial intelligence	1		2		2	1	1	7
Process optimization			4	1	1		1	7
Product knowledge	1		3				1	5
Communication skills	1		3				1	5
Negotiation		1	2				2	5
Supplier management		1	2				2	5
Contract Management		1	2				2	5
eProcurement Technology	1		3				1	5
Project Management		1	2				2	5
Logistics			2	1	1		1	5
Creativity			4				1	5
Financial acumen			3				1	4
Interpersonal Communication			3				1	4
Basic knowledge on PSM role & processes			3				1	4
Sales	1		2				1	4
Finance			2				1	3
Supply Chain			2				1	3
Marketing			2				1	3
Stakeholder Relationship Management			2				1	3
Conflict Resolution			2				1	3
Passion			2				1	3
Critical thinking			2				1	3
Skills for Blockchain			1		2			3
Effective questioning techniques			2				1	3
Statistical Skills			2				1	3
Skills for Cloud computing		1			1		1	3
Teamwork-working in teams			1				1	2
Risk management			1				1	2
Sustainability			1				1	2
Planning			2					2
Innovation sourcing			1				1	2
Skills for Machine Learning			1		1			2
Future thinking/Innovativeness			1		1			2
Strategic sourcing			1				1	2
Customer Focus			1				1	2
Integrity			1				1	2
Manufacturing/Production			1				1	2
Cost savings			1				1	2
Results focus driving for results			1				1	2
Openness, Open-minded,			1				1	2

Self-confidence			1				1	2
Engineering			1				1	2
Quality (QHSE)			1				1	2
R&D			1				1	2
Intellectual Property			1				1	2
KPI Reporting Design			1				1	2
Languages			1				1	2
Quality assurance			1				1	2
Automation			1				1	2
Skills for 3D Printing	1		1					2
Prioritization			1				1	2
Remote Virtual Working			1				1	2
Structured way of working			1				1	2
Curiosity			1				1	2
Deal with ambiguity			1				1	2
Humility			1				1	2
Mobility			1				1	2
Resilience			1				1	2
Self-reflection			1				1	2
Networking			1				1	2
Skills for Distributed Computing			1		1			2
Business ethics			1					1
International regulations/Legal knowledge			1					1
Operations research			1					1
Mathematical modelling			1					1
Skills for Solution development			1					1
Technological trends			1					1

Table 19 List of PSM skills which are mentioned in articles oriented on Industry 4.0 maturing purchasing technologies

As can be seen from table above, skills such as big data analytics, strategic thinking, business acumen, analytical skills and cross-functional abilities & knowledge are those most often mentioned in connection with maturing technologies.

Articles covering emerging procurement technologies were the final analysis area and the overview of skills linked to particular Industry 4.0 emerging technology is presented in the next table. (Table 20)

Emerging					
Skills	Blockchain	Sensors	Cyber Tracking	Virtual Reality / Spatial Analytics	N
Big Data Analytics	2	4	14		20
Strategic thinking	2	2	7	2	13

Business Acumen	1	1	7	1	10
Cross-functional abilities & knowledge	1	2	6	1	10
Analytical skills	1	1	7		9
Database Management	2	2	4	1	9
Decision making	1	2	6		9
Holistic Supply Chain Thinking	1	3	4	1	9
Learning agility	1	2	3	1	7
PSM Best Practice Intelligence Scouting	1	1	3	1	6
Innovative sourcing approaches	1	1	3	1	6
Leadership	1	1	3	1	6
Knowledge sharing	1	2	3		6
Skill for Artificial intelligence	2	2	2		6
Computer Literacy	1	1	3		5
Change Management	1	1	2	1	5
Cultural awareness	1	1	2	1	5
eProcurement Technology	1	1	3		5
Creativity		1	4		5
Skills for Blockchain	2	2	1		5
Tools and Systems Implementation		1	3		4
Process optimization		1	3		4
Future thinking/Innovativeness			4		4
Product knowledge			3		3
Communication skills			3		3
Financial acumen			3		3
Interpersonal Communication			3		3
Basic knowledge on PSM role & processes			3		3
Supply Chain		1	2		3
Skills for Machine Learning	1	1	1		3
Negotiation			2		2
Supplier management			2		2
Contract Management			2		2
Project Management			2		2
Logistics		1	1		2
Sales			2		2
Finance			2		2
Marketing			2		2
Stakeholder Relationship Management			2		2
Conflict Resolution			2		2
Passion			2		2
Critical thinking			2		2
Effective questioning techniques			2		2
Statistical Skills			2		2
Teamwork-working in teams		1	1		2

Planning			2		2
Innovation sourcing		1	1		2
Results focus driving for results		1	1		2
Openness, Open-minded,		1	1		2
Curiosity		1	1		2
Skills for Distributed Computing		1	1		2
Problem solving		2			2
Risk management			1		1
Sustainability			1		1
Strategic sourcing			1		1
Customer Focus			1		1
Integrity			1		1
Manufacturing/Production			1		1
Cost savings			1		1
Self-confidence			1		1
Engineering			1		1
Quality (QHSE)			1		1
R&D			1		1
Intellectual Property			1		1
KPI Reporting Design			1		1
Languages			1		1
Quality assurance			1		1
Automation			1		1
Skills for 3D Printing			1		1
Prioritization			1		1
Remote Virtual Working			1		1
Structured way of working			1		1
Deal with ambiguity			1		1
Humility			1		1
Mobility			1		1
Resilience			1		1
Self-reflection			1		1
Networking			1		1
Business ethics			1		1
International regulations/Legal knowledge			1		1
Operations research			1		1
Mathematical modelling			1		1
Skills for Solution development			1		1
Technological trends			1		1
Flexible thinking		1			1

Table 20 List of PSM skills which are mentioned in articles oriented on Industry 4.0 emerging purchasing technologies

Based on the definition, the emerging purchasing technologies are the technologies that could have impact on the procurement in the future. Looking at the skills which are mentioned in connection with such technologies, the skills needed for future procurement are similar to those skills which are needed for technologies that are currently transforming the procurement environment (known as maturing solutions). Big data analytics and Strategic thinking are also in this case at the top of the list.

The results of the provided literature review can be summarized into several key findings.

Key findings based on literature review:

1. Most of the articles covering PSM skills mention Industry 4.0 without a robust and proper definition of the concept.
2. Surveys regarding PSM skills for Industry 4.0 usually cover Industry 4.0 in general instead of trying to identify a PSM skillset for a particular area of Industry 4.0.
3. Although the most frequently mentioned skillset is technical skills, interpersonal skills are the second most mentioned PSM skill category in industry 4.0 oriented articles.
4. Big data analytics and strategic thinking are the top 2 PSM skills in Industry 4.0 oriented articles.
5. The articles which mention Industry 4.0 in general without a proper link to technology most frequently mention managerial skills, such as project management, teamwork, logistics and risk management.
6. The Importance of Big data analytics increases with the articles that focus on maturing and emerging Industry 4.0 purchasing technologies.
7. Strategic thinking is mostly mentioned in articles covering Industry 4.0. core (mainstream) purchasing technologies
8. Big data analytics, Analytical skills and Strategic thinking and Holistic Supply Chain Thinking were recognised as key future and Industry 4.0. PSM skills and competencies.
9. Analytical skills and strategic thinking were recognised as highly significant, not only in current, but also in future Industry 4.0. driven purchasing environment.
10. Most of the articles do not mention any form of skills training or education.

2.4. Summary of Industry 4.0. articles dealing with PSM skills

Scientific literature dealing with implementation of Industry 4.0. or its equivalents in the broad field of supply chain management is growing. Most of the articles are introducing or evaluating new technologies, models and approaches to increase quality, performance or reduce risk in the supply chain as a whole. Although implementation of all these enhancements is usually described in detail in a particular article, information regarding skills and competencies required for their use are usually missing. This systematic literature review aimed to analyse all articles which deal with PSM skills in Industry 4.0 oriented literature. From 3671 identified articles 50 of them were recognised as Industry 4.0 oriented and mention concrete skills linked to PSM, however only 36 articles were able to link PSM with concrete Industry 4.0. purchasing technology. The detailed analysis showed that there is broad and different understanding of the Industry 4.0 concept between authors of the articles, as well as between participants of their studies. Moreover, few articles provide some definition or description of the framework. In addition, the skills identified in the reviewed articles tend to be discussed generally and concrete examples of the involvement of skills in some Industry 4.0 oriented purchasing areas are often missing. With the growth of Industry 4.0, technical skills are becoming increasingly necessary and appear to supersede those skills of a more interpersonal nature. Further analysis also showed that, in articles which mention concrete Industry 4.0 purchasing technologies, technical skills such as analytical skills and big data analytics are becoming more significant and, together with strategic thinking and taking a supply chain holistic view, represent the most required skills for the future Industry 4.0 environment. It should be noted, that although some articles tried to connect PSM skills with specific Industry 4.0 procurement technology, the vast majority of articles do not provide a description of how to train and teach such PSM Industry 4.0 skills.

3. Gamification to support PSM teaching and learning

3.1. Introduction

The purpose of this element of Intellectual Output 1 (IO1) of project PERSIST is to establish how gamification techniques and tools can be used to support the teaching and learning of the skills, competencies and knowledge required in an Industry 4.0 influenced Purchasing and Supply Management (PSM) environment. Gamification can be defined as the use of game elements and game-design techniques in non-game contexts (Werbach & Hunter, 2013) and the process of making activities more game-like (Werbach, 2014). Gamification is an emerging area of focus in a variety of literature areas, across different industrial settings and within various education contexts. It has been used in a wide variety of subject-specific education contexts, including computer science (see Gari et al., 2018 for a detailed literature review); accountancy (see da Silva et al., 2019 for a detailed literature review); industrial engineering (Despeisse, 2018); enterprise resource planning (Wu, 2016) and quality management (Brauner et al., 2016). Gamified learning can strengthen both student knowledge and also their ability to communicate and cooperate with fellow students in furthering their understanding of learning content (Hamari, Koivisto, & Sarsa, 2014). In addition, using gamified learning should make the experience motivating and pleasant, rather than dull (Wu, 2011). As the concept of gamification is broad, the review covers both the use of using game elements for engagement (e.g. traditional classroom teaching but with a leader board of exam results) and also when the game is actively engaged in the teaching of the actual subject.

Examples of education usage of gamification in the wider Supply Chain Management (SCM) context include the oft-played beer-distribution game, developed by Jay Wright Forrester at the MIT Sloan School of Management in 1960 (Forrester, 1961). This game aims to simulate the coordination of typical problems in a supply chain process and promotes the need for information sharing, supply chain management and collaboration throughout a supply chain (Sterman, 1984). Development of the game has gone from a traditional (paper based) board game to online software versions and is still widely used today. There are a

number of other SCM related gamified education examples (e.g. supply chain optimization in van den Berg et al., 2017; sustainable SCM in Hidayatno et al., 2018; humanitarian logistics in William et al., 2018) and these are shown in table below (Table 21).

A structured approach was taken to review the literature in this area, as detailed in the methodology below, but this approach maintains a clear focus on the education use of gamification, rather than its deployment in operational settings (e.g. using leaderboards to monitor supplier performance). Four research questions were developed to obtain a more in-depth understanding of education gamification and the results of these are discussed after the methodology:

Research questions related to gamification overview are mentioned in the first chapter. :

3.2. Methodology - Literature identification

3.2.1. Search 1 – Education gamification in Purchasing & Supply Management

A search for any relevant sources of literature that analyse the use of gamification techniques and tools in a PSM specific setting was done using the search string pattern shown below to ensure that a full spread of literature was considered. The SCOPUS database was used and the search limited to outputs from the last 5 years, as our focus is on the potential of delivering gamified learning in an Industry 4.0 context (a new area of development) and also to take into account more recent technological and pedagogical developments. The search string includes some of the segments on skills/competencies and PSM taken from the previous searches of IO1. Journal and conference papers, as well as book chapters were included in the search scope.

TITLE-ABS-KEY ("PSM" OR "supply chain" OR "purchasing" OR "procurement" OR "outsourcing" OR "suppl* network") AND TITLE-ABS-KEY ("training" OR "education" OR "learning" OR "teaching") AND TITLE-ABS-KEY ("serious game" OR "augmented reality" OR "applied game design" OR "employee training software" OR "gamification" OR "badge" OR "leaderboard" OR "game mechanics" OR "gameful" OR "avatar" OR "quest") AND (

LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015)

This search yielded a total of 67 results and a detailed review of these papers was conducted and the following rejection criteria utilised:

1. Papers that related to operational usage.
2. Papers that did not focus on industrial PSM or SCM (e.g. consumer usage).
3. Papers that focused on the technical aspect of a gamified concept (e.g. augmented reality) but did not extend this to an education or PSM context.
4. Identified paper was actually only a summary of a full conference proceedings.
5. Full-text of the papers were inaccessible by members of the project team or were not in English or a language spoken by one of the team members (e.g. Shchepetova & Satdykov, 2018).
6. Papers that used a simulation with students as a method for testing non-education phenomena (e.g. Furukawa et al., 2017).

This detailed analysis resulted in 14 papers being identified as relevant, although it should be noted that many of them cover wider supply chain activities (e.g. logistics and distribution), rather than the more narrow focus of PSM, but these have been included for review due to their potential functional relevancy. These papers were as follows:

Authors	Title	Year	Source title	Document Type
Destyanto A.R., Fajar N.F., Ardi R.	Serious simulation game design to support extensive understanding of closed-loop supply chain concept in e-waste management context	2019	ACM International Conference Proceeding Series	Conference Paper
Despeisse M.	Games and simulations in industrial engineering education: A review of the cognitive and affective learning outcomes	2019	Proceedings - Winter Simulation Conference	Conference Paper
William L., Rahim Z.B.A., Boo I., De Souza R.	Embedding Mixed Reality in Humanitarian Logistics Gaming	2019	Proceedings of 2018 IEEE International Conference on Teaching, Assessment, and Learning for Engineering, TALE 2018	Conference Paper

Hidayatno A., Zulkarnain, Hasibuan R.G., Wardana Nimpuno G.C., Destyanto A.R.	Designing a serious simulation game as a learning media of sustainable supply chain management for biofuel production	2019	Energy Procedia	Conference Paper
Reggelin T., Weigert D.	A logistics management game for actors of a geographically distributed supply chain	2019	Lecture Notes in Networks and Systems	Book Chapter
Egilmez G., Gedik R.	A gamification approach for experiential education of inventory control	2018	ASEE Annual Conference and Exposition, Conference Proceedings	Conference Paper
Milosz M., Milosz E.	Computer decision simulation games for logistic training of engineers	2018	IEEE Global Engineering Education Conference, EDUCON	Conference Paper
Cuesta Aguiar V.A., Nakano M.	A model for the development of stealth serious games	2018	Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)	Conference Paper
Van Den Berg M., Voordijk H., Adriaanse A., Hartmann T.	Experiencing Supply Chain Optimizations: A Serious Gaming Approach	2017	Journal of Construction Engineering and Management	Article
Lindawati, Nugroho E., Fredericco R., Rahim Z.B.A., De Souza R.	ThinkLog: Interactive learning for supply chain management	2017	Proceedings of 2017 IEEE International Conference on Teaching, Assessment and Learning for Engineering, TALE 2017	Conference Paper
Horng-Jyh P.W.	Learning enterprise resource planning (ERP) through business simulation game	2016	ACM International Conference Proceeding Series	Conference Paper
Oates E.	Learning and designing with serious games: Crowdsourcing for procurement	2016	Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)	Conference Paper
Brauner P., Philipsen R., Ziefle M.	Projecting efficacy and use of business simulation games in the production domain using technology acceptance models	2016	Advances in Intelligent Systems and Computing	Conference Paper

Table 21 - Gamification in PSM and SCM education papers

3.2.2. Search 2 – a review of education gamification literature reviews in a wider context

Due to the limited results in search 1, the search was widened to incorporate a number of existing systematic literature reviews dealing both with general education and also more specific industrial settings. The search string TITLE ("gamification" AND "literature review") AND (LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015)) was used to in the SCOPUS database and a focus on the titles of the papers, to ensure that only systematic literature reviews were identified, rather than the literature sections of individual papers and

only papers over the last five years. This resulted in the identification of 26 papers, which were then reviewed in detail and 11 papers were rejected as they did not have a clear educational focus or the full-text of the papers were inaccessible by members of the project team. Details of the 15 remaining papers are presented in Table 22.

3.3. Analysis of education gamification literature

To address the research questions identified in the Introduction section, a detailed analysis of the papers from searches 1 and 2 covered three areas.

- Specific examples of gamified learning were analysed to extract the specific characteristics of gamification to identify the type of gamification (e.g. simulation), platforms used, learning being delivered, how effective it was and also any proposed improvements and the results of these are summarised in Table 3.
- A series of gamification principles and techniques underlying the development of effective gamification (shown in table 4).
- Any processes and stages that have been used to implement gamified activities (shown in table 5).

3.3.1. Specific characteristics of gamified learning in PSM/SCM

The purpose of this analysis was to distil some key characteristics that could be used to inform the development of gamified learning in a PSM context and the details of the papers used is shown in Table 23.

Authors	Title	Year	Source title	Document Type
Hosseini C., Haddara M.	Gamification in Enterprise Systems: A Literature Review	2020	Advances in Intelligent Systems and Computing	Conference Paper
Antonaci A., Klemke R., Specht M.	The effects of gamification in online learning environments: A systematic literature review	2019	Informatics	Article
Limantara N., Meyliana, Hidayanto A.N., Prabowo H.	The elements of gamification learning in higher education: A systematic literature review	2019	International Journal of Mechanical Engineering and Technology	Review
van der Poll A.E., van Zyl I.J., Kroeze J.H.	A Systematic Literature Review of Qualitative Gamification Studies in Higher Education	2019	Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)	Conference Paper
Larson K.	Serious Games and Gamification in the Corporate Training Environment: a Literature Review	2019	TechTrends	Review
Júnior E.S., Reis A.C.B., Mariano A.M., Barros L.B., De Almeida Moysés D., Da Silva C.M.A.	Systematic literature review of Gamification and Game-based Learning in the context of Problem and Project Based Learning approaches	2019	International Symposium on Project Approaches in Engineering Education	Conference Paper
da Silva R.J.R., Rodrigues R.G., Leal C.T.P.	Gamification in management education: A systematic literature review	2019	BAR - Brazilian Administration Review	Article
Hallifax S., Serna A., Marty J.-C., Lavoué É.	Adaptive Gamification in Education: A Literature Review of Current Trends and Developments	2019	Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)	Conference Paper
Muangsrinoon S., Boonbrahm P.	Game elements from literature review of gamification in healthcare context	2019	Journal of Technology and Science Education	Article
Gari M.R.N., Radermacher A.D.	Gamification in computer science education: A systematic literature review	2018	ASEE Annual Conference and Exposition, Conference Proceedings	Conference Paper
Fabricio De C.I.	Using gamification in education: A systematic literature review	2018	International Conference on Information Systems 2018, ICIS 2018	Conference Paper
Ortega-Arranz A., Muñoz-Cristóbal J.A., Martínez-Monés A., Bote-Lorenzo M.L., Asensio-Pérez J.I.	How gamification is being implemented in MOOCs? A systematic literature review	2017	Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)	Conference Paper
Könnölä K., Ranti T., Liukkonen T.N., Mäkilä T.	Food-related gamification: Literature review	2016	17th International Conference on Intelligent Games on Simulation, GAME-ON 2016	Conference Paper
Mora A., Riera D., Gonzalez C., Arnedo-Moreno J.	A Literature Review of Gamification Design Frameworks	2015	VS-Games 2015 - 7th International Conference on Games and Virtual Worlds for Serious Applications	Conference Paper
Azmi S., Iahad N.A., Ahmad N.	Gamification in online collaborative learning for programming courses: A literature review	2015	ARNP Journal of Engineering and Applied Sciences	Article

Table 22- Gamification in education literature reviews

Authors	Type	Education focus	Platform	Details	Results	Potential improvements
Destyanto et al. (2019)	Simulation	Understanding closed loop supply chains	Spreadsheets	Achieve the highest points on sustainability with four main aspects: net income, environmental performance, company image, and e-waste collection rate	Not shown	User interface improvement
William et al. (2019)	Digital single player mixed reality simulation game	Improve knowledge on the importance and complexity of SCM planning and execution in humanitarian crises	Online, but specifics not shown	Replicate and simulate a realistic disaster environment, the disaster relief game	Not shown	Not shown
Hidayatno et al. (2019)	Simulation	Planning and scheduling	Not shown	Played by four teams, consisting of four players who act as Purchasing Manager, Production Manager, Sales Manager, and Financial Manager, representing a company that will compete against each other to get the highest points at the end of the game	Positive impact on learning, although not clearly defined	Player interface needs developing to increase player comprehension and the motivation of players in competing and more use of related game information
Reggelin & Weigert (2019)	Simulation	Inventory control policy making	MS Excel & VBA	Ten players take different roles within a supply chain. The customer orders a product in four different variants. Each day every player has to decide how many products to order from the preceding actor in the supply chain	Not shown	Implement proposed game using the internet
Egilmez & Gedik (2018)	Simulation	Inventory control policy making	MS Excel	Students simulate inventory control policy of a product over 1 to 12 months	Positive impact on learning	Improve graphical user interface
Milosz & Milosz (2018)	Simulation	Various	Specifics not shown	Not shown	Not shown	Not shown

Cuesta Aguiar & Nakano (2018)	Simulation	Sustainable Supply Chain Management Stealth Serious Game	Not shown	Optimize their supply chain to meet environmental needs, achieve economic success, uphold ethical behavior in dealings with other players and manage risk to outperform rival supply chains and be the only player left in the game. The player is not fully aware they are learning, known as “stealth learning”, which has a high replay value	Some success	The next generation of SG should aim to educate and entertain in equal shares. The difficulty lies in balancing the previous two dimensions
Van Den Berg et al. (2017)	Board game	Improve the performance of a construction supply chain by continuously balancing scope, time, and cost throughout a project.	Physical product	Construction supply chain management (ordering etc.)	Positive impact on learning	Game rules were initially hard to understand, and a lack of a structured debriefing downplays learning (could be enhanced by the use of skilled facilitators) possibilities
Lindawati et al. (2017)	Board game	Fundamental concepts of SCM such as bullwhip effects, supply chain risk management and e-commerce fulfilment	Physical product	Ship, pay, order processes across manufacturer, distributor, wholesaler and retailer	Positive impact on learning	Develop a more comprehensive evaluation method to measure the learning outcome of the game
Horng-Jyh (2016)	Simulation	Business Process Integration and Management of Supply and Demand, including price setting	Not shown	Acquire and apply certain key ERP concepts, across our main functions: Sales, Marketing, Procurement and Material Requirement Planning	Not shown	Not shown

Table 23 Gamified learning characteristics

The key findings from this analysis show that:

1. The characteristics show a mix of both physical and technology supported games and therefore there are a range of opportunities to deliver gamified learning.
2. Some papers demonstrate a positive impact on learning and achievement and so care should be exercised in developing a range of relevant performance metrics that ensure that teaching objectives can be met and that the full process of learning is considered. Some papers noted that a potential improvement would be the development of more comprehensive learning outcome measurements.
3. Key improvements include the development of a robust user interface, which reflects the need for gamified learning to be engaging for students.
4. Most of the games deal with quantifiable scenarios, e.g. how much to order and to pay, within the wider SCM context, and so these would lend themselves more readily to simulation type games. However, there is an increasing focus on soft skills within PSM (e.g. Bals et al., 2019), so a wider range of game types should be considered that can develop and evaluate more qualitative requirements.

3.3.2. Gamification principles and techniques

To provide a more focused approach for the later IOs of project PERSIST, which will look at the development of gamified elements in PSM, we also identified some key principles and techniques from this literature that should underpin the design and implementation of any gamification. It should be noted that some of these relate to implementing gamification into an organisation, rather than specifically for education purposes, but the underlying principles and techniques can still be considered valid. (Table 24)

Source	Theme	Details
Mora et al. (2015)	Economic	Objectives: are their specific performance goals. Viability: a previous study, evaluation and analysis of the potential of applying gamification or refuse it. Risk: a probability or threat of damage, injury, liability, loss, or any other negative occurrence. ROI (Return On Investment): the benefit to the investor resulting from running a gamified experience. Stakeholders: a technique used to identify and keep in mind the people who have to interact with the design process.
	Logic	Loop: the game mechanics combined with reinforcement and feedback in order to engage the player in the key system actions. End game / Epic win: a pre-established end of game or glorious victory in the system, usually stretching players to the limits of their abilities. On-boarding: the way of starting the new participants. Rules: the body of regulations prescribed by the designer.
	Measurement	Metrics: the standards of measurement by which efficiency, performance, progress, process or quality. Analytic: the algorithms and data used to measure key performance indicators.
	Psychology	Fun: the enjoyment or playfulness. Motivation: the behaviour which causes a person to want to repeat an action and vice-versa. Social: the interaction between players. Desired behaviours: the expected response of the players after the interaction. Ethics: a branch of philosophy that involves systematizing, defending and recommending
Cuesta Aguiar & Nakano M. (2018)	Replay Value	The property of the SG to be played repeatedly, providing a new experience, and learning to the player every time the SG is played.
	Low rule complexity	If the rules are too complex the barrier to play the game becomes too high and some players might lose motivation to learn how to play.
	Stealth learning	When players are focused not on learning but on playing.
	Educational topics feed mechanics	The mechanics in the SG must be generated using the topics the designer wants the player to learn. It is important to state that the topics must be presented in such a way that the player does not fully realize he/she is learning.
	Fun	A combination of simulation, simplicity, and the gaming and stealth facet. Not a simulation: If the game is a simulation the SG becomes too complex for non-professionals and can potentially lead to boredom for those who are not professionals. Complexity in this case is defined as giving the player several variables and interdependencies to control when playing the SG, the ability to control every aspect of the game is not always met with joy by players. Not overly simple: If the game is too simple, professionals will not take the game seriously
	Visuals	Appealing: SG usually lack enthralling visuals; good visual representations allow for more player immersion and make the player feel excited about playing the SG. Provide support to play the SG: The player does not need to remember everything in the game. It is the game's responsibility to remind players about important rules, mechanics, and dynamics. Free Mental resources from the player: Well implemented visuals free mental resources in the player allowing him/her to focus on the strategic layer of playing the SG.
Williams et al. (2019)	Challenge	Enhance intrinsic motivation to learn new skills and knowledge voluntarily. In serious game, there are several techniques to create challenge, such as difficulty level, randomness and hidden information.
	Choice	Options or alternatives that the players can choose prior or during the game session. It may include expressive choices (i.e. avatars, cities, roles), strategic choices (i.e. difficulty level) and tactical choices (i.e. actions/decisions in the game).

	Competition	It can be used to motivate players to voluntarily complete the game activities better or faster to get a certain reward. It typically involves competition between players, playing against the computer or racing against the clock.
	Fantasy	Themes or fantasies can be defined as “non-actual” environment that creates images of physical or social situations that are not actually present. It is important to create engagement and immersion for the players. The fantasy can be presented by including elements of the fantasy world through the visual or audio channel.
	Goal	The goal (i.e. rewards/points) would be able to motivate the players to complete the game activities.
	Rule	Provides boundaries that restrict the players’ actions and decisions. It enables the players to practice specific skill sets as intended in the game’s learning objectives.
Van Den Berg et al. (2019) – based on Hartevelt (2011)	World of reality	The game’s connection to the physical world. It includes domain-specific knowledge to make a game experience intuitive and understandable. The type of game and its purpose determine how elaborate, realistic, and valid the game’s representations of (parts of) reality are.
	World of meaning	The types of value to be achieved by a game. This considers the meaningful effect beyond the game experience itself. This value proposal is an extensive description of how a game will affect the real world.
	World of play	The goals and rules of a game. Games are highly interactive and engaging tools that immerse people in a fictive situation.
Despeisse (2019)	Superficial gamification	The first level of gamification includes simple game elements e.g. avatars, points, badges and leaderboards in order to increase students’ interest and motivation in engaging with the course content.
	Deeper gamification	The second level involves similar game elements but also more complex game mechanics and dynamics embedded in the learning activities. This time, the gamified content is used as a tool to facilitate the learning process.
	Game based learning	The third level is the full implementation of a game or simulation, also called “serious game”, towards predetermined learning outcomes.
	Cognitive learning	Remembering, understanding, applying, analysing, evaluating and creating (some examples of specific games are given in the paper).
Brauner et al. (2016)	Guidelines for business simulation games	<ol style="list-style-type: none"> 1. Clearly visible short-term benefits of using the game. E.g., by making clear that the conveyed skills will be beneficial for an upcoming exam. 2. The player must perceive the presented environment as a simulacrum of the reality, e.g., by portraying realistic production processes. 3. Consider learner diversity, especially in regard to different levels of inclination towards games, e.g., by augmenting the game environment with traditional forms of knowledge dissemination. 4 Create enjoyable learning environments, e.g., by including potential players in the development to ensure target specific aesthetics and playfulness. 5. Avoid unnecessary complexity of the user interface and the simulation model, and provide a focused learning experience, e.g., by reducing the perceived effort for mastering the game through guided tutorials, help functions etc. 6. Provide adequate and immediate feedback on the learning performance, e.g., by linking the learning objectives with the company’s profit or by adding motivational incentives (badges, leaderboards).
Hallifax S., Serna A., Marty J.-C., Lavoué É (2019)	Profile	1. Player type 2. Personality 3. Expertise 4. Other
	Activity	1. Performance 2. Behaviours
Könnölä K., Ranti T., Liukkonen T.N., Mäkilä T. (2016)	Motivational design elements	1. Story 2. Time constraints 3. Assignments, quests and goals 4. Points, credits and levels 5. Achievements or badges 6. Leaderboards and collections 7. Friends, teams and groups 8. Reminders
Muangsrinoon S., Boonbrahm P. (2019)	Game elements	1. Achievements (completing goals) 2. Avatars (visual of a player’s character) 3. Badges (visual of achievement) 4. Boss fights (special challenges at the end of a level) 5. Collections (set of accumulated items or badges) 6. Combat (defined challenges) 7. Content unblocking (privilege for players) 8. Gifting (sharing resources with others) 9. Leaderboards (visual displays of social comparison) 10. Levels (the player’s

		progression) 11. Points (the virtual rewards against the player's effort) 12. Quests (predefined challenges) 13. Social graph (representation of player's social network) 14. Teams (group of players for a common goal) 15. Virtual goods (game assets)
Gari M.R.N., Radermacher A.D. (2018)	Game elements	1. Points 2. Badges 3. Leaderboards 4. Avatars 5. Storylines 6. Visualisations 7. Progress bars 8. Punishment 9. Levels 10. Challenges 11. Feedback
	Student learning focus (impact)	1. Participation 2. Engagement 3. Student achievements (e.g. grades) 4. Participation in knowledge construction processes 5. Learning 6. Usage patterns 7. Exposure to real issues
Hosseini C., Haddara M. (2020)	Game elements	1. Abstractions of concepts and reality (Abstracted reality gives inexperienced people to engage with concepts such as business strategy, processes etc.) 2. Goals 3. Rules 4. Conflict, competition, cooperation 5. Time (Motivating factor for player urgency, such as completing a customer support task. Similar use for consequences, not meeting a deadline etc.) 6. Reward structures 7. Feedback 8. Levels 9. Storytelling 10. The hero's journey (Story made up of characters, plot, tension and resolution) 11. Curve of interest (Flow and sequences of events that keep users engaged) 12. Aesthetics (Visual presentation to provide both feedback and pleasure) 13. Replay or do-over (Permission to "fail", giving opportunity to explore and experiment in the game)
da Silva R.J.R., Rodrigues R.G., Leal C.T.P. (2019)*	Gamification constructs	1. Motivation (the direction, intensity, persistence and quality of a given human behaviour) 2. Flow (a mental state characterized by high concentration and focus on tasks that cause high pleasure and intrinsic motivation) 3. Attitudes (a behavioural pattern that shows an individual's predisposition to adjust to designated social situations, conditioned response to certain stimuli that lead to social experiences) 4. Perceived learning (The use of teaching methods that are aligned with the students' preferences and needs thus helps them develop more favorable attitudes to acquiring knowledge, feel more fulfilled, and reach higher levels of performance)
Azmi S., Iahad N.A., Ahmad N. (2015)	Participation elements	1. Teamwork 2. Personal encouragement 3. Instructor support
	Game elements	1. Mechanics (badges, leaderboards, points, levels, game board feedback, reward, notifications, virtual goods, progress bar, paths, avatar, teams) 2. Dynamics (social personal – desire for reward, personal promotion / social dynamics – altruism, status, achievements competition, peer collaboration, confrontation, user scores, feedback system) 3. Aesthetics (challenges)
Ortega-Arranz A., Muñoz-Cristóbal J.A., Martínez-Monés A., Bote-Lorenzo M.L., Asensio-Pérez J.I. (2017)	Educational platforms	1. OpenHPI 2. OpenLearn 3. Claroline Connect 4. iMOOX 5. Quizlet 6. Telescopio 7. ECO platform 8. Canvas Network 9. Coopacademy 10. Coursera 11. MiriadaX
	Game mechanics used	1. Lives 2. Mini-games 3. Contests 4. 3D virtual teams 5. Team score 6. Useful rewards 7. Unlocking content 8. Social connections/stream 9. Narrative 10. Timers 11. Gamification paths 12. Difficulty progression 13. Peer classification 14. Virtual goods 15. Loops 16. Challenges 17. Duels/battles 18. Avatar customization 19. Progress/status bar 20. Levels 21. Votes/rates 22. Points (Karma, experiences) 23. Leaderboards/rankings 24. Badges/medals
	Student actions associated with game elements	1. Share contents 2. Watch videos 3. Log in frequently 4. Work efficiently in a group 5. Participate in social networks 6. Redeem rewards 7. Join a group 8. Do physical activity 9. Read content 10. Send/accept friend requests 11. Answer questions correctly 12. Review contents 13. Contribute to a task 14. Completing the course 15 Perform achievements 16. Get high score in quizzes 17. Receive/provide votes/rates 18. Ask/answer questions (forums) 19. Complete assignments
Larson K. (2019)	Ethical issues, challenges and constraints in a Corporate Environment	1. Fear of change 2. Potential exploitation of the labour market 3. Cumbersome change process in large organisations 4. Demonstrating a return on investment
Júnior E.S., Reis A.C.B., Mariano A.M., Barros L.B., De Almeida Moysés D., Da Silva C.M.A. (2019)	Competencies developed in students	1. Integrated knowledge 2. Teamwork 3. Communication 4. Self-improvement 5. Creativity 6. Collaboration 7. Proactivity 8. Decision-making 9. Rapid assimilation of content 10. Cooperation 11. Authenticity 12. Negotiation 13. Criticality 14. Leadership 15. Ability to put knowledge into practice 16. Objectivity 17. Self-management 18. Computational thinking 18. Logical reasoning

Antonaci A., Klemke R., Specht M. (2019)	Game elements	1. Badges 2. Leaderboards 3. Points 4. Feedback 5. Challenges 6. Likes/social features 7. Communication channels 8. Narratives 9. Levels 10. Progress bars 11. Teams 12. Agent 13. Medals 14. Avatars 15. Trophies 16. Time limit 17. Virtual currency 18. Personalising features 19. Mission 20. Replayability 21. Goal indicators 22. Competition 23. Win state
	Effects of game elements on learning	1. Performance 2. Motivation 3. Engagement 4. Attitudes towards gamification 5. Collaboration 6. Social awareness 7.
Limantara N., Meyliana, Hidayanto A.N., Prabowo H. (2019)	Game elements	1. Reward 2. Quest 3. Points 4. Badges 5. Narrative 6. Feedback 7. Competition 8. Publicity 9. Avatar 10. Card games 11. Task 12. XP 13. Ranking 14. Level 15. Leaderboard 16. Achievement 17. Quiz 18. Puzzle 19. Virtual goods
	Participation type	1. Mandatory 2. Voluntary 3. Random 4. Selected with reward
Fabricio De C.I. (2018)	Instrumental outcomes	1. Participation (Interaction, Response Accuracy, Student Participation, Time Spent, Response Time, Formation of Good Habits, Time-on-Task, Interactivity, Student Attendance, Task Completion, Usefulness, Procrastination, Carefulness, Contribution, Productivity, Behavioral Engagement, User Activity, Participation) 2. Performance based on student perception (Meaningful Learning, Perceived Achievement, Declarative Knowledge, Perceived Stakes, Perceived Learning, Perceived Efficiency) 3. Participation based on student grades (Retention of Knowledge, Procedural Knowledge, Declarative Knowledge, Knowledge Acquisition, Skills Improvement, Learning Outcomes, Driving Behavior, Student Achievement, Academic Success, Training Performance. Learning Gain, Academic Performance, Student Performance, Learning, Learning Achievement, Learning Performance) 4. Retention based on user activity (Attrition, Retention, Persistence, Players Retention).
	Experiential outcomes	Perceptions (experience in general), Motivation, Attitude (toward gamification, lessons, badges, in general), Satisfaction, Engagement (emotional and cognitive), Self-Efficacy, Flow/Cognitive Absorption, Others: Playfulness; Anxiety; Relevance; Cognitive Load; Pedagogical Affect; Confidence; Psychological Effects; Distraction; Cognitive Effects; Student Perception (toward badges); Negative Effects; Enjoyment; Attention; Self-Regulation; Positive Effects; Reactions to Training; Task Meaningfulness; Valence; Acceptance; Social Comparison; Fun; Usability; Interest; Mood State
* This paper also has a useful history of gamification in management education.		

Table 24 Principles and techniques of gamification implementation

These findings have been synthesised into a number of different categories that can be used as underlying principles and techniques that can be used to inform the more conceptual aspects of gamified design in PSM. (Table 25)

Enjoyment	Clear objectives and goals
Rewards and rankings	Abstractions of concepts and reality
Meaningful to specific stakeholders with specific domain-specific knowledge	Right level of rules and complexity
Performance and outcome measures relating to retention, satisfaction, attendance, engagement, motivation, improvements in learning, socialisation	Stealth learning (focused on playing, but not necessarily on learning)
Opportunities for feedback	Appealing aesthetics via user interface and gameplay
Recognising learner diversity	

Table 25 Summary of gamification principles and techniques

3.3.3. Gamification implementation processes/stages

The reviewed papers also identified a number of gamification implementation processes/stages, which are shown below, and these can be used as the basis to structure the practical deployment of gamified education in the PSM context, specifically in later Intellectual Outputs of project PERSIST:

Literature Review Source	Original Source	Processes/stages
Mora et al. (2015)	Werbach & Hunter (2012)	“Six Steps to Gamification” (6D), as starting from a definition of business objectives, target the expected behaviours, describes the players, devises the activity loops without forgetting the fun, and finally, deploys the gamification system with the appropriate tools.
Mora et al. (2015)	Marczewski (2012)	GAME framework, which is based on two phases, first, planning and designing (includes using a survey to gather key information, such as the users’ types in the gamification context) and then designing the best solution for achieving the goals and engagement and user activities and outcomes are measured.
Mora et al. (2015)	Marache-Francisco & Brangier (2013)	Design based on Human-Computer Interaction principles and that the design processes consists of the context analysis and the iterative conception of the gamification process. This paper also identifies a number of other process/stages papers as follows: Robinson & Bellotti (2013), Francisco-Aparicio et al. (2013), Versteeg (2013), Kumar (2013), Jacobs (2013), Julius & Salo (2013), Li (2014), Jimenez (2013), Herzig (2014).
Cuesta Aguiar & Nakano M. (2018)	Ibrahim & Jaafar (2009)	Educational Games (EG) Design Framework - Game Design, Pedagogy and Learning Content Modelling



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Hidayatno et al. (2019)	Katsaliaki et al. (2011)	Defining game objectives, model development, model implementation, then classroom pedagogy and evaluation.
Van Den Berg et al. (2019)		Repeated cycle of (1) prototyping, (2) testing and evaluating, and (3) continual redesign.
Destyanto et al. (2019)	Heide et al. (2018)	Design and prototyping stage, execution stage, and evaluation stage.

Table 26 Processes/stages of gamification implementation

An analysis of the key findings of these papers shows that a robust process should be used that incorporates the following, which can be used in conjunction with the principles of gamification contained in the preceding section.

1. Clear definition of both learning and game objectives with a focus on the curriculum (outcomes, assessment and feedback).
2. Gather data on the user types.
3. The use of a prototype/testing stage/phase incorporating best practices from game/software development and the use of cases.
4. Establish robust and relevant performance metrics and effective feedback measures.
5. Continual redesign based on feedback from learners and educators.

3.4. Summary of education gamification literature review

The research highlights that, although there are a number of examples of supply chain gamified learning (e.g. dealing with stock management, pricing and supply and demand), there is little that looks at specific PSM activities. In addition, much of the existing gamified learning uses simulations (either physical or technologically supported) that relies on quantitative decision making and therefore more qualitative factors could be introduced in a gamified context. There is therefore an opportunity to develop PSM focused gamified learning that is underpinned by relevant gamification principles and techniques (as per Table 24) and is deployed using pertinent gamification processes/stages (as per Table 26). This will ensure that this learning is robust and offers students a different learning environment, which will be more relevant to developing the key skills, competencies and knowledge required for working in and adapting to an Industry 4.0 environment.

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