D5.4

Policy Recommendations

Person responsible / Author:	Stefano Perini - POLIMI
Deliverable No.:	5.4
Work Package No.:	5
Date:	26.04.2016
Project No.:	609147
Classification:	Public
File name:	D5.4_Policy Recommendations
Number of pages:	50

Status of deliverable

Action	By	Date
Submitted (author)	Stefano Perini – POLIMI	26.04.2016
Responsible (WP Leader)	Manuel Oliveira – SINTEF	26.04.2016
Approved by Peer reviewer	Poul Hansen – AAU	22.04.2016

Revision History

Date	Revision version	Author	Comments
06.11.2015	V0.1	Stefano Perini	ToC
12.11.2015	V0.2	Stefano Perini	First Draft
18.11.2015	V0.3	Stefano Perini	Second Draft
25.11.2015	V0.4	Stefano Perini	Methodology Finished. Draft of Policy Recommendations
08.12.2015	V0.5	Stefano Perini	Integration of Lisbon Meeting's inputs. Refinement of the methodology
15.12.2015	V0.6	Stefano Perini	Final draft of Policy Recommendations
21.12.2015	V0.7	Stefano Perini	Final version for Internal Peer Review
22.12.2015	V0.8	Poul Hansen	Internal Peer Review
28.12.2015	V0.9	Stefano Perini	Integration of Advisory Board's inputs
30.12.2015	V1.0	Stefano Perini	Final Version
18.04.2016	V1.1	Stefano Perini	Final version for Internal Peer Review after RM (Engineering Education Policy Recommendations – Chapter 5)
22.04.2016	V1.2	Poul Hansen	Internal Peer Review after RM
26.04.2016	Final	Stefano Perini	Final Version after RM

Authors contact information

Name	Organisation	E-mail	Tel
Stefano Perini	POLIMI	stefano.perini@polimi.it	
Marco Taisch	POLIMI	marco.taisch@polimi.it	
Dimitris Kiritsis	EPFL	dimitris.kiritsis@epfl.ch	
Maria Margoudi	EPFL	maria.margoudi@epfl.ch	
Stratos Antoniou	LMS	antoniou@lms.mech.upatras.gr	
Poul Hansen	AAU	kyvs@business.aau.dk	
Manuel Oliveira	SINTEF	manuel.oliveira@sintef.no	

Hadrien Szigeti	DS	Hadrien.SZIGETI@3ds.com	
Joao Costa	HSZ	joao.costa@highskillz.com	
Arnaud Varlet	KEONYS	arnaud.varlet@keonys.com	

Table of Contents

EXECUTIVE SUMMARY **7**
1. INTRODUCTION **9**
1.1. GENERAL METHODOLOGY 9
1.2. OBJECTIVES AND SCOPE 10
1.3. CONTRIBUTION TO OTHER WPS AND DELIVERABLES 10
1.4. STRUCTURE OF THE DOCUMENT 10
2. EXISTING POLICY RECOMMENDATIONS **12**
2.1. ANALYSIS OF EXISTING POLICY RECOMMENDATIONS 12
2.2. AGGREGATION OF RELEVANT ELEMENTS 12
2.3. GAP ANALYSIS 16
3. DEVELOPMENT OF MANUSKILLS POLICY RECOMMENDATIONS - OBJECTIVES AND METHODOLOGY **19**
3.1. OBJECTIVES 19
3.2. METHODOLOGY 19
4. MANUSKILLS POLICY RECOMMENDATIONS **21**
4.1. PR 1 – RAISE AWARENESS ON MANUFACTURING'S ROLE IN EUROPEAN SOCIETY 22
4.1.1. Proposed Concrete Actions *22*
4.2. PR 2 - INTEGRATE MANUFACTURING INTO STEM PIPELINE 23
4.2.1. Proposed Concrete Actions *23*
4.3. PR 3 - DIGITIZE MANUFACTURING EDUCATION 24
4.3.1. Proposed Concrete Actions *24*
4.4. PR 4 - DEVELOP TRAINING INITIATIVES ON MANUFACTURING FOR TEACHERS 25
4.4.1. Proposed Concrete Actions *25*
5. MANUSKILLS POLICY RECOMMENDATIONS & OTHER POLICY RECOMMENDATIONS ON ATTRACTING YOUNGSTERS TO ENGINEERING **26**
5.1. SEARCH 26
5.1.1. General reports *26*
5.1.2. Projects *27*
5.2. ANALYSIS 27
5.3. COMPARISON BETWEEN MANUSKILLS POLICY RECOMMENDATIONS & IDENTIFIED POLICY RECOMMENDATIONS ON ATTRACTING YOUNGSTERS TO ENGINEERING 29
5.3.1. Awareness and communication *29*
5.3.2. Education in the STEM pipeline *29*
5.3.3. Cooperation among the stakeholders *30*
5.3.4. ICT-based education *30*
6. CONCLUSIONS **31**
7. REFERENCES **32**
8. ANNEXES **33**
8.1. ANNEX I - ANALYSIS OF EXISTING POLICY RECOMMENDATIONS 33
8.1.1. Manufacturing Education *33*

DELOITTE, "Managing the Talent Crisis in Global Manufacturing A Deloitte Research Global Manufacturing Study Strategies to Attract and Engage Generation Y", A Deloitte Research Global Manufacturing Study, 2007 ... 33
MI, "Recommendations for Action: Promoting Industry Certifications and Enhancing Two- and Four-Year Articulation", Roadmap for Manufacturing Education, The Manufacturing Institute, 2010 ... 33
ASEE, "Government Policy and Manufacturing Education", American Society for Engineering Education, 2012 ... 34
MANPOWER, "Report Five: Policy Prescriptions for the Manufacturing Talent Gap", part of "The Future of the Manufacturing Workforce" research paper, Manpower, 2012 ... 34
SME, "Workforce Imperative: A Manufacturing Education Strategy", Society of Manufacturing Engineers, 2012 ... 35
SHRM, "Current Issues in HR: Closing the Manufacturing Skills Gap", SHRM Foundation Executive Briefing, 2013 ... 35
8.1.2. STEM Education ... 36
EC 2007, "Science Education NOW: A renewed pedagogy for the future of Europe", High Level Group on Science Education, European Commission, 2007 ... 36
Osborne J. & Dillon J., "Science education in Europe: Critical reflections", A report to the Nuffield Foundation, 2008 ... 37
INGENIOUS, "Science, technology, engineering and mathematics education: Overcoming challenges in Europe", European Schoolnet, EngineeringUK, inGenious, Intel, 2011 ... 37
EC 2011, "Science Education in Europe: National Policies, Practices and Research", EURYDICE, 2011 ... 38
8.1.3. ICT-based Education ... 39
UNESCO 2011, "ICTs FOR NEW ENGINEERING EDUCATION", Policy Brief, 2011 ... 39
UNESCO 2013, "ICT in Education: Policy, Infrastructure and ODA Status in Selected ASEAN Countries", UNESCO Asia Pacific Regional Bureau for Education APEID/ICT in Education, 2013 ... 40
GESCI, "Education: 8 Policy Recommendations for the advancement of knowledge societies across Africa", A product of the African Leadership in ICT Course, 2013 ... 42
EC 2014, "High Level Group on the Modernisation of Higher Education", Report to the European Commission on New modes of learning and teaching in higher education, 2014 ... 42
8.1.4. Engineering Education ... 44
NAOE, "CHANGING THE CONVERSATION – MESSAGES FOR IMPROVING PUBLIC UNDERSTANDING OF ENGINEERING", NATIONAL ACADEMY OF ENGINEERING, 2008 ... 44
ATTRACT, "ATTRACT – ENHANCING THE ATTRACTIVENESS OF STUDIES IN SCIENCE AND TECHNOLOGY", ATTRACT, 2008 ... 44
IPPR, "WOMEN IN ENGINEERING – FIXING THE TALENT PIPELINE", INSTITUTE FOR PUBLIC POLICY RESEARCH, 2014 ... 45
HAYS, "DIVERSIFYING THE TALENT PIPELINE – WOMEN IN ENGINEERING", HAYS, 2016 ... 45
WOMEN-CORE, "WOMEN IN CONSTRUCTION SCIENTIFIC RESEARCH", WOMEN-CORE, 2008 ... 46
MOTIVATION, "MOTIVATION – FINAL PROJECT REPORT", MOTIVATION, 2010 ... 47
HELENA, "INTERDISCIPLINARITY TOWARDS GENEDER EQUALITY IN ENGINEERING AND TECHNOLOGY EDUCATION - RECOMMENDATIONS" IN "GIEE 2011 – GENDER AND INTERDISCIPLINARY EDUCATION FOR ENGINEERS 2011", SENSE PUBLISHERS, 2011 ... 48
IRIS, "IRIS PUBLISHABLE SUMMARY – INTERESTS AND RECRUITMENT IN SCIENCE", IRIS, 2012 ... 48
MASCIL, "POLICY BRIEF ON THE STATE-OF-AFFAIRS ON INQUIRY BASED LEARNING & THE WORLD OF WORK IN 13 EUROPEAN EDUCATIONAL CONTEXTS – INSIGHTS FROM A COMPARATIVE OVERVIEW", MASCIL, 2014 ... 49
INSTEM, "AN INQUIRY INTO INQUIRY: EU PROJECTS AND SCIENCE EDUCATION", INSTEM, 2015 ... 49

Figures

Figure 1 – General Methodology for T5.4 ... 10
Figure 2 – Specific Methodology for the development of ManuSkills Policy Recommendations ... 20

Tables

Table 1 – Policy Recommendations – Aggregation of Relevant Elements 14
Table 2 – Meta-analysis of Policy Recommendations’ documents 17

Abbreviations and Acronyms:	
STEM	Science, Technology, Engineering, Mathematics
ICT	Information and Communication Technology
WP	Work Package

EXECUTIVE SUMMARY

The main aim of the document is the presentation of ManuSkills Policy Recommendations as well as of the structured methodology followed in order to develop them. ManuSkills Policy Recommendations represent the final output of the project and are coherent with the final Vision (D2.2.2) (1) and with the main results of all its other deliverables.

The general methodology adopted for T5.4 is consistent with the one presented in D4.1.1 (2) for the evaluation methodology and testing experiments of ManuSkills and with the overarching goals of the project and the experiments developed:

1. **Analysis of existing Policy Recommendations,** where existing relevant Policy Recommendations about manufacturing, STEM and ICT-based education have been identified and analysed.
2. **Aggregation of relevant elements,** where, basing on the analysis, the main common elements of Policy Recommendations have been simplified, aggregated and organized in the six areas: of Image, Educational practice, Certification/Standardization, Monitoring, Partnerships and Funding.
3. **Gap Analysis,** where the aggregation of relevant elements has been integrated with a meta-analysis of the documents identified aiming at identifying their positioning in terms of the strategic dimensions of Age Groups addressed, presence of the ICT component, presence of Concrete Actions, presence of Gender issues, Countries addressed, Geographical Level considered and Stakeholders included. The results of the meta-analysis have helped in the strategic positioning of ManuSkills Policy Recommendations and in the alignment of their content with project's high level objectives.
4. **Development of ManuSkills Policy Recommendations,** where the objectives and methodology of ManuSkills Policy Recommendations have been defined coherently with the high level objectives of the project, in order to guarantee the final delivery of consistent and effective guidelines for policy makers.

The main objective of ManuSkills Policy Recommendations has been defined as that of providing a set of guidelines able to support European policy makers in the definition of actions to attract young talents to manufacturing and to support their acquisition of specific manufacturing skills. In particular, ManuSkills Policy Recommendations pay particular attention to the following three aspects:

- The involvement of primary, secondary and university education
- The use of ICT as a supporting delivery mechanism
- The proposal of concrete actions to implement the guidelines provided

On that basis, a specific three-step methodology for the development of ManuSkills Policy Recommendations has been set up:

A. **Creation of the body of knowledge,** where all the activities performed in order to create the necessary basis to subsequently develop consistent Policy Recommendations have been considered:
    a. **Results of the Experiments (D4.2)** (3)
    b. **Contributions collected from researchers and practitioners** during the a variety of dissemination activities
    c. **Internal workshops within consortium members**, who have had the opportunity to collect a wide range of experience on the field
    d. **Existing Policy Recommendations**, even though not addressing specific ManuSkills topics, in order to be able to complement the other sources and better position the guidelines developed

B. **Definition of high level Policy Recommendations,** where, on the basis of the four abovementioned sources, general guidelines for manufacturing education at European level have been developed.
C. **Definition of Concrete Actions to be implemented,** where, starting from each of the high level Policy Recommendations developed, a brief list of Concrete Actions to be taken to fulfill the related main guideline has been provided.

As an output of the specific methodology, a set of four Policy Recommendations has been developed:

1. **Raise awareness on manufacturing's role in European society**
2. **Integrate manufacturing into STEM pipeline**
3. **Digitize manufacturing education**
4. **Develop training initiatives on manufacturing for teachers**

Each of them has been accompanied by a set of proposed Concrete Actions to effectively implement it.
The ManuSkills Policy Recommendations have been formulated in order to be agile and self-explaining guidelines targeting regional, national and European policy makers as well as valuable material for a wider range of interested stakeholders such as manufacturing companies, professional associations and educational institutions.
Specific contact points and differences with existing **Policy Recommendations** on **attracting youngsters to engineering** have been also identified, thanks to a detailed analysis and comparative evaluation as reported in Chapter 5.

1. INTRODUCTION

In Chapter 1, the General Methodology for T5.4 (Paragraph 1.1), the objectives and scope (Paragraph 1.2), the contribution to other WPs and deliverables (Paragraph 1.3) and the structure of the document (Paragraph 1.4) are presented.

1.1. General Methodology

The present deliverable follows a general methodology made of four subsequent steps. The methodology is integrated and coherent with the one discussed in D4.1.1 (2) for the evaluation methodology and testing experiments of ManuSkills. Indeed as already showed in D4.1.1 (2) the testing and evaluation methodology of ManuSkills was developed in collaboration with T5.4, starting from the analysis of existing Policy Recommendations about manufacturing, STEM and ICT-based education and concluding with the elaboration and analysis of the results of the experiments set up. Therefore the Research Questions, the design features of the testing experiments and the evaluation plan itself described in D4.1.1 (2) and D4.1.2 (4) were defined in order to fill the gaps in the relevant Policy Recommendations identified and relevant for high level ManuSkills objectives.
On this basis, a general four step-methodology for T5.4 has been identified in order to guarantee coherence with the overarching goals of the project and with the experiments developed:

1. **Analysis of existing Policy Recommendations:** Existing relevant Policy Recommendations about manufacturing, STEM and ICT-based education have been identified and analysed. These focus points have been chosen since manufacturing is the domain of interest, STEM disciplines provide the appropriate ground and support for the implementation of manufacturing topics in different educational levels (primary and secondary education), and ICT is the specific delivery mechanism that ManuSkills is addressing. The list of the more relevant Policy Recommendations analysed is reported in Annex I.
2. **Aggregation of relevant elements:** Basing on the analysis, the main common elements of Policy Recommendations have been simplified, aggregated and organized in the six Areas of Image, Educational practice, Certification/Standardization, Monitoring, Partnerships and Funding. These areas have been defined with a bottom-up approach based on the progressive clustering of the Policy Recommendations found. This just in order to be able to resume the findings and be able to identify relevant gaps in the following step. The elements organized in the six Areas are showed in Chapter 2.
3. **Gap Analysis:** The just mentioned aggregation of relevant elements has been integrated with a meta-analysis of the documents identified aiming at identifying their positioning in terms of different strategic dimensions such as Age Groups addressed, Geographical Level and Stakeholders included. The use of the first table has supported from a conceptual view the identification of the main dark areas to be addressed by the Experiments (formalized by means of the Research Questions analysed in D4.2 (3)), while the use of the second table helped in the strategic positioning of ManuSkills Policy Recommendations and in the alignment of their content with project's high level objectives. The meta-analysis of the documents is showed in Chapter 2.
4. **Development of ManuSkills Policy Recommendations:** After the Gap Analysis, the objectives and methodology of ManuSkills Policy Recommendations have been defined coherently with the high level objectives of the project, in order to guarantee the final delivery of consistent and effective guidelines for policy makers. The objectives and methodology followed are described in Chapter 3 while the Policy Recommendations developed are presented in Chapter 4.

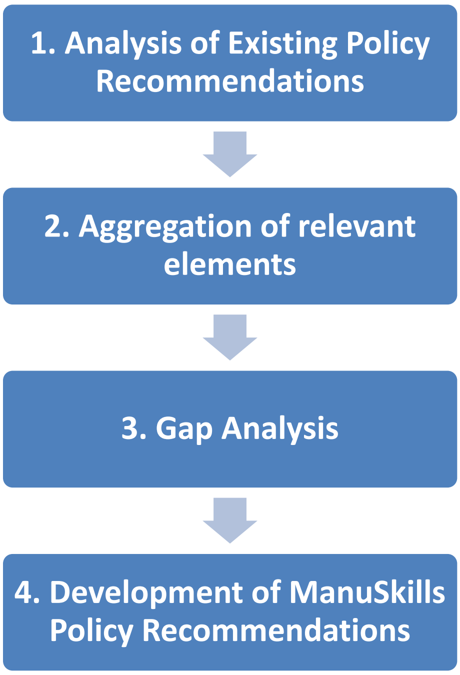

Figure 1 – General Methodology for T5.4

1.2. Objectives and scope

The objective of the present document is that of presenting ManuSkills Policy Recommendations and the structured methodology adopted in order to develop them. ManuSkills Policy Recommendations represent the final output of the project, providing a set of guidelines that resume all the relevant results achieved by the consortium throughout project's lifecycle.

1.3. Contribution to other WPs and Deliverables

The document is coherent with the final version of the Vision (D2.2.2) (1) and with all the other WPs and Deliverables of the project, whose main results have been extracted and elaborated in order to develop the Policy Recommendations and Concrete Actions proposed. For the results of the Experiments of the project, please refer to D4.2 (3).

1.4. Structure of the document

The document is organized in the following way.

In Chapter 1 the General Methodology followed for T5.4 is presented, as well as document's objective, contribution and structure.

In Chapter 2 the Analysis of Existing Policy Recommendations, the Aggregation of Relevant Elements and the Gap Analysis is presented.

In Chapter 3 the specific objectives and methodology of ManuSkills Policy Recommendations are presented.

In Chapter 4 ManuSkills Policy Recommendations and their related Concrete Actions are presented.

In Chapter 5 other Policy Recommendations on attracting youngsters to engineering are analysed and compared with ManuSkills ones.

In Chapter 6 conclusions are discussed.

2. EXISTING POLICY RECOMMENDATIONS

In this Chapter, first the existing Policy Recommendations about Manufacturing, STEM and ICT-based education are presented (Paragraph 2.1). For each document, Policy Recommendations have been identified and resumed by means of tables. If also Concrete Actions were provided, they have been added at the end in order to show the two levels of detail.
Afterwards, the aggregation of the Relevant Factors of the Policy Recommendations identified is presented (Paragraph 2.2) and finally the Gap Analysis of existing Policy Recommendations is performed (Paragraph 2.3) integrating these results with the ones of the strategic meta-analysis of the related documents.

2.1. Analysis of Existing Policy Recommendations

The detailed analysis of existing Policy Recommendations is presented in Annex I, where the relevant Policy Recommendations identified are resumed according to the three categories of manufacturing education, STEM education and ICT-based education.

2.2. Aggregation of Relevant Elements

The relevant factors of the Policy Recommendations collected in Paragraph 2.1 have been identified and aggregated according to different dimensions, i.e. the field to which they belong (manufacturing, STEM and ICT-based education) and the relevant Areas that they address. The approach used is a bottom-up one with different iterations discussed and approved by the consortium during project meetings. This step has been fundamental in order to constitute a first basis for the subsequent Gap Analysis addressed in Paragraph 2.3. the six relevant areas identified are the following:

I. **Image:** This Area includes all the relevant factors of Policy Recommendations addressing the problem of the wrong/misleading image of Manufacturing among youngsters, especially (even if not exclusively) for those involved in primary and secondary education (as already pointed out by D2.2.1 (5)). The relevant factors in this case are all oriented towards two main guidelines. The former about the massive promotion of awareness actions (for manufacturing education), while the latter about the information of students about the actual career opportunities (for STEM education).

II. **Educational Practice:** This Area includes all the relevant factors dealing with the reform of current curricula and programs throughout the educational pipeline, covering all age groups from primary school level to university education. Therefore the main guidelines suggested include the implementation of current pedagogical and learning theories -such as experiential learning, game-based learning etc.- in the teaching of STEM disciplines and also use STEM as a leveraging mechanism in introducing manufacturing concepts earlier in the educational pipeline (even for primary and secondary school students); the identification and sharing of common best practices (manufacturing and STEM education); the better support of the teaching practice by empowering teachers through appropriate training and relevant updated educational materials (STEM education); the integration and use of ICT-based delivery mechanisms in order to enable the access to state-of-the-art educational sources and to boost the already existing variety of learning activities for different age group of students (manufacturing and ICT-based education); the increase of the participation and self-confidence of girls in STEM related activities (STEM education).

III. **Certification/Standardization:** This Area includes the relevant factors of Policy Recommendations suggesting the development and formalization of common mechanisms for the evaluation of manufacturing and STEM skills and their codification in a standard body of certifications to be adopted both at national and international level (manufacturing and STEM education). These guidelines evidently imply the involvement of local and global institutions and the collaboration with companies and academia in order to create a system able to facilitate the link between the educational and working world and also the mobility of experienced professionals, as also identified in D2.1 (6).

IV. **Monitoring:** This Area includes all the relevant factors dealing with the continuous mapping of manufacturing educational challenges, best practices and needs of the industry in order to be able to continuously update in time the actions needed to fill the existing manufacturing skills gap. This point is also about the continuous monitoring of the ICT infrastructures, services and software needed to support the actions identified. To this respect, the lack of recognized national and international institutions able to have this role is considered one of the main weaknesses.

V. **Partnerships:** The relevant factors of this Area are all about the consolidation and establishment of partnerships among institutions, academia, research centers and companies in order to support both from a political and economic perspective the sustainability of manufacturing and STEM education and promotion activities. The creation and enhancement of multi-stakeholders partnerships should be considered as a priority, involving in capillary way also local communities and promoting the formation of a network of permanent organizations.

VI. **Funding:** The Area of funding is finally the one supporting all the other ones and the key enabling factors for their actual implementation. This is especially true and definitely needed for manufacturing education, where the lack of institutionalized funding at many levels represents the first main obstacle to be faced to combat the current manufacturing skills gap.

Table 1 – Policy Recommendations – Aggregation of Relevant Elements

	Manufacturing education	STEM education	ICT-based education
Group 1 (Image)	Awareness Actions	Inform students about careers in science	
	Create Excitement		
	Promote		
	Change mind-sets		
Group 2 (Educational practice)	Apply Modern Pedagogical Theories to the Educational Practice of Manufacturing	Reform of STEM curricula to act on low student motivation	The integration of digital technologies and pedagogies should form an integral element of higher education institutions' strategies for teaching and learning.
		Use of new assessment methods	
	Integrate ICT to Manufacturing Education	Provide major explanations of the material world that science offers	
		Engage students before 14 with science and scientific phenomena	
	Insert “real-life approach” practices to manufacturing education.	Hands-on activities in science curricula	Explore delivery mechanisms for ICT use in educational provision to provide access for expanding school populations.
		From an integrated approach to science at lower levels to separate subject teaching in the later stages of schooling	
	Foster collaboration and training initiatives in manufacturing education.	Increase participation and self-confidence of girls in science	
		Recruitment and continuous professional training of good quality teachers	
	Support national technology and engineering frameworks	More support to STEM teachers	At tertiary level, e-learning should be intrinsic to teaching and learning model adopted by public/private institutions.
		Support for low achievers in science	
	Expand on the strong programs and best practices that exist	Embed science fairs and festivals in the mainstream of school activity	
		Learn from and build on excellent approaches	
Group 3 (Certification/ Standardization)	Standardize core of manufacturing knowledge	Standardised assessment in science at least once during compulsory education	
	Certification of skills		
	Sharing and Coordination among stakeholders		
Group 4 (Monitoring)	Mechanisms for monitoring manufacturing challenges, best practices and future needs with respect to education, workforce, etc.		Taking readiness of personnel and infrastructure into consideration, and maintaining a balance between allocations for equipment, Internet services, software, teaching materials, maintenance and training.

	Manufacturing education	STEM education	ICT-based education
Group 5 (Partnerships)	Strengthen partnerships among different stakeholders (academia, industry, government, associations, etc.)	Establish and enhance sustainable multi-stakeholder partnerships	
		Establish a European Science Advisory Board involving representatives of all stakeholders	
		Promote the participation of cities and the local community in the renewal of science education	
Group 6 (Funding)	Institutionalized funding at many levels		

2.3. Gap Analysis

After the aggregation of the relevant factors of Policy Recommendations and on that basis, a meta-analysis of Policy Recommendations' documents has been done. While the aggregation of relevant factors has been used for the definition of the Research Questions reported in D4.2 (3) and for the design of the Experiments, the objective of the following meta-analysis has been the definition of the strategic positioning of ManuSkills Policy Recommendations and the alignment with project's high level objectives. The specific objectives and methodology of ManuSkills Policy Recommendations are described in Chapter 3 while in the present paragraph the meta-analysis of Policy Recommendations' document is showed in detail. Afterwards, the results of the Gap Analysis based on that meta-analysis and on the previous aggregation of relevant factors is presented.
Using as knowledge base the analysis of existing Policy Recommendations (Paragraph 2.1) and the analysis of their relevant factors (Paragraph 2.2), for each field (manufacturing, STEM and ICT-based education) different strategic dimensions have been identified, verifying the covering of the documents according to them. The strategic dimensions have been derived from the overarching objective of ManuSkills project as reported in D2.2.1 (5) and explicated in Paragraph 3.1:

A. **Age Group:** The three different Age Groups the project is addressing, i.e. primary, secondary and university students.
B. **ICT Component:** The presence or absence of Policy Recommendations taking into account the use of ICT-based delivery mechanisms in order to engage or educate students.
C. **Concrete Actions:** The proposal of Concrete Actions to be implemented by institutions, research centres, academia and companies in order to foster the specific field of education (Tactical/Operational level) and not only the provision of high-level guidelines for policy makers (Strategic level).
D. **Gender:** The presence or absence of Policy Recommendations taking into account gender issues in education.
E. **Countries:** The countries involved in the analysis or the ones which the Policy Recommendations refer to.
F. **Geographical Level:** The geographical level of detail of the guidelines proposed, i.e. what levels among the regional, national and international ones they are addressing.
G. **Stakeholders:** The stakeholders involved in the analysis, i.e. youngsters, educators and parents.

Table 2 – Meta-analysis of Policy Recommendations' documents

	Name	Year	Age Group			ICT	Concrete Actions	Gender	Countries	Geographical Level			Stakeholders		
			Primary	Secondary	University					Regional	National	International	Youngsters	Educators	Parents
Manufacturing Education	DELOITTE (7)	2007		X	X	X		X	World			X	X	X	
	MI (8)	2010			X		X		US	X	X		X	X	
	ASEE (9)	2012			X				US		X		X	X	
	MANPOWER (10)	2012			X			X	US + Canada		X		X	X	
	SME (11)	2012	X	X	X				US + Canada		X		X	X	
	SHRM (12)	2013		X	X		X		US		X		X	X	
STEM Education	EC (13)	2007	X	X				X	Europe		X	X	X	X	
	Osborne J. & Dillon J. (14)	2008	X	X					Europe		X	X	X	X	
	INGENIOUS (15)	2011	X	X			X		EMEA		X	X	X	X	
	EC (16)	2011	X	X		X	X	X	Europe		X	X	X	X	
ICT-based Education	UNESCO (17)	2011			X	X	X		World		X	X	X	X	
	UNESCO (18)	2013	X	X	X	X		X	ASEAN		X	X	X	X	X
	GESCI (19)	2013	X	X		X			Africa		X	X	X	X	X
	EC (20)	2014			X	X		X	Europe		X	X	X	X	

On the basis of the whole analysis of the existing Policy Recommendations culminated in the aggregation of relevant factors (Table 1) and on the meta-analysis of Policy Recommendations' documents (Table 2) has been eventually possible to perform a Gap Analysis aiming at identifying the main existing Policy Recommendations' needs according to ManuSkills overarching objective. In particular:

- The **Age Groups** targeted are closely depending on the field considered. STEM education's Policy Recommendations are focusing on primary and secondary schools students, while ICT-based education ones are considering also University. Manufacturing education is massively addressing university and sometimes secondary schools, while primary is just quickly addressed once by US-centred SME's Policy Recommendations.
- The **ICT component** is addressed rarely for manufacturing and STEM education. EC's Policy Recommendations of 2011 about STEM are taking into account the problem (16), as well as Deloitte's ones about manufacturing (7), but the latter just provide general guidelines at global level.
- The presence of **Concrete Actions** (Operational/Tactical level) beyond pure high-level strategies is rare but equally distributed among the different fields. For manufacturing education only MI (8) and SHRM (12) are proposing specific activities to be implemented for US.
- **Gender issues** are present in some Policy Recommendations for all the fields of analysis. In those cases, while for STEM education have attracted specific attention, for ICT-based and manufacturing education they are just quickly and not addressed in detail.
- It is evident a neat predominance of **US-centred** Policy Recommendations for manufacturing field, while the situation for STEM and ICT-based education is definitely more **Europe-centred**. This can be motivated by the relative European difficulty to provide common visions when addressing sectorial education as the manufacturing one is.
- The main **Geographical Levels** addressed are the national and international ones, thus depending also on the countries which are the focus of the analysis. The difficulties in addressing also the regional level are equally common to all fields.
- **Parents** are rarely taken into account as target of Policy Recommendations and even when they are mentioned (i.e. only for ICT-based education) the provision of guidelines addressing them is marginal.

3. DEVELOPMENT OF MANUSKILLS POLICY RECOMMENDATIONS - OBJECTIVES AND METHODOLOGY

On the basis of the Gap Analysis previously presented and according to the high level objectives of ManuSkills, in this Chapter the specific objectives and methodology for the development of ManuSkills Policy Recommendations are described.

3.1. Objectives

The overarching goal of ManuSkills is the study of ICT-based delivery mechanisms and training methodologies able to raise the awareness and interest of young talents towards manufacturing and to support their acquisition of new manufacturing skills. To this respect, its aim is to provide policy makers with guidelines on how to support manufacturing education along the whole STEM pipeline (primary, secondary, university) in order to be able to fill the existing manufacturing skills gap, as documented in D2.2.1 (5).

As identified by the strategic meta-analysis of existing Policy Recommendations' documents, there is at the global level the lack of guidelines addressing the issue identified by targeting primary, secondary and university education, by providing specific attention on the use of ICT-based delivery mechanisms and by proposing also concrete actions to be supported by policy makers. At the European level, there is even the lack of a consistent and common body of recommendations to promote and improve manufacturing education all over the continent.

As a consequence, the main objective of ManuSkills Policy Recommendations is to provide a first set of guidelines able to support European policy makers in the definition of actions to attract young talents to manufacturing and to support their acquisition of specific manufacturing skills.

The ManuSkills Policy Recommendations provide an innovative set of indications on how to combat the existing manufacturing skills gap affecting Europe by paying particular attention to the following three aspects:

- The involvement of primary, secondary and university education
- The use of ICT as a supporting delivery mechanism
- The proposal of concrete actions to implement the guidelines provided

3.2. Methodology

Coherently with the specific objectives formalized above, the methodology for the development of ManuSkills Policy Recommendations has comprised three main steps:

A. **Creation of the body of knowledge:** The creation of the body of knowledge comprises all the activities performed in order to create the necessary basis to subsequently develop consistent Policy Recommendations. The sources used in this step have been several, in order to take into account all the different channels experimented by the consortium during the project, i.e.:
   a. **Results of the Experiments (D4.2)** (3)
   b. **Contributions collected from researchers and practitioners** during the several dissemination activities
   c. **Internal workshops within consortium members**, who have had the opportunity to collect a wide range of experience on the field
   d. **Existing Policy Recommendations**, even though not addressing specific ManuSkills topics, in order to be able to complement the other sources and better position the guidelines developed

B. **Definition of high level Policy Recommendations:** On the basis of the four abovementioned sources, development of general guidelines for manufacturing education at European level

C. **Definition of Concrete Actions to be implemented:** Starting from each of the high level Policy Recommendations developed, provision of a brief list of Concrete Actions to be taken to fulfill the related main guideline

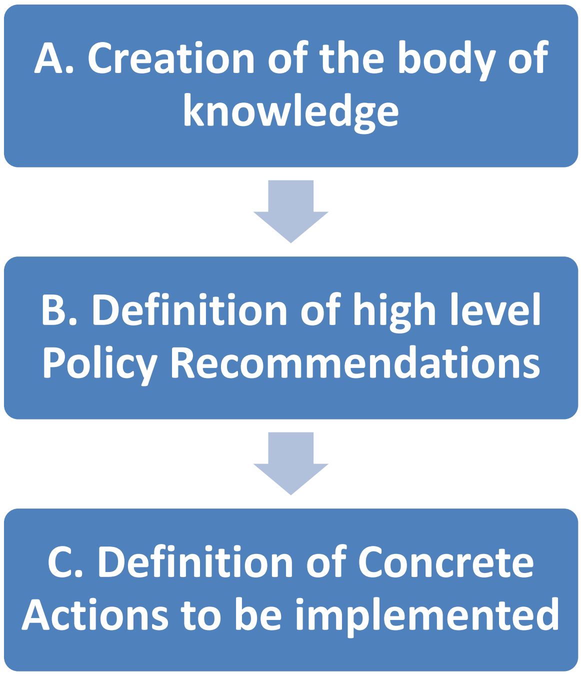

Figure 2 – Specific Methodology for the development of ManuSkills Policy Recommendations

4. MANUSKILLS POLICY RECOMMENDATIONS

The ManuSkills Policy Recommendations represent a set of guidelines to support European policy makers in the definition of actions to foster manufacturing education and eventually fill the existing manufacturing skills gap.

The ManuSkills Policy Recommendations focus on four main directions, i.e. the awareness on manufacturing, the integration of manufacturing education into STEM pipeline, the digitization of manufacturing education and the manufacturing training for teachers. For each Policy Recommendation, a set of concrete actions to effectively implement it is proposed.

4.1. PR 1 – Raise awareness on manufacturing's role in European society

Nowadays, the perception of manufacturing in society is weak and it is still affected by an old fashioned idea of the factory as a grey, polluting and dangerous place. This misleading conception belongs to different actors of the society (parents, teachers, youngsters) and it is already present among children, who have already started to think at their future working ambitions and possible jobs. Furthermore, manufacturing is often perceived as a low-skilled work environment, where no innovation or progress is pursued. The appeal of emerging sectors (e.g. ICT) is strong and the competition for the recruitment of the brightest talents is very high.

Therefore, the current awareness gap of society towards manufacturing is evident and should be urgently filled in. As a consequence, awareness on the effective role of manufacturing in European society should be raised. A correct perception of manufacturing should be reestablished by means of a widespread popularization of its actual economic and innovative impact on society and of its fundamental contribution in everyday life. The real image of the factory should be diffused, as well as the cutting edge results manufacturing is obtaining in terms of environmental sustainability. The concept of "Circular Economy" and its application in the industrial world should be fostered.

To this respect, the promotion of attractive careers in line with the modern challenges of manufacturing should be promoted by showing to all the stakeholders of the society the renewed possibilities that this world offers. The collaboration among institutions, schools, universities and companies should be reinforced in order to develop advanced and innovative career paths.

4.1.1. Proposed Concrete Actions

- Leverage and foster existing networks amongst institutions, schools, universities and manufacturing companies (e.g. Scientix at European level, STEMNET (UK) at national level) in order to:
    - Promote the actual image of manufacturing as an innovative and sustainable sector
    - Promote technology as an enabler of manufacturing development
    - Make clear all the possible careers associated to manufacturing, in line with the current advancements of the sector
- Foster the connection between manufacturing companies and society by means of targeted initiatives:
    - Give access to real life industrial cases to secondary and university students
    - Give anybody the opportunity to see what companies do (physically and also virtually by means of ICT mechanisms)
    - Leverage existing professional associations for the creation of dissemination events open to the public
    - Organize events in primary and secondary schools targeting both students and parents to show the activities that are actually done in manufacturing companies
- Involve media for the promotion of manufacturing to public through a coordinate action on different channels (e.g. newspapers, magazines, TV, internet)
- Creation of fairs and events on a large scale for the promotion of manufacturing
    - Foster the active involvement of parents
    - Create a *World Manufacturing Forum* for children
- Development of specific actions to increase the participation of female students in manufacturing
    - Bring attention to the opportunities that manufacturing offers to girls
    - Promote success stories of women in manufacturing
- Take into account the different cultural aspects across European countries
    - Customize awareness activities according to the existing culture and perception of manufacturing
    - Leverage the existing national and regional associations and initiatives with potential synergies

4.2. PR 2 - Integrate manufacturing into STEM pipeline

STEM (Science, Technology, Engineering, Mathematics) disciplines are pivotal to form the workers of the future. Scientists, IT developers, engineers but also managers, sales and marketing people with a sound technical background will be needed in the future in order to support and improve the competitiveness of European manufacturing. Currently, scientific disciplines like mathematics and natural sciences are taught from primary education in European schools, while technical subjects are introduced gradually in the programmes when basic scientific concepts have been learned by students. In particular, a strong technical education is usually provided in technical high schools and in vocational schools that prepare specifically for the working world, while advanced engineering education is provided in bachelor, master and doctoral curricula at university level. Despite this situation, the teaching of specific manufacturing concepts integrated in the general STEM pipeline (primary and secondary schools and universities) is still scant. In fact, manufacturing principles are rarely addressed in STEM disciplines and, if taught, they remain restricted to specific education curricula aiming at preparing low and medium-skilled workers.
In light of this, it is evident the need to integrate the teaching of manufacturing concepts into the general STEM pipeline, introducing to the main manufacturing principles a much wider segment of the population. Basic manufacturing concepts should be gradually introduced early in formal education, allowing between primary and secondary school the formation of a manufacturing culture also for those students not enrolled in specific technical and vocational programmes. Furthermore, specific manufacturing applications and cases should be also integrated into university non-engineering STEM curricula such as mathematics and informatics. The introduction of manufacturing concepts into the educational programmes should be done in the way it is appropriate for the specific age group with coordinated actions at both regional and national level.
The advantage of this kind of approach is twofold. On one hand, it will make possible to show students the actual core of manufacturing, allowing a more aware career choice and an improved initial preparation for engineering university curricula. On the other hand, it will guarantee the rapid and effective integration of STEM non-engineering graduates into the manufacturing world, facilitating the development and integration of the interdisciplinary competences needed nowadays by the sector.

4.2.1. Proposed Concrete Actions

- Support the introduction of manufacturing concepts into the national curricula of primary and secondary schools
    - Promote the networking of schools and the coordination within STEM subjects
- Develop supporting teaching material
    - Align the teaching material with the needs of the industry
    - Link the skills developed by manufacturing curricula to the skills that companies require from their employees
- Adapt appropriate pedagogical approaches to support the introduction of manufacturing concepts to different age groups
    - Support the early involvement of children with manufacturing concepts
    - Leverage delivery mechanisms appropriate to the specific age group, considering the necessary engaging and fun elements
- Take care to tailor the teaching activities and material proposed to the specific needs of female and male students
    - Check carefully the adequacy of interventions given the different gender groups
    - Monitor the effectiveness of interventions on female and male students
- Take into account the features of the different educational systems across European countries
    - Customize interventions according to the content of the existing STEM curricula
    - Plan interventions according to the schedule of the existing STEM curricula

4.3. PR 3 - Digitize manufacturing education

Current manufacturing education still relies extensively on traditional teaching approaches based on frontal lectures. The explanation of complex manufacturing concepts is more and more supported by interactive learning experiences but the use of digital tools for manufacturing teaching is still in its developing stage. In fact, the actual potential of ICT-based manufacturing teaching remains largely unexplored, given the current potentialities of ICT and also the great aptitude of new generations to study and learn by means of digital applications. The advantages of ICT-based teaching for new tech savvy generations go beyond the well-known strong points of scalability and reuse of material, because they can enable the representation of processes and systems that most of the times would not be possible to effectively introduce to students, especially when dealing with the most advanced topics of operations management such as lean thinking and sustainability.

Therefore, we strongly recommend to explore the great potential of ICT mechanisms for learning purposes and to properly customize it to manufacturing education. The extensive digitization of manufacturing education will allow the possibility to train proactive professionals that will be ready to provide their knowledge directly to the working world. The support of digital hands on experiences will be ideal to integrate the laboratory and industrial activities necessary for the complete education of manufacturing students. For those purposes, there is a wide range of ICT mechanisms that should be leveraged, e.g. serious games, simulations, virtual reality as well as distance learning. Each delivery mechanism should be customized to the specific learning need and integrated in a wider spectrum of activities combining the other existing teaching approaches (i.e. frontal lectures, laboratory, industrial experiences).

Furthermore, the use of digital applications should not be limited to university courses, but should be used as a valuable methodology to support the introduction of manufacturing concepts also in primary and secondary schools. Indeed the use of ICT mechanisms can be extremely helpful also for younger age groups, provided that the complexity of the applications and the underpinning pedagogical approaches are appropriate. For this reason, proper combination of ICT mechanisms and teaching approaches should be leveraged at all age levels in order to improve both depth and variety of manufacturing education.

4.3.1. Proposed Concrete Actions

- Use contemporary pedagogical principles to support manufacturing teaching
  - Promote the co-design of ICT educational tools between manufacturing companies and teachers
- Promote the use of ICT-based evaluation tools to improve the quality of teaching
  - Use of learning analytics applications
- Use ICT mechanisms such as serious games and simulations for teaching manufacturing concepts
  - Use of serious games as a mean to differentiate and personalize classes
  - Use of serious games to introduce manufacturing to youngsters under 14 years old
- Promote and integrate professional software to manufacturing education
  - Digitalization of real cases for educational purposes (for secondary schools and universities)
  - Use of professional software to introduce manufacturing to youngsters between 15 and 19 years old

4.4. PR 4 - Develop training initiatives on manufacturing for teachers

The role of teachers in education is pivotal. Teachers pass on their knowledge to students but also take care of mentoring and sustaining them in the key passages of life. Therefore, they should be put in the right condition to really empower teaching impact and help each student in the way it is most appropriate for him/her. For STEM education, initiatives at regional, national and European level are doing a lot of effort in this direction with excellent results. Unfortunately, for manufacturing education the situation changes radically, since nowadays no structured programme is taking care of supporting primary and secondary teachers in the hard task of creating and disseminating an actual and modern manufacturing culture among students. Without systematic and widespread initiatives in this sense, any kind of action directed exclusively to students will unfortunately doomed to failure.

Therefore, we strongly encourage that any manufacturing awareness and education activity for primary and secondary students is previously preceded and supported by a systematic training of teachers. We believe it essential to create a strong culture with respect to the values and principles of manufacturing for the teachers of the various levels of education.

The central role of the teacher in the general process of manufacturing awareness and education should be enhanced through his/her involvement and his/her proactive participation in the concept and development of all the educational and promotional activities which will then be submitted to students. Indeed it is vital to invest the teachers of the role of *change makers*, through the creation of a strong and branched supporting network in which institutions, universities and manufacturing companies collaborate with them to continually refine and improve joint programmes of manufacturing awareness and education.

4.4.1. Proposed Concrete Actions

- Make teachers aware of the existence of advanced ICT mechanisms for manufacturing education
    - Explain the benefits of using ICT mechanisms such as serious games and simulations for manufacturing education
    - Provide them with hands-on experiences for getting familiar with those tools
- Develop ICT-based and classroom-ready training kits for manufacturing cases
- Training of teachers in manufacturing concepts as fostered by the KIC on Added Value Manufacturing (KIC AVM)
    - Make them familiar with manufacturing principles in order to use them in classroom
- Introduce mentorship programmes for teachers within manufacturing
    - Provide them with continuous advice and support by universities and institutions
- Involvement of head teachers in manufacturing awareness and education actions
    - Exploit already existing best practices in the STEM field such as Scientix initiative by European Schoolnet

5. MANUSKILLS POLICY RECOMMENDATIONS & OTHER POLICY RECOMMENDATIONS ON ATTRACTING YOUNGSTERS TO ENGINEERING

Finally, an additional analysis was made on policy recommendations developed by earlier projects on attracting youngsters to engineering. This in order to compare them with ManuSkills ones and identify differences and contact points, since manufacturing can be considered as belonging to the more general engineering domain.

To address this, the existing policy recommendations about engineering were searched in two ways. First of all, they were searched by using Google, in order to find general reports not contained in any existing database, or referring to extra-European projects. Second of all, the Scientix database about existing STEM education European projects was accessed, in order to find existing projects included in the Scientix network, the official initiative of European SchoolNet, the non-profit organization including 30 European Ministries of Education.

In the analysis of the policy recommendations, only those not previously analyzed in STEM field (as reported in Chapter 2) were considered. Indeed, as already highlighted, the main policy recommendations about STEM were taken into account and, therefore, only those specifically addressing engineering were selected at this point. On that basis, eventually a comparison between the policy recommendations specifically targeting the attraction of youngsters to engineering and ManuSkills' ones was done, underlying similarities and particular features belonging expressly just to manufacturing domain.

5.1. Search

5.1.1. General reports

For the general reports, different combinations of key-words were used by searching in Google:

Attraction-Youngsters-Engineering
Involvement-Youngsters-Engineering
Awareness-Youngsters-Engineering
Interest- Youngsters-Engineering
Attraction-Students-Engineering
Involvement-Students-Engineering
Awareness-Students-Engineering
Interest-Students-Engineering
Attraction-Women-Engineering
Involvement-Women-Engineering
Awareness-Women-Engineering
Interest-Women-Engineering
Attraction-Girls-Engineering
Involvement-Girls-Engineering
Awareness-Girls-Engineering
Interest-Girls-Engineering

This in order to consider the three different components of the search, i.e. the topic of attraction (with related terms of involvement, awareness and interest), the topic of youngsters (with the synonym of student, and the gender-oriented terms women and girls), and the topic of engineering. Each of the 16 sequences was associated for the search with the term "report" in order to look directly for relevant documents and avoiding as much as possible the presence of events, newspapers, articles, etc. For each of the 16 sequences of three key-words, the first 5 pages of results were analyzed in order to identify relevant documents and/or initiatives.
After this first iteration, 12 documents were identified as relevant for the purposes of the search. After a second more detailed reading of the documents, 4 were identified as effectively useful because containing explicitly policy recommendations and/or strategies in order to attract youngsters to engineering, i.e.:

1. NATIONAL ACADEMY OF ENGINEERING (2008) (21)
2. ATTRACT (2012) (22)
3. IPPR (2014) (23)
4. HAYS (2016) (24)

5.1.2. Projects

The existing database of projects of the Scientix networks was accessed at http://www.scientix.eu/web/guest/projects. The description of all the projects reported was analyzed, in order to find existing or past projects dealing with the attraction of youngsters to engineering. After this first search, 16 projects were identified. Subsequently, the results of these projects were analyzed more in detail in order to understand which of them actually produced policy recommendations to be taken as a reference point. The final list comprised the following 6 projects whose policy recommendations were taken into account:

1. WOMEN-CORE (2008) (25)
2. MOTIVATION (2010) (26)
3. HELENA(2011) (27)
4. IRIS (2012) (28)
5. MASCIL (2014) (29)
6. INSTEM (2015) (30)

5.2. Analysis

Following the rationale of Chapter 2, each of the 10 documents selected was analyzed and policy recommendations were identified and resumed by means of tables (Annex I). Then the aggregation of Relevant Factors was done. The aggregation followed the framework already provided in Paragraph 2.2 and approved by the consortium, with the six relevant areas of Image, Educational Practice, Certification/Standardization, Monitoring, Partnerships and Funding:

	Engineering education
Group 1 (Image)	Effective communication to “reposition” engineering image
	Coordinated and long-term communications campaign to improve the public understanding of engineering
	Provision by media and youth media of more diverse and realistic job images including engineering
	Improve the poor understanding of engineering careers and the engineering pathway among youngsters
	Larger awareness campaign about existing mentoring programmes
	Encourage more girls to pursue engineering subjects, addressing the perception of engineering careers, among both girls and their families, as ‘masculine’ or ‘brainy’
	Present to youngsters engineering role models, especially female engineers
Group 2 (Educational practice)	Expand and make compulsory for students at an early age a wider spectrum of scientific and engineering topics
	Contextualization of the teaching of engineering concepts, in order to make them more attractive for students
	More focus in the right preparation of the transition from “easy” hands-on science to advanced engineering concepts
	Provide a variety of school engineering experiences to match the different interests of students within science
	Provide higher level of core engineering content for all students, regardless of their area of specialization
	Include teaching and learning about socio-scientific engineering issues within school science curricula
	Open the engineering curricula to a more interdisciplinary dimension
	Improvement and extension of the retention initiatives for engineering courses at university
	Prepare and motivate teachers to introduce basic engineering concepts
	Improve professional development for teachers, in order to improve their confidence and repertoires of actions in relation to engineering topics
Group 3 (Certification/ Standardization)	Increase the number of girls acquiring the prerequisite qualifications in engineering subjects
Group 4 (Monitoring)	Improve access to sex-disaggregated data in engineering field
	Use of aptitude tests at university entry to evaluate students’ strengths and potential areas of difficulty
	Identify and report on activities/memberships that seem to correlate to academic performance changes
	Improve the research about the evaluation of engineering programmes and curricula
Group 5 (Partnerships)	Foster cooperation among engineering employers, schools, institutions and research in order to engage young people within the 14–17 age range, educating them on the many different types of engineering roles available and future career paths
	Promote a greater use of professional networks, including collaboration with teachers and researchers on new methods, materials and topics for engineering education and awareness
	Support the creation of a wide network involving all the existing engineering education and promotion initiatives for all the different age groups

	Engineering education
Group 6 (Funding)	Ensure safe funding for the creation of long-term partnerships between engineering companies, schools, institutions and academia

5.3. Comparison between ManuSkills Policy Recommendations & identified Policy Recommendations on attracting youngsters to engineering

5.3.1. Awareness and communication

As well as ManuSkills Policy Recommendations, also the other Policy Recommendations about engineering focus on the issue of communicating to the society as a whole the right essence of the subject. Indeed both fields suffer from a general misconception of their main features even though manufacturing sector faces also the problem of the wrong perception of the factory as a grey and polluting place. Therefore Policy Recommendations about engineering focus on long-term communication strategies aiming at providing the correct understanding of engineering as a brain intensive, creative and complex work able to foster the progress of the society. Even though also manufacturing completely shares this main problem, ManuSkills Policy Recommendations also suggest to promote the last advancements of the sector, i.e. the extreme attention to environment and sustainability and the intensive use of advanced technologies that are continuously transforming the factory in a more and more human-friendly and innovative place.
Both ManuSkills and engineering Policy Recommendations stress the attention on a more precise and pervasive about technical careers, and both of them put a particular focus on gender equality, encouraging more girls to pursue a career in engineering/manufacturing. Indeed both focus on the importance of fighting the bias identifying the two fields as masculine, promoting success stories of women in engineering/manufacturing and presenting gender-neutral experiences introducing the main concepts of the two disciplines. Furthermore, also the involvement of parents is promoted by both Policy Recommendations, as well as the cultural change of existing media as a mean to deliver new messages to the society. On the other hand, ManuSkills Policy Recommendations also highlight the specific cultural differences that different countries may have in the perception of the factory and of the industrial world as a whole.

5.3.2. Education in the STEM pipeline

ManuSkills and engineering Policy Recommendations agree on the importance of introducing early in the STEM pipeline manufacturing and engineering concepts. This in order to make more aware youngsters about the rudiments of the two disciplines and to prepare them the reasoning approach typical of them. Anyway, while for general engineering the introduction can be easily contextualized in the stream of mathematics and physics applications, for manufacturing specific programmes have to be developed and customized to the specific target age group. For this reason, ManuSkills Policy Recommendations suggest the adoption of ad hoc pedagogical approaches that should be further developed also taking into account the last advancements and needs of the industrial world. Both sets of Policy Recommendations also suggest the contextualization of the concepts introduced to real life. To this respect, manufacturing topics should be customized to the specific needs of the given target age group, as well as to the given gender. Moreover, for manufacturing the contribution of research institutions and companies should be extremely high, given the difficulty of communicating manufacturing concepts without the support of a realistic industrial environment which refer to while teaching youngsters. Engineering and manufacturing fields share also the issue of forming the teachers to be able to teach those basic technical concepts. In particular, as already explained, for manufacturing field the effort will be even higher, but it could mitigate with the previous preparation of “teaching kits” to be provided to teachers in electronic format.

In particular, ManuSkills Policy Recommendations stress the importance of training first of all teachers in the proper way. It was proven that ICT-based delivery mechanisms, supported by suitable pedagogical scenarios, can successfully be used to promote awareness and interest about manufacturing as well as the increase of manufacturing skills. On that basis, ManuSkills argues that teachers should be made aware of the existence of such kind of ICT-based delivery mechanisms (e.g. serious games, simulations). Specific training initiatives about manufacturing for teachers should be developed, with the continuous support of universities and research institutions.

5.3.3. Cooperation among the stakeholders

Given the complicated set of abovementioned actions, ManuSkills and engineering Policy Recommendations definitely sustain strong cooperation about a wide range of stakeholders, i.e. schools, institutions, universities, research centers and manufacturing companies. All these stakeholders should work together on the development of educational initiatives and material, programmes, advanced ICT-based delivery mechanisms and guarantee the long-term sustainability of the actions implemented. In the same way, both sources strongly focus on the evaluation and monitoring of all the awareness and education programmes and initiatives already in place and that will be developed. Indeed systematic tracking of all the actions undertaken will finally lead to a more deep understanding of the proper strategies to address the lack of youngsters in engineering and manufacturing.

5.3.4. ICT-based education

Based on the results achieved, what ManuSkills actually strongly encourages also beyond existing engineering Policy Recommendations is the pervasive use of ICT in manufacturing education. ICT-based educational tools proved to be effective for different target age groups (children, teenagers, young adults) and for different educational objectives (awareness, interest, knowledge), provided that are supported by suitable pedagogical scenarios. The use of ICT-based delivery mechanisms can hence foster teaching in a multifaceted way, enabling the contact of youngsters with concepts that would be otherwise difficult to be presented. In addition, ICT-based solutions could also be used to personalize classes, for evaluation purposes and to present to the classroom complex real cases. Professional software could be also used as a further support, especially for secondary school students. Finally, the use of “co-design” activities between teachers and manufacturing companies could be adopted in order to provide students with cutting edge ICT-based educational experiences.

6. CONCLUSIONS

The main aim of ManuSkills has been the study of advanced ICT-based technologies and training methodologies able to give a concrete help in solving the increasing problem of the lack of young talents in manufacturing, providing also a support in their acquisition of new manufacturing skills. The project has taken into account a wide range of ICT-based delivery mechanisms such as serious games, teaching factory and virtual reality.

Over a period of 10 months (*February - November 2015*), the project has conducted 22 experiments in 5 European countries (Denmark, France, Greece, Italy, Switzerland), involving a total of 18 educational institutions and 461 students among primary, secondary and tertiary education. The main results of the Experiments, reported in D4.2 (3), have been elaborated and integrated in the set of Policy Recommendations that represents the final output of ManuSkills.

ManuSkills Policy Recommendations are able to support European policy makers in the definition of actions to attract young talents to manufacturing and to support their acquisition of specific manufacturing skills, by paying particular attention to the following three aspects:

- The involvement of primary, secondary and university education
- The use of ICT as a supporting delivery mechanism
- The proposal of concrete actions to implement the guidelines provided

The methodology for the development of ManuSkills Policy Recommendations has followed three steps:

A. **Creation of the body of knowledge**
    a. **Results of the Experiments (D4.2)** (3)
    b. **Contributions collected from researchers and practitioners**
    c. **Internal workshops within consortium members**
    d. **Existing Policy Recommendations**
B. **Definition of high level Policy Recommendations**
C. **Definition of Concrete Actions to be implemented**

Different sources of knowledge have been considered, ranging from the results of the Experiments to the experiences collected from the stakeholders throughout the project lifecycle.

On that basis, four Policy Recommendations have been drawn up:

1. **Raise awareness on manufacturing's role in European society**
2. **Integrate manufacturing into STEM pipeline**
3. **Digitize manufacturing education**
4. **Develop training initiatives on manufacturing for teachers**

For each of them, a detailed explanation as well as a set of Concrete Actions to effectively implement it has been proposed.

The Policy Recommendations have been reviewed with the support of the project's Advisory Board, that helped in evaluating their consistency and efficacy and in revising the most critical passages.

The ManuSkills Policy Recommendations have been formulated in order to be agile and self-explaining guidelines targeting regional, national and European policy makers as well as valuable material for a wider range of interested stakeholders such as manufacturing companies, professional associations and educational institutions.

Specific contact points and differences with existing **Policy Recommendations** on **attracting youngsters to engineering** have been also identified, thanks to a detailed analysis and comparative evaluation as reported in Chapter 5.

7. REFERENCES

1. **ManuSkills.** *D2.2.2 - ManuSkills Vision - Final.*
2. —. *D4.1.1 - Test scenarios definition.*
3. —. *D4.2 - Report on the evaluation and analysis of the studies .*
4. —. *D4.1.2 - Report on recruitment and pilot run setup .*
5. —. *D2.2.1 - ManuSkills Vision .*
6. —. *D2.1 – Analysis emerging industrial needs in Factories of the Future.* 2014.
7. **Deloitte.** *Managing the Talent Crisis in Global Manufacturing - Strategies to Attract and Engage Generation Y.* 2007.
8. **Manufacturing Institute.** *Roadmap to education reform for manufacturing.* 2010.
9. **American Society for Engineering Education.** *Government policy and manufacturing education.* 2012.
10. **Manpower.** *The future of the manufacturing workforce.* 2012.
11. **Society of Manufacturing Engineers.** *Workforce imperative: a manufacturing education strategy.* 2012.
12. **SHRM Foundation Executive Briefing.** *Current issues in HR: Closing the manufacturing skills gap.* 2013.
13. **High Level Group on Science Education - European Commission.** *Science education now: A renewed pedagogy for the future of Europe.* 2007.
14. **Osborne, Jonathan e Dillon, Justin.** *Science Education in Europe: Critical Reflections.* s.l. : King's College London, 2008.
15. **Schoolnet, European, et al., et al.** *Science, Technology, Engineering and Mathematics education: Overcoming challenges in Europe.* 2011.
16. **Eurydice - European Commission.** *Science education in Europe: National policies, practices and research.* 2011.
17. **UNESCO.** *ICTs for new engineering education.* 2011.
18. **UNESCO Asia Pacific Regional Bureau for Education.** *ICT in education: Policy, infrastructure and ODA status in selected ASEAN countries.* 2013.
19. **GESCI.** *Education: 8 policy recommendations for the advancement of knowledge societies across Africa.* 2013.
20. **European Commission.** *High level group on the modernisation of higher education.* 2014.
21. **Engineering, National Academy of.** *Changing the conversation - Messages for improving public understanding of engineering.* 2008.
22. **Attract.** *Attract - Enhancing the attractiveness of studies in science and technology.* 2008.
23. **Research, Institute for Public Policy.** *Women in engineering - Fixing the talent pipeline.* 2014.
24. **Hays.** *Diversifying the talent pipeline - Women in engineering.* 2016.
25. **Women-Core.** *Women in construction scientific research.* 2008.
26. **Motivation.** *Motivation - Final project report.* 2010.
27. **Helena.** Interdisciplinarity towards gender equality in engineering and technology education - Recommendations. *GIEE 2011 - Gender and interdisciplinary education for engineers 2011.* s.l. : Sense Publishers, 2011.
28. **IRIS.** *IRIS publishable summary - Interests and recruitment in science.* 2012.
29. **Mascil.** *Policy brief on the state-of-affairs on inquiry based learning & the world of rork in 13 European educational contexts - Insights from a comparative overview.* 2014.
30. **INSTEM.** *An inquiry into inquiry: EU projects and science education.* 2015.

8. ANNEXES

8.1. ANNEX I - Analysis of Existing Policy Recommendations

8.1.1. Manufacturing Education

DELOITTE, "Managing the Talent Crisis in Global Manufacturing A Deloitte Research Global Manufacturing Study Strategies to Attract and Engage Generation Y", A Deloitte Research Global Manufacturing Study, 2007

Policy Recommendations	
1	Combat the lack of basic employability skills
2	Improve manufacturing's negative public image
3	Win the competition with other industries
4	Stem the inadequacy of job-related continuing education
5	Developing educational programs to promote careers in manufacturing
6	Partnering with local colleges and business schools to provide challenging internship assignments
7	Fostering relationships with MBA and other graduate programs that offer relevant concentrations around manufacturing industries — such as operations management, marketing, sales, service, and R&D — to facilitate direct recruitment of graduates
8	Developing a web presence to attract the tech-savvy talent pool of Generation Y

MI, "Recommendations for Action: Promoting Industry Certifications and Enhancing Two- and Four-Year Articulation", Roadmap for Manufacturing Education, The Manufacturing Institute, 2010

Policy Recommendations	
1	Increase Employer Demand for Industry Certifications
2	Link Industry Certifications to an Agenda of Business Competitiveness and Innovation
3	Influence Accreditation Standards Completion
4	Advocate for Industry Certifications as a Measure of Completion

5	Launch the Manufacturers Endorsed Education Alliance
Concrete Actions	
1	Expand employer engagement
2	Engage four-year institutions and policy leaders
3	Define and refine metrics
4	Capture promising practices
5	Promote a recognition initiative

ASEE, "Government Policy and Manufacturing Education", American Society for Engineering Education, 2012

Policy Recommendations	
1	Support national technology and engineering frameworks
2	Develop mechanisms to help key policymakers develop an understanding of the unique challenges of advanced manufacturing education
3	Perform an ongoing gap analysis with regard to manufacturers' needs and what is currently available in the educational community and make funding decisions accordingly
4	Bundle grant support for advanced manufacturing that includes faculty development, advanced manufacturing equipment and facilities
5	Encourage the development of a holistic understanding of advanced manufacturing as an "innovation engine" in its own right
6	Develop a national clearinghouse for the dissemination of promising and proven practices similar to the NSF's ITEST structure for the Advanced Technology Education (ATE) program
7	Sponsor a joint research project on the state of manufacturing education in coordination with the National Governors Association

MANPOWER, "Report Five: Policy Prescriptions for the Manufacturing Talent Gap", part of "The Future of the Manufacturing Workforce" research paper, Manpower, 2012

Policy Recommendations	
1	A race to the top for manufacturing education

2	Institutionalized funding at many levels
3	A greater degree of sharing and coordination
4	Certification programs
5	Changing the culture

SME, "Workforce Imperative: A Manufacturing Education Strategy", Society of Manufacturing Engineers, 2012

	Policy Recommendations
1	Attract more students into manufacturing by promoting the availability of creative, high-tech jobs and giving students a strong STEM foundation
2	Articulate a standard core of manufacturing knowledge to guide the accreditation of manufacturing programs and certification of individuals
3	Improve the consistency and quality of manufacturing curricula to better prepare students for manufacturing employment
4	Integrate manufacturing topics into STEM education, so that more students are exposed to manufacturing concepts
5	Develop faculty that can deliver a world-class manufacturing education in spite of a growing number of challenges
6	Strategically deploy existing and new resources into STEM and manufacturing education programs

SHRM, "Current Issues in HR: Closing the Manufacturing Skills Gap", SHRM Foundation Executive Briefing, 2013

	Policy Recommendations
1	Reach out to high school students. Most highskilled jobs require only a high school education in conjunction with on-the-job training
2	Increase visibility at the high school level to create awareness and improve the image of manufacturing—a major problem cited in the recruitment of talent
3	Expand on the strong programs and best practices that exist to develop skilled employees
4	Link community colleges more closely to the needs of manufacturers
5	Use demographic risk management and workforce planning tools to anticipate issues and enlarge the pool of potential candidates

6	Reinvest in internal training programs to build required capabilities
7	Anticipate future needs and begin to match younger talent with experienced employees in an apprenticeship model
8	Collaborate with education partners and governments to build programs that focus on developing specific skills
Concrete Actions	
1	Partner with Community Colleges
2	Create an Apprenticeship Program
3	Work with a Nonprofit Coalition
4	Make Credentials Portable

8.1.2. STEM Education

EC 2007, "Science Education NOW: A renewed pedagogy for the future of Europe", High Level Group on Science Education, European Commission, 2007

Policy Recommendations	
1	Because Europe's future is at stake decision-makers must demand action on improving science education from the bodies responsible for implementing change at local, regional, national and European Union level
2	Improvements in science education should be brought about through new forms of pedagogy: the introduction of inquiry-based approaches in schools, actions for teachers training to IBSE, and the development of teachers' networks should be actively promoted and supported
3	Specific attention should be given to raising the participation of girls in key school science subjects and to increasing their self-confidence in science
4	Measures should be introduced to promote the participation of cities and the local community in the renewal of science education in collaborative actions at the European level aimed at accelerating the pace of change through the sharing of know-how
5	The articulation between national activities and those funded at the European level must be improved and the opportunities for enhanced support through the instruments of the Framework Programme and the programmes in the area of education and culture to initiatives such as Pollen and Sinus-Transfer should be created. The necessary level of support offered under the Science in Society (SIS) part of the Seventh Framework Programme for Research and Technological

	Development is estimated to be around 60 million euros over the next 6 years
6	A European Science Education Advisory Board involving representatives of all stakeholders, should be established and supported by the European Commission within the Science in Society framework

Osborne J. & Dillon J., "Science education in Europe: Critical reflections", A report to the Nuffield Foundation, 2008

Policy Recommendations	
1	The primary goal of science education across the EU should be to educate students both about the major explanations of the material world that science offers and about the way science works. Science courses whose basic aim is to provide a foundational education for future scientists and engineers should be optional
2	The primary goal of science education across the EU should be to educate students both about the major explanations of the material world that science offers and about the way science works. Science courses whose basic aim is to provide a foundational education for future scientists and engineers should be optional
3	EU countries need to invest in improving the human and physical resources available to schools for informing students, both about careers *in* science – where the emphasis should be on why working in science is an important cultural and humanitarian activity – and careers *from* science where the emphasis should be on the extensive range of potential careers that the study of science affords
4	EU countries should ensure that: • teachers of science of the highest quality are provided for students in primary and lower secondary school; • the emphasis in science education before 14 should be on engaging students with science and scientific phenomena. Evidence suggests that this is best achieved through opportunities for extended investigative work and 'hands-on' experimentation and not through a stress on the acquisition of canonical concepts
5	Developing and extending the ways in which science is taught is essential for improving student engagement. Transforming teacher practice across the EU is a long-term project and will require significant and sustained investment in continuous professional development
6	EU governments should invest significantly in research and development in assessment in science education. The aim should be to develop items and methods that assess the skills, knowledge and competencies expected of a scientifically literate citizen
7	Good quality teachers, with up-to-date knowledge and skills, are the foundation of any system of formal science education. Systems to ensure the recruitment, retention and continuous professional training of such individuals must be a policy priority in Europe

INGENIOUS, "Science, technology, engineering and mathematics education: Overcoming challenges in Europe", European Schoolnet, EngineeringUK, inGenious, Intel, 2011

Policy Recommendations	
1	Establish and enhance sustainable multi-stakeholder partnerships to combine forces to tackle the challenges of STEM education
2	Enhance and reform STEM curricula, pedagogy and assessment
3	Embed science fairs and festivals in the mainstream of school activity
4	Offer more support to STEM teachers
5	Learn from and build on excellent approaches
Concrete Actions	
1	Defining a collaborative environment: ecosystems and partnerships
2	STEM in schools: curriculum, pedagogy and assessment
3	The role of science fairs and events in stimulating interest in STEM topics and careers
4	Equipping teachers to better address the challenge of STEM teaching and learning

EC 2011, "Science Education in Europe: National Policies, Practices and Research", EURYDICE, 2011

Policy Recommendations	
1	Countries support many separate initiatives but overall strategies to improve science education are rare
2	From an integrated approach to science at lower levels to separate subject teaching in the later stages of schooling
3	Increased attention to context-based issues and hands-on activities in science curricula
4	No specific support measures for low achievers in science"
5	Traditional assessment methods still prevail
6	Standardised assessment in science at least once during compulsory education
7	Teacher education: many national initiatives to help improve teachers' skills
8	Initial teacher education: still curriculum focused
Concrete Actions	
1	Experiments and explanations: a. Making scientific observations b. Recognising issues that are possible to investigate scientifically c. Designing and planning experiments/investigations d. Conducting experiments/ investigations e. Evaluating explanations f. Justifying explanations

	g. Presenting experimental results
2	Discussions and argumentations: a. Describing or interpreting phenomena scientifically b. Framing problems in scientific terms c. Formulating potential explanations d. Debating current scientific and societal issues
3	Project-work: a. Self-directed (individual) project work b. Collaborative project work
4	Use of specific ICT applications: a. Computer simulations b. Video conferences (e.g. for demonstrations, other)

8.1.3. ICT-based Education

UNESCO 2011, "ICTs FOR NEW ENGINEERING EDUCATION", Policy Brief, 2011

Policy Recommendations	
1	**The Four Pillars of Education:** *"Learning to Know", "Learning to Be", "Learning to Live Together" and "Learning to Do".*
2	**The 5-E Model for Engineering Education:** *Engineering, Enterprising, Educating, Environmenting and Ensembling*
3	**The three strategies to reform engineering education:** *University-industry Cooperation, Learning by Doing and Internationalization.*
4	**A comprehensive set of quality assurance standards:** *CDIO (Conceive, Design, Implement and Operate) includes integrated curriculum design, qualifications of instructors, students' engineering competency, and a balanced syllabus that covers both theoretical content as well as practical engineering skills, adequate workspaces for team-based learning activities.*
5	**Integrated Learning Activities and Resource Allocation:** *moving from today's lecturer-centred instructions to student-centred learning activities.*
Concrete Actions	
1	**Data collection and analysis by means of using ICTs:** *… a rigorous data collection work targeted at the skill levels of engineering school graduates and the needs of employers must be conducted regionally or even globally…*

2	**ICT-enabled Pedagogical Approaches:** *....globalized content pool could offer students many formats and styles of explanation that cannot be covered by traditional lecture-hall based teaching methods…*
3	**Learning Process Management:** *…ICT-enabled process control is the use of web-based learning tools…*
4	**Workspace Design and Technology Fusion:** *…ICT-enabled workspaces could help reduce overall costs, because it may enable traditional workspaces to serve multiple functions…*
5	**Open Source and the freedom to learn:** *…The creative freedom enabled by these sharable intellectual properties has become a major source of engineering educational content…*

UNESCO 2013, "ICT in Education: Policy, Infrastructure and ODA Status in Selected ASEAN Countries", UNESCO Asia Pacific Regional Bureau for Education APEID/ICT in Education, 2013

Policy Recommendations	
1	**Cambodia** a. Increase access to basic education, tertiary education and life-long learning, both formal and non-formal, by using ICT as an alternative education delivery media b. Improve the relevance and effectiveness of basic education by harnessing the potential of ICT as a major tool to enhance the quality of teaching and learning c. Develop the ICT-based professional skills needed by graduates for employment in a knowledge-based society and to ensure that Cambodia can compete and cooperate in an increasingly interconnected world d. Increase the effectiveness and efficiency of the Ministry and school management
2	**Republic of the Union of Myanmar** a. Establish a national committee for information culture movement (2012) b. Promote information culture (2012-2015) c. Revise laws and rules to accelerate e-awareness (2011-2012) d. Incorporate ICT training into the school curriculum (2012-2014) e. Train teachers in ICT usage (2012-2015) f. Develop teaching materials for ICT training (2012-2015) g. Revise laws and rules to promote digital literacy (2011-2013) h. Install national LAN and Internet connections for 1000 high schools (2012-2015)
3	**Thailand**

	a. Providing tax incentives or special loans for parents of school children to buy computers for home use b. Providing incentives to service providers to develop ICT infrastructure for schools c. Taking readiness of personnel and infrastructure into consideration, and maintaining a balance between allocations for equipment, Internet services, software, teaching materials, maintenance and training d. Promoting the local development of content, in the Thai language e. Building opportunities for applying open source software in the education sector f. Encouraging public-private partnerships with both domestic and foreign firms g. Improving the quality of learning h. Improving educational management through ICT-enable evaluation and collaborations i. Creating a large number of ICT specialists meeting international standards
4	**Malaysia** a. Provide Internet access and virtual learning environments via 1BestariNet for all 10,000 schools by 2013 b. Augment online content to share best practices, starting with a video library in 2013 of "Excellent Teachers" delivering lessons in science, mathematics, Bahasa Malaysia and the English language c. Maximize use of ICT for distance and self-paced learning to expand access to high-quality teaching regardless of location or student skill level
5	**Indonesia** a. Develop ICT networks for public and private universities as well as research and education networks in Indonesia b. Use ICT as an essential part of the curricula and learning tools in schools/universities and training centres c. Establish distance education programmes, including participation in Global Development Learning and other networks d. Facilitate the use of Internet for more efficient teaching and learning
6	**The Republic of Singapore** a. The goal is for students to develop competencies for self-directed and collaborative learning through the effective use of ICT and become discerning and responsible ICT users b. The goal is for school leaders to provide the directions and create the conditions to harness ICT for learning and teaching c. The goal is for teachers to have the capacity to plan and deliver ICT-enriched learning

	experiences d. The goal is for ICT infrastructure to support learning anytime, anywhere

GESCI, "Education: 8 Policy Recommendations for the advancement of knowledge societies across Africa", A product of the African Leadership in ICT Course, 2013

Policy Recommendations	
1	Explore delivery mechanisms for ICT use in educational provision to provide access for expanding school populations
2	Digitised administration/management information systems in schools should be linked to Ministries of Education
3	ICT literacy or media literacy should be integrated in curriculum reform and all management strategies
4	Provide ICT – competency professional development to teachers
5	Parents should be able to keep track of their childrens' learning and curriculum delivery and also access a parent-teachers corner for discussions and sharing
6	At tertiary level, e-learning should be intrinsic to teaching and learning model adopted by public/private institutions
7	Open and distance education policies should be designed to promote lifelong learning of teachers and learners
8	Digital media should enable outreach to even the most remote parts of a country to address the economic divide and barriers hindering information access
9	Build sufficient ICT infrastructure and broadband internet access in schools and colleges

EC 2014, "High Level Group on the Modernisation of Higher Education", Report to the European Commission on New modes of learning and teaching in higher education, 2014

Policy Recommendations	
1	The European Commission should support Member States in developing and implementing comprehensive national frameworks for diversifying provision and integrating new modes of learning and teaching across the higher education system. It should promote mutual learning on key aspects including skills development, infrastructures, legal frameworks, quality assurance, and funding, in particular by exploiting the potential of the Erasmus+ programme
2	The European Commission should prioritise support to higher education institutions under the Erasmus+ programme to enhance digital capacity and mainstream new modes of learning and

	teaching within the institution. Erasmus+ funding should also be made available to promote experimental partnering with specialist service providers
3	The integration of digital technologies and pedagogies should form an integral element of higher education institutions' strategies for teaching and learning. Clear goals and objectives should be defined and necessary organisational support structures (such as the European Academy of Teaching and Learning) established to drive implementation
4	National authorities should facilitate the development of a national competency framework for digital skills. This should be integrated into national professional development frameworks for higher education teachers
5	All staff teaching in higher education institutions should receive training in relevant digital technologies and pedagogies as part of initial training and continuous professional development
6	National funding frameworks should create incentives, especially in the context of new forms of performance-based funding, for higher education institutions to open up education, develop more flexible modes of delivery and diversify their student population
7	National authorities should introduce dedicated funding to support efforts to integrate new modes of learning and teaching across higher education provision. Funding should encourage collaborative responses to infrastructural needs, pedagogical training and programme delivery
8	National and regional authorities should utilise opportunities under the European Structural and Investment Funds programme to support the development of necessary supporting infrastructures, technologies and repositories
9	Public authorities should develop guidelines for ensuring quality in open and online learning, and to promote excellence in the use of ICT in higher education provision
10	The European Commission should support cross-border initiatives to develop quality standards for open and online learning under the Erasmus+ programme
11	Higher education institutions should ensure that quality assurance arrangements apply to all forms of credit-awarding provision in the institution. Institutions should use the quality assurance system to monitor retention rates and inform the development of appropriate supports
12	The European Commission and national authorities should encourage and incentivise higher education providers to award and recognise credits under the European Credit Transfer and Accumulation System for all forms of online courses. The current revision of the ECTS Guide should incorporate these principles
13	Governments and higher education institutions should work towards full open access of educational resources. In public tenders open licences should be a mandatory condition, so that content can be altered, reproduced and used elsewhere. In publicly (co-)funded educational resources, the drive should be to make materials as widely available as possible

14	Member States should ensure that legal frameworks allow higher education institutions to collect and analyse learning data. The full and informed consent of students must be a requirement and the data should only be used for educational purposes
15	Online platforms should inform users about their privacy and data protection policy in a clear and understandable way. Individuals should always have the choice to anonymise their data

8.1.4. Engineering Education

NAOE, "CHANGING THE CONVERSATION – MESSAGES FOR IMPROVING PUBLIC UNDERSTANDING OF ENGINEERING", NATIONAL ACADEMY OF ENGINEERING, 2008

Policy Recommendations	
1	To present an effective case for the importance of engineering and the value of an engineering education, the engineering community should engage in coordinated, consistent, effective communication to "reposition" engineering.
2	The four messages that tested well in this project—"Engineers make a world of difference," "Engineers are creative problem-solvers," "Engineers help shape the future," and "Engineering is essential to our health, happiness, and safety"—should be adopted by the engineering community in ongoing and new public outreach initiatives.
3	More rigorous research should go forward to identify and test a small number of taglines for a nationwide engineering-awareness campaign.
4	To facilitate deployment of effective messages, an online public relations "tool kit" should be developed for the engineering community that includes information about research-based message development initiatives and examples of how messages have and can be used effectively.
5	A representative cross section of the engineering community should convene to consider funding, logistics, and other aspects of a coordinated, multiyear communications campaign to improve the public understanding of engineering.

ATTRACT, "ATTRACT – ENHANCING THE ATTRACTIVENESS OF STUDIES IN SCIENCE AND TECHNOLOGY", ATTRACT, 2008

Policy Recommendations	
1	Examination of the factors which influence the decision-making process in relation to subject choice at high school and beyond.
2	Mechanism which allows for the later 'streaming' of students into designated tracks or branches of Education.
3	Higher level of core STEM content for all students, regardless of area of specialization.
4	Encourage more girls to pursue STEM subjects.
5	Increase participation in engineering among students from lower socio-economic groups.
6	Use of aptitude tests at university entry for information purposes, to evaluate students' strengths and potential areas of difficulty.
7	A successful transition would require that universities ensure that entrant students: • Have a comprehensive face to face academic advising session; • Gain more knowledge of student support services; • Reduce anxiety about the transition to university life;

	• Understand the necessity of taking ownership and academic responsibility in their educational process.
8	Maintain or increase student self-reports of having made meaningful connections with peers.
9	Maintain or increase student involvement in university activities.
10	Maintain or increase student self-reports of meaningful interactions with faculty and/or administrators.
11	Maintain or increase student understanding of and compliance with the university's expectations of them.
12	Increase the number and percentage of third year students who report satisfaction with their chosen major and perform successfully in that major.
13	Increase the number and percentage of students who demonstrate progress toward the development of a preliminary life/career plan.
14	Identify and report on activities/memberships that seem to correlate to academic performance changes as compared to appropriate comparison groups.
15	Maintain or increase the percentage of first year students who are retained to their second year.
16	Increase the percentage of second year students who are retained to their third year.

IPPR, "WOMEN IN ENGINEERING – FIXING THE TALENT PIPELINE", INSTITUTE FOR PUBLIC POLICY RESEARCH, 2014

Policy Recommendations	
1	Too few girls acquire the prerequisite qualifications in STEM subjects.
2	Addressing the unhelpful perception of STEM and engineering careers, among both girls and their families, as 'masculine' or 'brainy'.
3	Poor understanding of engineering careers and the engineering pathway.
4	The STEM ecosystem is fragmented, which increases the likelihood of duplication.

HAYS, "DIVERSIFYING THE TALENT PIPELINE – WOMEN IN ENGINEERING", HAYS, 2016

Policy Recommendations	
1	Refresh the image - A high percentage of people we surveyed don't believe that the breadth of engineering careers available is being adequately portrayed to young women. Engineering isn't viewed by potential recruits as a sufficiently prestigious or accessible industry to hold their attention. Compounding the problem is the archaic, yet dangerously enduring idea that engineering is a 'boys club' in which people work in noisy shop floor environments. This needs to be continually tackled – starting at school-age level. Potentially, rebranding the subject could be one way to engage with not only women but young people as a whole.
2	Change the culture - Companies with a high percentage of male engineers, especially if their workforce is predominantly made up of people approaching the end of their careers, may want to consider whether their overall corporate culture is as attractive as it could be to women recruits. Introducing more flexible working patterns may be one potential step towards attracting and retaining female talent in the future. Firms investing in apprenticeship training could also increase their appeal to young women looking at engineering roles to develop a culture that supports an equal workforce.
3	Educate young people - The need to modify young people's preconceptions that engineering is about working with dirty machines, is something that can't be stated too often. Organisations should look to offer training opportunities and working schemes so that newly qualified engineers are given the chance to develop their theoretical skills. Engineering employers should partner with schools and educational facilities and aim to engage young people within the 14–17 age range, educating them on the many different types of engineering roles available and future career paths.

WOMEN-CORE, "WOMEN IN CONSTRUCTION SCIENTIFIC RESEARCH", WOMEN-CORE, 2008

Policy Recommendations	
1	Additional effort for updating surveys, databases, studies, etc. on a regular basis: • There is a strong need for the European Commission and the Member States to make additional effort for improving access to sex-disaggregated data in industrial research.
2	Establishing new rules for increasing women's presence in construction research: • Female encouragement at educational level. The lack of encouragement of women in scientific careers at educational level has been considered as one of the obstacles to obtaining gender equality in construction research. This can be started at school level. • Recruiting and retaining women in research-orientated careers in the construction sector. Given the relatively high proportions of women undertaking construction related degrees (bachelors and masters), but lower proportions of women in scientific and more senior construction research positions, it is important to consider measures for recruiting and retaining women in research-orientated careers in the construction sector. • There is a strong need to include men into gender issues. The idea that gender discrimination is not a problem or that it affects only women has to be firmly fought. There is a strong need to include men into gender issues, since they concern both women and men as a whole society. Some of the main barriers to women-only measures include the fact that women do not want to be perceived as a 'special case', concerns that men may perceive these measures as reverse discrimination. • Fostering equal participation between women and men in childcare, family responsibilities and domestic work. The reconciliation between work and private life is the main obstacle for female researchers, especially for those who have children. Work-life balance measures are mainly taken up by women with children and this fact is in many cases prejudicial for their careers. A balanced participation between women and men in childcare, family responsibilities and domestic work should be fostered by EC and National Governments. Better infrastructure of childcare facilities should be provided to ensure equal opportunities for women and men. • More childcare facilities are needed, especially in countries like Spain and Czech Republic and even in Germany, particular for the first three years of children.
3	Other proactive measures to progress towards gender equality in construction research: • A larger awareness campaign about mentoring programmes should be promoted. Within the construction sector only a few comprehensive mentoring programmes have been identified. They practically always pursue the specific aims of the founder (University or large company). In SMEs sufficient conditions to guarantee a systematic long-term mentoring programme are usually difficult to create. The possibility to derive benefits from external organisers, external mentors and possibly from external financial subventions could be welcomed. • Additional support for networking is needed. Further research is necessary to determine the advantages and disadvantages of women-only networks, including exploration of women's own views on this.
4	Promoting a gender mainstreaming approach in public R&D policies relevant for the Construction sector: • Enabling new multidisciplinary fields and new approaches of research. Emerging more social sensitive fields of research must be supported in terms of financing, material resources and professional recognition. Construction research areas should be redefined and provided with funding programmes to promote multidisciplinarity and foster sustainable oriented approaches. Analysis of women's rate of publication indicated that women may have a higher rate of participation in softer areas of construction research such as the environment or architecture. However, further analysis of women's horizontal segregation in construction research is necessary as this was not conclusive in other tasks. Horizontal

	segregation should also be considered. • Redefine scientific excellence minimising gender bias. Different criteria of scientific excellence should be designed and established. Indicators of quality such as impact factors and number of citations rendered by work would define scientific excellence on a more consistent qualitative basis, although these criteria should be re-examined, to assure their fairness and equality. The current criteria in the evaluation of scientific excellence, favour high specialised career paths. New criteria should be introduced to appraise multidisciplinary curricula. • Other measures for progressing towards gender equality in construction research: There is not enough information and awareness about the work done the last years by the European Commission regarding Women and Science in the research community. The European Commission should better disseminate information in the scientific community the actions taken regarding gender issues.
5	Further research: • There is a need for further research into working conditions in construction research. In order to increase knowledge on the nature of gender equality measures and employees more detailed research into organisations with both strong gender equality measures and high proportions of women staff is necessary. There is a need for further research into the position of employees, their working time, conditions of employment and distribution in research activities and areas, and the specific nature of gender equality measures that have been implemented and the reasons for implementation. • Studies that include a time perspective are particularly needed. This will improve our knowledge of the effects of the gender equality measures and thus enable a transfer of the more successful measures on to other types of institutions and other parts of society. • It is also necessary to further explore the significance of publishing and patenting in industrial and academic careers and whether or not women are better represented in academia than industry. • Further research in specific countries. Further research is necessary to explain the decrease in women's participation in construction research within particular countries. Additional research may explore whether this pattern is specific to construction research or a pattern reflected more generally within certain countries.

MOTIVATION, "MOTIVATION – FINAL PROJECT REPORT", MOTIVATION, 2010

	Policy Recommendations
1	More diverse and realistic job images should be integrated in youth media
2	Soap producers and soap authors should look for industries' and universities' support
3	Good practice TV series could be taken as example
4	Teenager's interests have to be included in SET presentation: relevant topics for the audience
5	Female SET related role models should be created to reduce gender stereotypes
6	SET has to be contextualised to rise more interests in pupils
7	Pupils' motivation is essential: Liking is not choosing and choosing is not liking
8	Teachers' motivation is essential: Teachers training is necessary especially for rising gender awareness and further their pedagogy
9	Research should focus on transition from "easy" hands-on science to advanced levels
10	Choosing SET does not mean choosing a SET career
11	Making SET subjects compulsory

12	Images of SET should be less stereotypical and less gendered
13	Family relations have to be changed to non-traditional pattern
14	Media and inclusion initiatives should spread diverse images
15	It is recommendable to change both the image and the content of SET careers
16	Adapt successful concepts
17	Start at an early age and continue
18	Establish a network with other initiatives for different age groups
19	Foster cooperation with academic and also non-academic institutions and companies
20	Use role models from real life
21	Include young people‘s interests
22	Gain approval and establish the initiative among important persons and organisations in politics, university and industry
23	Ensure safe funding for years ahead
24	Do not forget to evaluate from the start
25	More research about evaluation is needed

HELENA, "INTERDISCIPLINARITY TOWARDS GENEDER EQUALITY IN ENGINEERING AND TECHNOLOGY EDUCATION - RECOMMENDATIONS" IN "GIEE 2011 – GENDER AND INTERDISCIPLINARY EDUCATION FOR ENGINEERS 2011", SENSE PUBLISHERS, 2011

	Policy Recommendations
1	Additional efforts are needed for updating surveys, databases, studies, etc. on a regular basis
2	Open the E&T curricula to a more interdisciplinary dimension
3	Establishing new rules for increasing women's presence in E&T higher education

IRIS, "IRIS PUBLISHABLE SUMMARY – INTERESTS AND RECRUITMENT IN SCIENCE", IRIS, 2012

	Policy Recommendations
1	Understanding educational choice and supporting STEM choice: 1. Acknowledge that educational choice is an ongoing process over time 2. Acknowledge the crucial role of identity in educational choice: In order to choose a STEM education, a student must be able to see her/himself as a 'STEM person'. 3. Make parents, teachers and other persons in touch with young people aware of the important role they can play in young people's identity work and educational choice process 4. Present a range of different possibilities available in STEM careers to young people
2	Develop school science curricula that support informed participation in post-compulsory STEM: 5. Develop recruitment initiatives across the full age range within schools 6. Provide a variety of school science experiences to match the differing interests of students within science 7. Include teaching/learning about socio-scientific issues within school science curricula
3	Support teachers in providing STEM instruction that creates and maintains interest for female and male students: 8. Make teachers aware of how they can motivate girls and boys with different interests, strengthen students' self efficacy, and display the variety of applications and careers related to STEM 9. Help teachers to develop teaching approaches and work forms where girls and boys with a variety of learning styles are motivated and feel secure to participate and develop their understanding. For instance, collaborative work forms may be particularly important for many girls. 10. Teaching staff familiar with gender equity issues and STEM stereotypes can contribute to encouraging

	students in general, and females in particular, towards (PhD) STEM studies and careers.
4	Develop varied recruitment initiatives with opportunities for personal meetings: 11. Develop recruitment initiatives that provide a variety of experiences: strengthening interest, building self efficacy, providing role models, and giving career examples 12. Provide arenas for personal meetings between secondary students and tertiary STEM students 13. Provide secondary students with information on the broad range of STEM professions available 14. Present STEM role models, especially female scientists 15. Allow recruitment initiatives to be developed and improved over time
5	Support undergraduate STEM students to enhance retention: 16. Reducing the non-completion rate is particularly important for STEM programmes 17. Do not expect that students just fit into their new study programme 18. Address the sequence of courses within the study programme to secure first-year social and academic integration 19. Improve possibilities for student-staff interaction 20. First year is important, but retention initiatives should extend to second and third year
6	Address the views on STEM presented through media: 21. Use the power of popular science and STEM-related fiction to provide examples of STEM identities and applications 22. Counter the stereotypic images of scientists that are still prevalent

MASCIL, "POLICY BRIEF ON THE STATE-OF-AFFAIRS ON INQUIRY BASED LEARNING & THE WORLD OF WORK IN 13 EUROPEAN EDUCATIONAL CONTEXTS – INSIGHTS FROM A COMPARATIVE OVERVIEW", MASCIL, 2014

Policy Recommendations	
1	There is a need for coherence in policy rhetoric between expectations of students' learning and expectations of teachers' training. The proposed compatibility between policy envisions regarding the teaching of mathematics and sciences as evident in policy documents and policy orientations regarding teacher training, will be a step towards bridging the gap between what is envisioned in theory and has is implemented in practice
2	Inquiry based learning seems to be prioritized more in primary and general secondary than in vocational education. Policy makers should consider the potential of the methodology in vocational contexts, and make more effort in promoting inquiry based learning in vocational contexts.
3	The connections between schooling and the world of work seems to be prioritized at a level of a general rhetoric in some counties without concrete action plans, especially in primary and general secondary education. Policy makers should further consider the potential of such a connection, in the view of enhancing employability.
4	Transforming teacher practice should be a long-term project, requiring significant and sustained investment in continuous professional development. Short-term cycles of training initiatives have proven to be unsustainable and of little effect in transforming classroom practice.
5	Concrete guidelines or measures on how equity, low-achievement and entrepreneurship issues are to be addressed in science and mathematics education are needed. Important to this respect is the consideration on how specific teaching methodologies (such as inquiry based teaching and learning) may be a lever towards the accomplishment of such aims.

INSTEM, "AN INQUIRY INTO INQUIRY: EU PROJECTS AND SCIENCE EDUCATION", INSTEM, 2015

Policy Recommendations

1	Section A: Policy A.1 Educational change in Europe should be implemented in line with a well-defined long-term vision, which incorporates the best features of national systems. A.2 There should be a wider interpretation of 'innovation' in relation to educational interventions, to allow for methods complementary to IBL. A.3 Greater coherence is needed between policies and actions in primary, post primary and the tertiary sector. A.4 There should be more interaction between science education, the world of work, and research, in order to provide students with a sense of purpose and real engagement with science. A.5 There is a need for shared understandings regarding the impact for STEM projects and a related need to create monitoring and feedback systems to ensure that this impact can be measured. A.6 Project durations and start dates for education projects should reflect the reality of school timeframes. A.7 There should be more Interaction between the administrative systems of the European Commission (including the executive agencies such as EACEA and REA) and project coordinators. A.8 There should be clear coordination of EU actions related to STEM education, with connections between Horizon 2020, Erasmus Plus and relevant policy instruments
2	Section B: National level B.1 There should be better alignment between pedagogy, curricula and assessment systems. B.2 There should be better coordination between curricula, textbooks, online resources and teacher competence. B.3 There should be more professional development for teachers, in order to improve their confidence and repertoires of actions in relation to IBL. B.4 More attention should be paid to student voice and rights in relation to STE(A)M subjects, in order to encourage students, as future citizens, to take responsibility for research and innovation.
3	Section C: School level C.1 There needs to be commitment at school governance/management level to implement new practices effectively. C.2 Inter-disciplinary working and teacher collaboration are essential to maximise the potential of innovations in teaching and learning, C.3 Teacher professional development requires time, space and coherent structures. C.4 The informal sector has an increasing part to play in implementing innovative forms of science education. C.5 Classroom environment: The essential precondition for IBL to have any effect is an inquiry-friendly classroom environment, in which student questions are valued and curricula are sufficiently flexible to allow for deviations from planned lessons. C.6 The role of 'enabling knowledge' is important, and there are many aspects of science or mathematics that do not lend themselves to discovery by students. C.7 Supporting teachers to implement inquiry-based learning requires a greater use of professional networks, including collaboration with other teachers, working with the informal sector and working with researchers on new methods, materials and topics.