A COMPETENCE-BASED INDUSTRIAL LEARNING APPROACH FOR FACTORIES OF THE FUTURE
A Result of the FP7-FoF Project ActionPlanT

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Abstract: In this paper we propose a generic competence-based approach for Industrial Learning. The approach is composed of (i) an Industrial Learning model which serves to represent and understand competence-based learning, and (ii) a methodology which implements through a number of steps the Industrial Learning actions defined using the Industrial Learning model in industrial organisations. Both the model and the methodology are presented in details. A metrics-based method for evaluating the implementation of the approach is also described.

1 INTRODUCTION

The research project ActionPlanT is co-funded by the European Commission under the Private-Public Partnership (PPP) "Factories of the Future" initiative of the Seventh Framework Programme (FP7) for research and technological development (Grant Agreement Number 258617). ActionPlanT aims to develop a vision on the short, medium, and long term role of Information and Communication Technology (ICT) in the European manufacturing industry. The research project started in June 2010 and will end in May 2012.

For Europe to hold on to its global leadership and excellence in manufacturing, it is imperative that improvements at both the technological and the awareness level are made for ICT-enabled manufacturing processes. ActionPlanT is set out to address the improvement in this respect of the short, medium and long term role of ICT in the manufacturing industry. On a more holistic level, ActionPlanT will outline the vision of the future role of ICT in manufacturing for the European Commission's FP8/CSF. Moreover, it will explore a concept of disseminating knowledge and future requirements through a well-established platform consisting of manufacturing and ICT experts from both academia and industry.

In summary, the two main activities of ActionPlanT are:

▪ Establishing an ICT-enabled manufacturing vision for use cases and services of the future using this analysis as a basis. This vision will pave the way for a detailed roadmap which will prioritize and schedule most promising topics for the upcoming work program for Research and Innovation of Framework Programme 8 (FP8) ;

▪ Developing and validating a concept for Industrial Learning (IL), extensively piloted via Industrial Learning Pilot Events (ILPEs) and workshops amongst stakeholders in industry, academia, and the European technology platforms alike.

These two parallel work streams "Vision & Roadmap" and "Awareness & industrial Learning" of ActionPlanT project are depicted in Figure 1.
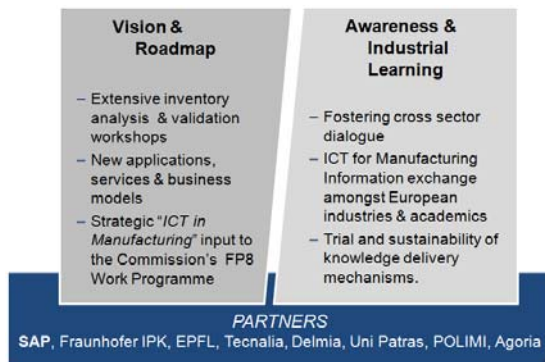
Figure 1: ActionPlanT Parallel Work streams.

The approach presented in this paper relates to the second work stream "Awareness & industrial Learning".

2 RATIONALE FOR INDUSTRIAL LEARNING

Promoting excellence in manufacturing emerges as a strategic goal in the years to come, both for industry and society.

Manufacturing education is expected to be a major driver to achieving this goal. To respond to this role, manufacturing education should follow a new approach to prepare industry for the next-generation innovation and support its growth (Manufuture, 2006). More specifically, it should focus on:

▪ promoting synergy between the academia stakeholders and industry; the comprehension of the needs of the manufacturing industry for training and education, the joint definition of the content, the pedagogic approach and the delivery mechanisms for future curricula,   as well as the integration of research   and innovation with education and training activities, are considered as the main priorities;

▪ developing the ICT for manufacturing skills required by the manufacturing labour force   to face new   professional   needs;   the   adaptation   of educational content and its delivery mechanisms to the new requirements of   ICT-based manufacturing, the provision   of integrated engineering competencies, including a variety of soft skills, and the promotion of innovation and entrepreneurship spirits, are considered as major priorities.

In order to achieve these objectives, manufacturing education has to address several challenges in the years to come. As far as the IL aspect of

manufacturing education is concerned, some major challenges are discussed hereafter.

New skills are required by the future generations of "knowledge workers". To that direction, an adaptation of the educational content and its delivery mechanisms to the new requirements of knowledge-based manufacturing is required. Manufacturing strategy with focus on digital business, extended production and virtual enterprises should be greatly considered. On the other hand, there is a growing need for expanding the technological aspect of education, with an extension to the 'soft skills'.

The development of educational curricula has not kept pace with the growing complexity of industry, technology and economy. Moreover, research outcomes of educational institutions are typically presented to the scientific community without being directly accessible to industry. Within this context, it is difficult for industry to comprehend and to adapt to the technological advances in a direct way.

In the industrial context knowledge is generated by Universities and Research institutes and implemented in Industries as illustrated by the Knowledge Triangle concept in Figure 2 (Westkämper, 2008). ActionPlanT covers the area within the marked (green) border. This figure illustrates the sources of knowledge to be transferred to Industry using the ActionPlanT IL Model.
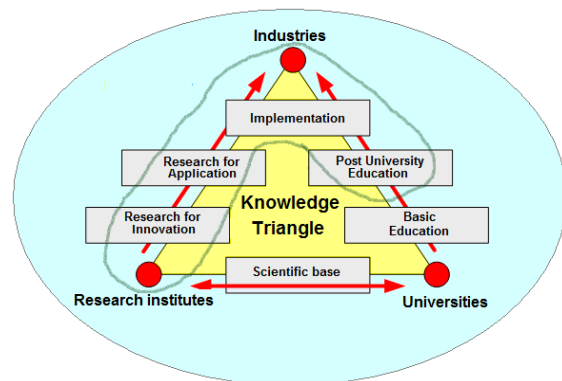

Figure 2: The Knowledge Triangle in industrial education (Westkämper).

The need for integrating the cornerstones of the knowledge triangle (Figure 2) into a single framework for supporting manufacturing education, has given rise to a number of learning paradigms and mechanisms.

3 STATE OF THE ART AND GAP ANALYSES

The state of the art analysis (see list of references) reveals that the existing learning methodologies suffer from the following weaknesses:

▪ The definition of professional competencies is based on company internal needs analysis which excludes new ICT for manufacturing competencies defined from knowledge assets created from other sources such as research & innovation projects, best practices, etc.;

▪ Most of existing learning methodologies focus on the transfer of "mature" knowledge (e.g., knowledge developed several years ago);

▪ The existing learning approaches are type-specific (e.g., vocational training, technology transfer, etc.) and vary from one type to the other, due to the different learning goals;

▪ Most of the existing approaches are customized according to the learning content;

▪ Despite their potentiality for competence development, Living Labs are mainly considered at the R&D level (e.g. open innovation platforms, exposing test bed applications to the users, etc.) and have not been systematically used for training so far;

▪ Most of the reported applications of the Teaching Factory paradigm focus on academic training rather than on IL;

▪ The emerging ICT-based learning formats, such as collaborative learning environments, game-based learning, virtual reality environments, etc. appear so far only in prototype software applications or highly specialized applications addressing a narrow range of learning cases.

The ActionPlanT IL approach is developed in a way to fill most of the gaps of existing approaches. Among its main characteristics we can quote:

▪ Using ActionPlanT IL model, the new professional competencies are created from the recent achievements of research and innovation actions in the domain of "cutting edge" ICTs for manufacturing;

▪ Based on the "extended" Teaching Factory concept, the ActionPlanT framework suggests the integration of research and IL activities, which brings "cutting edge" knowledge in the learning process;

▪ The ActionPlanT IL approach that addresses all the cognitive range of IL, from attitude building to competence development is generally applicable and

may be adjusted to the needs of each specific learning activity;

▪ The ActionPlanT IL methodology is generally applicable and consequently it can accommodate learning content from a big range of challenging topics on "ICT for Manufacturing";

▪ ActionPlanT framework suggests Living Labs as a major tool for competencies development;

▪ ActionPlanT suggests an extended Teaching Factory concept as a basis for the IL framework;

▪ The ActionPlanT framework integrates the emerging ICT-based learning formats, such as collaborative learning environments, game-based learning, interactive multi-media training, etc., in a systematic approach that addresses all the cognitive range of IL, from attitude building to competence development;

▪ The evaluation scheme in the ActionPlanT IL methodology considers relevant sets of metrics for impact measurement of the training activities for: attitude, knowledge, skills and competence.

4 COMPETENCE BASED LEARNING

The ActionPlanT model / methodology provides answers to the following questions:

▪ *What* are the cognitive / learning aspects to be addressed by the IL activities on ICTs for manufacturing?

▪ *How* should these aspects be addressed, namely how should IL on ICTs for manufacturing be delivered?

4.1 Competence Development in the ActionPlanT framework

The aim would be to address training needs for a systematic, but also visionary, use and exploitation of knowledge and skills for innovating industrial products and processes. Training would address issues such as understanding of opportunities, combining different pieces of new knowledge and developed skills to solve problems, promoting creativity and innovative spirit, etc.

In this framework, IL actions in ActionPlanT should be designed along the three main dimensions: Knowledge, Skills and Attitude:

▪ **Transfer of Knowledge:** focus on "Industrial Communities of Practice" using Synchronous (webinars, teaching factory, summer school, etc.)

and Asynchronous (e-learning, virtual factory, etc.)
learning methods and tools;

▪ **Development of Skills:** Focus on dissemination
in "Vocational Training" audience;

▪ **Influence of Attitude:** Focus on dissemination
& awareness raising in society in general and
specific target groups (i.e. high schools).
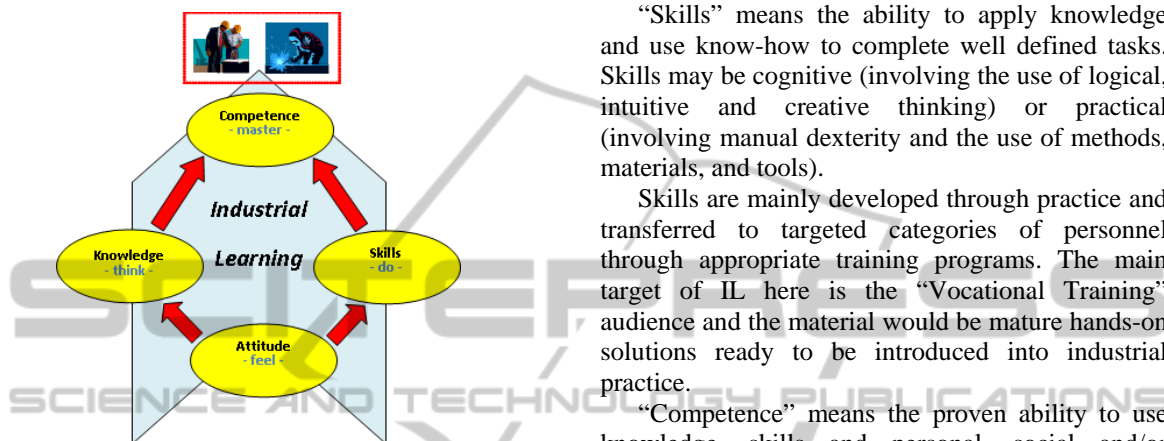
This is illustrated in Figure 3.

Figure 3: Building blocks of the learning process.

In the ActionPlanT context we have to do with
the development and implementation of new
professional competencies created by recent
achievements of research and innovation actions in
the domain of ICT for Manufacturing.

4.2 Building Blocks of Learning

In this subsection, we describe the 4 building blocks
of learning: *attitude*, *knowledge*, *skills* and
competence (Figure 3). They are part of the learning
process and considered in the learning programs and
actions of ActionPlanT IL.

"Attitude" is a hypothetical construct that
represents an individual's degree of like or dislike
for an item. Attitudes are generally positive or
negative views of a person, place, thing, or event.

In the industrial context attitude is the actual
perception of manufacturing and related ICT
activities by the society in general and the interest
that this perception generates for the relevant
societal characteristics: job creation, attractiveness
of manufacturing activities, will to work in an
industrial environment, contribute to "create"
something, etc.

"Knowledge" is the outcome of the assimilation
of information through learning. Knowledge is the

body of facts, principles, theories and practices that
is related to a field of work or study.

Knowledge can be seen as the higher level of
competence and needs to be continuously updated
with new achievements of research and innovation
as illustrated in the Knowledge triangle presented in
Section 2. The main goal of IL here is the Transfer
of Knowledge from research and innovation results
to concerned industrial stakeholders.

"Skills" means the ability to apply knowledge
and use know-how to complete well defined tasks.
Skills may be cognitive (involving the use of logical,
intuitive and creative thinking) or practical
(involving manual dexterity and the use of methods,
materials, and tools).

Skills are mainly developed through practice and
transferred to targeted categories of personnel
through appropriate training programs. The main
target of IL here is the "Vocational Training"
audience and the material would be mature hands-on
solutions ready to be introduced into industrial
practice.

"Competence" means the proven ability to use
knowledge, skills and personal, social and/or
methodological abilities. Competence is also
described in terms of responsibility and autonomy.

Competences may be considered as the interface
between the learning and the innovation processes.
As such, the ActionPlanT learning model /
methodology would address competence
development as a major requirement.

It is worth noting that ActionPlanT ILPEs are
evaluated on the basis of the improvements made
with respect to the 4 building blocks of learning.

5 THE ACTIONPLANT IL MODEL

The ActionPlanT IL Model is composed of a
Competence Specifications Framework (the lower
block in Figure 4) and a *Competence
Implementation* part (the upper block in Figure 4)
which includes a sub-part (inner block) for the
identification and definition of *Elements of
Competence Development* (knowledge assets) in a
specific sector or, more general, in an Industrial
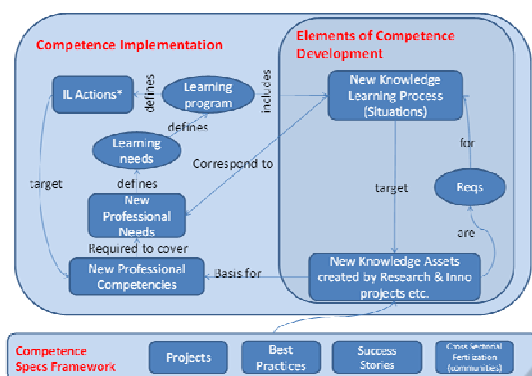Community of Practice.

Figure 4: The ActionPlanT IL Model.

5.1 The Competence Specifications Framework

In the context of ActionPlanT, the competence specification framework is limited within the scope of "ICT for Manufacturing". The requirements and specifications of the IL actions are gathered from relevant research projects, best practices etc. and are in line with the first ActionPlanT work stream of Figure 1.

The competence specifications framework describes the current needs for development of competencies in terms of knowledge, skills, and attitude for a sector or community of practice.

5.2 The Elements of Competence Development

The progress of science and technology creates the so called "knowledge assets" whose transfer in applications in industrial environments create needs and requirements for new professional situations, which are the "Basis for" New Professional Competencies as illustrated by the link in the lower part of the model in Figure 4. New Professional Competencies cover New Professional Needs, which can be developed through an adequate learning process which is the means to implement and realize the transfer of the defined knowledge assets as illustrated by the link between "New Knowledge Learning Process" and "New Professional Needs" in Figure 4.

5.3 Competence Implementation

The knowledge assets and associated learning process that have been defined to cover identified professional needs (and associated competencies) create Learning Needs which are addressed by the

training or Human Resources departments of industrial organisations with the design and implementation of Learning Programs which include a well-designed series of IL actions as illustrated by the upper left part of the model in Figure 4.

6 THE ACTIONPLANT IL METHODOLOGY

The ActionPlanT IL methodology aims at implementing through a number of steps the IL actions defined using the ActionPlanT IL model for a specific learning situation. This includes the choice of adequate delivery mechanisms and appropriate evaluation tools. At each step of the methodology, all relevant available techniques including the emerging ones are considered in order to meet the learning styles of the different target audiences and the requirements of the various learning topics.

Unlike traditional IL methodologies which are need-driven meaning that they are designed to respond to specific needs raised by demanding companies, the ActionPlanT IL methodology is opportunity-driven aiming to offer for manufacturing companies an opportunity to develop and implement new professional competencies created by recent achievements of research and innovation actions in the domain of cutting edge ICT for manufacturing.

Exploring the experience developed in training activities of the FP6 PROMISE project (Brintrup and Ranasinghe 2008, Matta et al. 2007) the steps defined in Figure 5 are the main elements of the methodology to implement IL in industrial communities of practice.
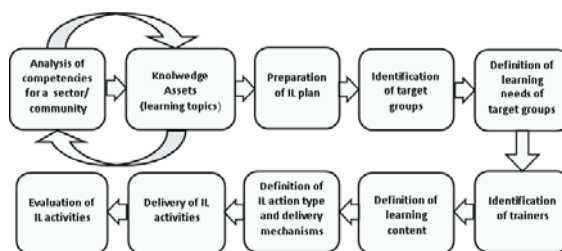

Figure 5: The ActionPlanT IL methodology.

The order of steps in Figure 5 is specific to the ActionPlanT training case; the order may be different in other training situations.

The different steps of the ActionPlanT IL methodology are described in the following sub-sections.

6.1 Step 1: ICT for Manufacturing Competencies Analysis

The ICT for manufacturing competencies analysis is based on the ActionPlanT IL model presented in the previous section.

In the ActionPlanT IL model new ICT for manufacturing knowledge assets (learning assets) are created from various sources such as research & innovation projects, best practices, etc. These learning assets provide a basis for the development of new professional competencies in the field of ICT for manufacturing which are useful for companies to develop new knowledge and skills in their manufacturing domains. Indeed, the acquisition by manufacturing companies of the most advanced ICT developed by specialized research institutes and their implementation are often quoted among the main factors to improve competitiveness.

There is an interaction between ICT for manufacturing competencies and ICT for manufacturing knowledge assets. Indeed, the development of an ICT for manufacturing competence requires ICT for manufacturing knowledge asset(s) and an ICT for manufacturing knowledge asset defines one or more ICT for manufacturing competencies.

6.2 Step 2: ICT for Manufacturing Topics/Modules

This step is concerned with the identification of the broad topic areas that should be included in the ActionPlanT training program about ICT for manufacturing in order to fulfil the training needs related to the ICT for manufacturing professional competencies.

ActionPlanT framework pursues the direct employment of "cutting-edge" / "fresh" knowledge, produced in recently finished or even still running research projects, in IL activities. That approach can speed up the innovation process.

6.3 Step 3: Preparation of ActionPlanT IL Plan

The preparation of the ActionPlanT IL plan is based on the analysis of the expertise and the learning infrastructure available for the organization of the IL activity.

In the case of ActionPlanT project, the distribution of learning topics among the different IL actions is based on the expertise and the learning infrastructure available at the organizing ActionPlanT consortium member in order to better use the available resources for ActionPlanT IL learning activities.

6.4 Step 4: Identification of Target Groups

Different audiences are considered in ActionPlanT from different perspectives with regard to their role in ActionPlanT learning process:

▪ Professional target group including the professional audience at various levels of the manufacturing industry including SMEs as well as among consultancy and relevant service providers.

▪ Specialized training institutions, professional chambers and their training bodies, etc.

▪ Academic target group which includes audience from both engineering and vocational training schools.

▪ Society in general will be considered with possible focused dissemination actions at high school audiences.

For each IL action, the target groups are identified among the audiences mentioned above on the basis of a set of relevant selection criteria such as functional domain, manufacturing sector, ICT skills, etc. Nonetheless, the priority will be given to the industrial professionals.

6.5 Step 5: Definition of Learning Needs of Target Groups

This step deals with the definition of the training needs of the target groups identified in the previous step with respect to the ICT for manufacturing topics considered in Step 2.

Each IL action focuses on one or more learning topics and targets specific audiences. The needs of these audiences relate o the learning topic(s) addressed in the IL action.

A usual technique that is commonly used to address this problem is the "skills matrix" where the target groups are listed in the first column of the matrix and the ICT for manufacturing addressed in the learning topic in the first row of the matrix, and the cells indicate the potential training needs of the target groups with respect to the considered ICT for manufacturing issues. If the individuals in the group have different capabilities regarding the ICT issues in manufacturing topics, then the "skills matrix" should be applied at the level of individuals.

6.6 Step 6: Identification of Trainers

The aim of this step is to identify the experts on ICT for manufacturing that would provide the training material in connection with their field of expertise to the target audiences on the selected learning topics.

The selected trainers should have the necessary competencies on the use of ICT tools in the training activities and be up-to-date with the cutting-edge ICT matters in manufacturing related to the selected topics in order integrate them in these topics.

In the case of ActionPlanT project, the trainers are primarily selected among the partners of the ActionPlanT project on the basis of their expertise with respect to the topics retained for the IL actions. Only in the case where no expert from the consortium can provide the training for a given learning topic, then the appeal for experts from outside the consortium is considered.

6.7 Step 7: Definition of Learning Content

The learning content should be tailored to the needs of target groups with respect to the selected topics. This can be the improvement of existing knowledge/skills about ICT for manufacturing or the development of completely new knowledge/skills.

To facilitate the elaboration of the content of the learning modules, the usual approach consists in dividing the modules into subjects, the subjects in sub-subjects until obtaining the elementary subjects: the units. The rule is that the decomposition continues until obtaining of the most elementary elements for which it is easy to define the contents. Indeed, it is easier to develop the content for the concise and precise subjects than for the general subjects which can involve numerous and varied types of information.

The development of learning content for the selected topics is the responsibility of the trainers identified in the previous step.

6.8 Step 8: Definition of IL Action Type and Delivery Mechanisms

For the delivery of the training programs, various instruments are proposed in order to suit the different learning styles and constraints of trainees and the requirements of the learning topics.

The list of the delivery methods used for the different learning topics considered in the IL actions includes both traditional and recent methods such as onsite: seminar / workshop / conference, synchronized/ non-synchronized virtual classroom, Internet-based training, webinar, serious games, workshops at future factory, etc.

A special attention is given to human oriented approaches, employing ICT tools to support human interaction with the "real" environment and application, and human-to-human interaction (e.g. collaborative environments, etc.).

6.9 Step 9: Delivery of IL Activities

The implementation of IL occurs during the different IL actions which are defined by using the competence-based IL model.

6.10 Evaluation of IL Activities

The evaluation determines to what extent the training provided through the ActionPlanT IL approach has responded to the training requirements of target audiences. Kirkpatrick's four levels of evaluation model (Kirkpatrick, 1959) is very useful to handle these issues. In ActionPlanT, we focus on the following three levels: (i) reaction of learners: what they thought and felt about the training, (ii) learning: the resulting increase in knowledge or capability, and (iii) behaviour: extent of behaviour and capability improvement and implementation / application.

In addition to the assessment of the level of success achieved through the training program, the follow up and evaluation allow to determine what updates are needed for the knowledge content and the delivery mechanisms in order to ensure an efficient and effective life-long training of the target groups.

Due to the importance of the evaluation and the validation of the proposed approach, a whole section (section 7) is dedicated to this issue.

7 EVALUATION AND VALIDATION OF THE ACTIONPLANT IL APPROACH

A set of IL actions are used for the assessment of the effectiveness of the suggested learning approach and knowledge delivery mechanisms. The evaluation output will help to further improve the implementation aspects of the suggested approach and identify best practices in the use of knowledge delivery mechanisms for IL.

IL actions involve different S&T themes on "ICT for manufacturing" and knowledge/training delivery mechanisms (Table 1). They are structured around a theoretical session for basic knowledge transfer and a practical session for hands-on exercise. Target groups include heterogeneous teams of engineers coming from industry and academia.

Table 1: Initial set of IL actions.

A#	S&T Theme	Training delivery mechanism
1	Shop floor data processing	Teaching Factory
2	Lean Manufacturing	Serious Game
3	Closed Loop PLM	Best Practice Tutorial

IL actions are assessed against the achievement of a set of goals, related with: attitude, knowledge, skills, competencies (Table 2, Table 3). The evaluation is based on the feedback of the trainees to a questionnaire, which is filled-in by all IL actions' participants/trainees, right after the end of the event. The questionnaire itself is structured in a way to assess the improvement of the attitude, knowledge, skills and competence of the trainees with respect to the introduced learning module.

Table 2: General goals of the IL actions.

	IL actions general goals
Attitude	Create awareness, attract interest, increase motivation to learn & apply
Knowledge	Create a basic technology understanding (basics of relevant theory & SW) oriented to industrial practice, and acquaint with relevant ICT tools to search for further information
Skills	Acquaint with the use of dedicated software tools, complete a well defined task involving processing of data with the given tools
Competencies	Build-up basic ability to combine different pieces of knowledge, developed skills and own understanding, to make decisions and address real life-like use cases

The evaluation of the IL actions includes both a qualitative and a quantitative assessment. Qualitative assessment aims to draw conclusions, on the basis of the statistical analysis of the trainees' feedbacks, about:

- the improvement of the attitude, knowledge, skills and competence of the trainees with respect to the introduced learning module,

- the actual work flow and performance of the group, the difficulties encountered by the trainees, their actual involvement and co-operation level,
- the strong / weak aspects of the introduced training delivery mechanism and areas of possible improvement for the training delivery.

Table 3: Example of specific goals of an IL action (Lean Manufacturing).

	2nd IL action specific goals
Attitude	Create awareness and attract interest with respect to Lean Manufacturing and the supporting ICTs
Knowledge	Create a basic understanding about the major principles, pillars and limitations of Lean Manufacturing, as well as about the manufacturing ICTs (e.g. MES, ERP, RFID etc.) implementing the underlying principles and enabling lean production
Skills	Apply different schemes for team work organization and information processing in assembly operations, including traditional schemes, self-organization and lean principles
Competencies	Develop the capability of addressing realistic use cases involved in car assembly operations, requiring decision making and optimization of teamwork organization and information processing

A systematic approach is also being suggested for the quantified impact measurement of the IL actions. It is based on the concept of the weighted sum model (WSM), which is the best known and simplest multi-criteria decision analysis method (Fishburn, 1967). The overall performance of an ILPE is calculated by taking the weighted sum of the normalized values of the ILPE performance criteria (building blocks of the learning process), i.e. *attitude* improvement, *knowledge* delivery, *skills* delivery and *competences* development (Equation 1). The weights assigned to these performance values depend on the relative importance of the respective performance criteria for each ILPE. For example, an ILPE may be focused more on practical training, e.g. skills delivery and competence development, rather than on theoretical aspects. Thus, higher weights would be assigned to the respective performance values.

A set of performance indicators is identified referring to each ILPE performance criterion (building block of the learning process). The weighted sum of the normalized values of these indicators is used to calculate the overall value of the respective ILPE performance criterion (e.g. Equation 2 is used for Attitude). The weights assigned to

these values depend on the relative importance of the respective indicator in the achievement of the ILPE goals for the specific ILPE performance criterion. Each performance indicator is associated with a specific question included in the Questionnaire used for IL actions evaluation. The trainees' responses will be processed appropriately, so as to assign specific values to the performance indicators (Figure 6).

PIA$_2$ - Improvement of business potential understanding after attending the IL action = +27,5%
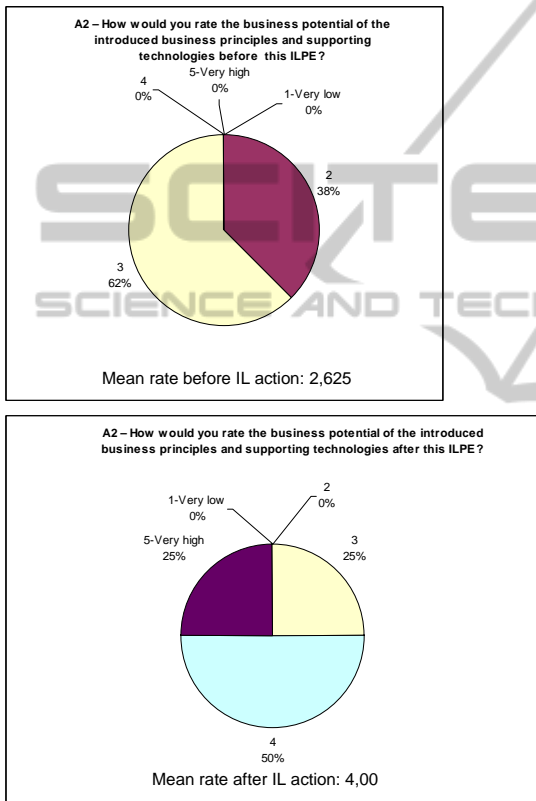

Figure 6: Example of performance indicator estimation.

For each ILPE performance criterion (building block of the learning process), the performance indicators will help measuring in a quantified way the achievement of the respective training goal (Table 3). The performance indicators aim to capture the "contribution" of the IL actions in improving the attitude, knowledge, skills and competence of the trainees with respect to the introduced learning module. Thus, they will measure the "difference" in the levels of attitude, knowledge, skills and competence, before and after the IL action as perceived by the trainees.

$$P = w_A \times A + w_K \times K + w_S \times S + w_C \times C \qquad (1)$$

P: overall IL Action Performance Value
A, K, S, C : overall value of the respective ILPE performance criterion (attitude, knowledge, skills, competences)
$w_{i=A,K,S,C}$: weight assigned to the respective ILPE performance criterion (IL action specific), $\Sigma w_i = 1$

$$A = w_{PIA1} \times PIA_1 + w_{PIA2} \times PIA_2 + ... + w_{PIAn} \times PIA_n \qquad (2)$$
A : overall Attitude Performance Value
$PIA i=1,..., n$: performance indicators of Attitude (A)
$wi=PIA_1,...,PIA_n$: weight assigned to the respective performance indicator (IL action / technology specific), $\Sigma wi = 1$

8 CONCLUSIONS

The generic competence-based IL approach presented in this paper comprises: (i) an IL model which serves to represent and understand competence-based learning, and (ii) a methodology with a number of steps to implement IL in industrial organisations.

The ActionPlanT IL model is competence-based and is suitable for creating new knowledge assets related to "cutting edge" ICTs for manufacturing, identifying corresponding new professional competencies, and defining relevant learning actions to train workers to develop these competencies.

The ActionPlanT IL methodology is developed on the of extensive state-of-the-art and gap analyses in order to propose a comprehensive methodology incorporating the most promising techniques including the emerging ones at each of its steps. The ActionPlanT IL methodology is developed in a way to overcome the weaknesses and fill the gaps of existing learning methodologies.

The novelty of the ActionPlanT IL methodology relates to two aspects: (i) the definition of IL actions using a competence-based IL model, and (ii) the comprehensiveness and the content of the steps of the methodology.

A metrics-based method is developed to evaluate the implementation of ActionPlanT IL methodology. The metrics aim to capture the "contribution" of the methodology in improving the attitude, knowledge, skills and competence of the trainees with respect to the introduced learning topic.

During the implementation of each IL action, the suitability of the delivery mechanism to the learning topic is tested and evaluated and the results are used to improve the choice of delivery mechanisms for learning topics in the forthcoming IL activities.

Among the future research issues related to the work presented in this paper, we can quote:

▪ development of mechanisms and methods to test the suitability of emerging delivery mechanisms to advanced ICT for manufacturing learning topics and learning constraints of the manufacturing labour force,

▪ definition of new ICT for manufacturing skills related to advanced ICT for manufacturing,

▪ development of mechanisms and methods to define learning content for IL curricula from recent achievements of research and innovation actions in the domain of ICT for manufacturing.

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