E-learning Readiness and Absorptive Capacity in the Manufacturing Industry

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***Abstract*—The manufacturing industry constantly strives to develop the competencies of their expert production engineers in order to achieve and maintain a competetive advantage. Research shows that the absorptive capacity of a firm is central in order to reach such a goal. The absorptive capacity is the firm´s ability to recognize the value of new external information, assimilate it, and apply it to commercial ends, and thereby exploit the conditions for innovation. In this paper the concept of absorptive capacity is used as a lens for analyzing managerial rationales for engaging in technology enhanced competence development projects. Through interviews with key informants in 15 manufacturing firms we study the capabilities and readiness that organizations need for participation in e-learning initiatives. We present a framework of readiness for technology enhanced competence development comprised of the following interrelated constructs; awareness, e-learning maturity, dynamic capability and co-creativity. Results show a broad variation of levels within the constructs among the firms. Notable is the low level of e-learning maturity and dynamic capability. We argue that e-learning maturity is dependent on all four constructs.**

***Index Terms*—absorptive capacity, e-learning readiness, technology enhanced competence development, work-integrated learning.**

I. INTRODUCTION

Competence development initiatives within the industrial contexts have widely been researched and reported primarily as success stories [1], [2]. Still, many initiatives fail due to firms lacking capabilities to absorb new knowledge through learning initiatives [3], [4]. This case study draws on earlier studies which show that e-learning initiatives within higher education are more successful than in the workplace [5]. Reasons for this are because other conditions cause dilemmas in the work organization, on management levels, in the user interface and in the system development process [6], [7]. As we shift from traditional educational models in higher education into technology enhanced learning as e-learning courses integrated in the workplace, we need to rethink companies' abilities to gain new knowledge to sustain a competitive and innovative advantage.

Viewing the workplace as a learning arena implies a knowledge-based view of the firm, and also capabilities to manage information and knowledge throughout the whole organization [8]. To clarify the relationship between knowledge acquisition and firm innovation, the concept of absorptive capacity, can be used to define the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends as critical to its innovative capacity [9]. Over the years researchers have reconceptualized and extended their description of absorptive capacity, and also applied it to different organizational contexts or studies of phenomena [10]-[13].

In this paper we build our reasoning on absorptive capacity, and extend the discussion on companies' abilities to learn as crucial for their knowledge creation and innovative capability. We suggest that new constructs will shed light on manufacturing firms' abilities to foresee their readiness for taking part in e-learning initiatives here described as technology enhanced competence development initiatives. Assimilation of knowledge and learning from e-learning initiatives cannot only be understood from a firm's absorptive capacity, but also need to be deliberated with deeper knowledge on what other conditions prepossess learning and knowledge creation [14], [15]. Education supported by information technology (IT) potentially provides employees with new opportunities to learn, and as a consequence formalized education such as e-learning courses in an industrial context is increasing [16]. Accordingly, within the research area of *e-learning readiness*, instruments and criteria to assess a firm's readiness for implementing e-learning have been developed [15]-[17]. These instruments assess a firm's readiness for e-learning participation and implementation. Through a combination of absorptive capacity and organizational e-learning readiness categories together present a framework of constructs that a firm can apply to accomplish a valuable participation through competence development initiatives.

Therefore, the aim is to present a wider understanding of manufacturing industry readiness for e-learning initiatives by combining constructs based on theoretical concepts from absorptive capacity and e-learning readiness categories in relation to a study of 15 manufacturing firms located in the western part of Sweden. We present a reconceptualized framework of constructs that builds on our analysis of qualitative interview data in the case study that is part of the MERIT project. The overall aim of the MERIT project is to design and offer e-learning courses with knowledge content that are co-created between University West and the collaborating manufacturing firms.

In the following section, the perspectives of absorptive capacity and e-learning readiness are discussed. Thereafter the study, including the context, methodology and analytical framework is presented. The final section describes the content of the framework of e-learning readiness in relation to the results from the case study.

II. THEORETHCIAL FRAMEWORK

Production technology is an interdisciplinary field with technical, social, environmental and economic elements that expert engineers in the manufacturing industry continuously should acquire. Consequently, knowledge work within this field is multifaceted and calls for both expert knowledge, and general know-how are necessary [18]. Effective industrial work also emphasizes capabilities to handle diversification of knowledge [19]-[20]. Knowledge to absorb and adopt are of various kinds, within humans and within machines and technology, and thus advanced expert knowledge in engineering work can be explained as systematic comparison undertaken for various reasons [19]. Communicating knowledge is not only a process of transferring information from sender to receiver. Since information flows through different media, and passes through different technologies, on distance, at different times and in various spaces, information tends to differ. This means that information needs to be translated through learning into knowledge.

A. Absorptive capacity

Absorptive capacity was originally introduced, by Cohen and Levinthal, as a concept to label a firm´s capability, "to recognize the value of new information, assimilate it, and apply it to commercial ends" [9], [21]. Absorptive capacity depends on prior related knowledge and diversity background, and therefore the focus on investments in R&D is central for development of the concept. Cohen and Levinthal emphasize absorptive capacity as cumulative, due to that it is more effective for firms to continuously capitalize knowledge instead of making isolated investments. However, R&D not only generates new knowledge for innovation purposes, but also enhances the learning ability of the firm [9].

R&D investments can provide the firm with technological capacities within the organization that also facilitate the assimilation of new knowledge developed in other contexts [22]. The capacity to learn from other firms is also developed and enhanced through in-house R&D activities [22], which is in line with the original Cohen and Levinthal´s concept, that the more a firm invests in R&D, the more it will be able to absorb and appreciate new external information. To develop capabilities for integration and utilization of newly acquired knowledge is therefore accentuated [9].

Absorptive capacity has been re-conceptualized and extended by various researchers, mainly through empirical studies [10]-[13]. Different definitions and outcomes of the original concept have emerged to a heterogeneous variety, both empirically and theoretically [23]. Some research areas that use and develop absorptive capacity are; knowledge management [24], human resources [25], organizational learning [26], the resource-based view [12] and dynamic capabilities of the firm [27]. Most research studies apply absorptive capacity on the organizational level, even if the original concept by Cohen and Levinthal meant that organizations´ absorptive capacity depends on its individual members and with the view of learning as a cumulative process [9].

Zahra and George extended absorptive capacity with a new definition; *"a set of organizational routines and processes by which firms acquire, assimilate, transforms and exploit knowledge to produce a dynamic organizational capability"* [10]. They introduced two dimensions: *potential absorptive capacity;* and *realized absorptive capacity*. The first dimension focuses on acquisition and assimilation of new knowledge, and the second focuses on the transformation and exploitation of capabilities. Regardless of the different use of absorptive capacity mentioned above, this, and other conceptualizations use the concept as a capability to address rapidly changing environments. Barney also relates to capabilities as competences on a higher level that prevail on different individual capabilities, building on each other to yield absorptive capacity, giving the firm a foundation on which to achieve a competitive advantage [28]. Grant highlights that capabilities represent productivity and firm-specific skills, and should also to be understood as *how to* use resources, not only as nonspecific input units [8].

B. Absorptive capacity and case study

From the perspective that absorptive capacity still is a heterogeneous construct, and that available methods are used with diverse operationalization, Duchek presents a more practice-based approach of absorptive capacity [23]. With a critical review of the construct of absorptive capacity, a framework of methods for measuring absorptive capacity is presented [23]. The framework is divided into research studies that perform either *quantitative* or *qualitative methods*. Quantitative methods are classified into studies using indicators or questionnaires.

Studies using *indicators* usually measure R&D efforts and R&D human capital. Limitation of this method is that we cannot assume that the indicators tell us anything about the knowledge absorption process within a firm. Furthermore, studies using *questionnaires* measure mainly absorptive capacity at the operational level, or as multiple components (instruments) of absorptive capacity. These studies are the most common for the construct [10], [13], [14]. Multiple instruments give richer answers of organizations' absorptive capacity as a whole, and are better used than indicator proxies. They are also better suited to capturing and identifying the process of knowledge absorption, and are not limited to input and output variables, though, there are other limitations. Surveys show mainly abstract processes or routines of knowledge absorption, and do not represent absorption in practice in a specific context. Furthermore, Duchek argues that the use of quantitative research methods only visualize standardized and predefined items and new flexible data will easily be missed during the research process [23]. Instead Duchek reports from a German case study where a practice-based approach is outlined that consist of three components: *technology scouting* – a practice of knowledge acquisition; *face-to-face communication* – meetings with intense knowledge sharing; ongoing feedback between partners; and *informal promotion of new ideas* [23]. Accordingly, the practice-based approach of the construct will aid in, open up, and uncover the black box of absorptive capacity.

In this paper we share Duchek´s view [23] in line with other researchers [11], [29]. These authors suggest a broad spectrum of other factors that can be studied by ethnographic methods using observations or interviews. Jones and Craven studied how work routines and organizational activities could grasp the process of how new knowledge was acquired, rather than the nature of knowledge in a manufacturing firm [29]. Their study concluded that to

improve a firm's absorptive capacity development of *new coordination capabilities* that help codify, tacit knowledge is required.

C. E-learning readiness

We define e-learning as learning tools and systems that are intended to serve as a support and stimulus for learning in and between the participating actors, i.e. employees, academic teachers/researchers and other research institutions. Examples of applications and systems that support courses on-line are web meeting systems (audio and video), learning management systems, wikis, and blogs. These applications aim to support communication and interaction through both synchronous and asynchronous systems [30].

Another stream of research is of e-learning instruments that assess firms' readiness for e-learning investments and IT-adoption [15]-[17]. These instruments are mostly developed as quantitative surveys with questionnaires.

As e-learning has become essential when investing in employees learning, it is usually large scale implementation that can cause hurdles [31]. Though, Haney argues for assessment of organizational readiness for e-learning, and has developed 70 questions, divided into seven top aspects involved in e-learning assessment for professional groups in the whole organization [17]. These top aspects are; human resource, Learning Management System (LMS), learners, content, IT, finance, and vendor. The approach to this assessment is performative and system oriented, and can be used to evaluate implementation of any IT system, e.g. enterprise information system. Each question requires managers to choose levels of importance from "not very", "moderate" or "very" important.

Aydin and Tasci present a questionnaire with 83 questions that analyze the resources a firm possesses, and the skills and attitudes of the employees and managers, targeted for Turkish firms (i.e. three constructs – resources, skills and attitudes) [16]. Four factors are correlated with these three constructs: technology, innovation, people and self-development. However, this survey is very similar to Haney's approach, even though learning styles and self-assessment also are included.

Another framework for e-learning assimilation and adoption was recently presented by a Canadian research group [15]. They raise the contradiction between a rapid growth in the e-learning market, and a still slow adoption among firms. The integrative framework they present is therefore built on the need for a deeper insight into sense-making of technological and organizational factors in relation to the e-learning context, and for shaping organizational competencies leading to e-learning adoption and assimilation. They propose that technological and environmental factors indirectly affect e-learning adoption through the effect they have on these factors i.e. organizational structures and information technology maturity.

III. THE STUDY

A. Context in the manufacturing industry

The manufacturing industry faces high pressure from the global market and must adjust the production system to consumer demands. This pressures engineers and industry firms to assess new expert knowledge and adapt to changes that imply short-term flexibility, instead of long-term perspectives [32]. The production system, in general, is highly automated, and most work therefore focus on monitoring and controlling the production system. Engineering work is problem solving, technological development, and continuous improvement, among other things.

An increasingly important topic in engineering research is knowledge of concurrent and complex phenomenon, and also about the development of industrial modeling and simulation [33]. The techniques and the skills required to master the underlying theories are often limited in the industry, while experience-based expertise and practical skills are often high. To be a learning organization with capacities to absorb new knowledge is important to survive international competition. Collaboration between different professions, and skills in the production chain, can reinforce knowledge development, but conditions for this collaboration can also be understood from different angles [34]. Accordingly, when companies are performing challenging tasks, inter-firm collaboration is not always a feasible solution due to inherent risks of bringing out valuable knowledge. Instead, they suggest that knowledge can be found internally through use of technology. This may be true if the firm has high internal knowledge, or an R&D department. Though we believe that interaction between academia and a network of industry have the potential for joint collaboration, where both parties together co-produce knowledge content for expertise and innovation.

B. Methodology

The research case study is part of the ongoing project, MERIT (Manufacturing Education and Research with Information Technology). The research aim is to describe conditions for design and implementation of technology enhanced courses on postgraduate level to support work-integrated learning for employees in the manufacturing industry. The overall aim of the MERIT project is to test that flexible e-learning courses will provide opportunities for the firms to gain new knowledge, and support them as a learning organization. University West, located in the west of Sweden, ran the MERIT project during 2013-2015, and is collaborating with manufacturing industries in the region. Together industry and academia aim to co-produce knowledge in the courses within the fields of industrial automation, virtual manufacturing, robotics and applied simulation of manufacturing processes.

When we appointed informants for this initial case study, our preconception was that perceived management support give better readiness and performance for individuals taking part in e-learning competence initiatives [35]. We wanted to grasp the management view on how different knowledge flows through the organization, and what capabilities for learning and knowledge there are within the organizations.

As a part of other collaborative activities in the study, 16 interview sessions with 15 manufacturing firms were conducted during 2013 (in one firm, two interview sessions took part). The target informants were the top-level production manager (or plant manager) and the top human resource managers, who were interviewed simultaneously in sessions roughly one and a half hours in duration. In total, 30 informants were invited, and among these 27 informants participated. The sessions were carried out as meetings, and a semi-structured interview guide was sent out at least one week before the meeting (see Table 1).

TABLE 1
SEMI-STRUCTURED INTERVIEW GUIDE

Question themes	Question areas
Competence work	Education level among engineers Competence work (individual perspective) Research and development work
Knowledge areas and competence content	Knowledge content need for expert knowledge Critical production processes Competences and education for these areas
IT infrastructure	Organization and implementation of education and training in the workplace Use of web conference systems, e-learning tools for on-line learning and competence networks Use of simulation and or visualization soft-ware's, equipment etc.
Knowledge, learning and education as abilities for innova-tion	Management´s discussions of interrelations between individual competences, efficiency and innovation Organizational learning
Collaboration and co-production of knowledge	Collaboration with the university about possible co- production of knowledge for an engineering master program based on competence needs Organization and implementation of a advanced master program or courses Other external networks for competence devel-opment

During the sessions we discussed what key knowledge within the production field is needed for competence development among experts in the firm in relation to the organization effectiveness, business goals, and innovative capabilities. We also discussed the process of handling knowledge, and the level of readiness for e-learning initiatives integrated in the workplace.

C. *Analytical framework*

A qualitative data analysis approach on the interview data was used [35]. Through an iterative and thematic approach, we identified four constructs that are presented in the framework in Table 2. These constructs are mainly developed from the interpretation of the managers' perceptions, and knowledge of their competence work within their organization. Furthermore, the analysis is informed by concepts from absorptive capacity and e-learning readiness categories [16], [17]. These are re-conceptualized into a framework that builds on our new findings from a process-oriented view on industry firms' readiness for technology enhanced competence development initiatives. The constructs in Table 2 are described and exemplified through excerpts from the data material.

We used three levels of categories for each construct: low, medium and high level of readiness. The results show variations between the firms in relation to these constructs which are presented by figures and quotations in the next section.

IV. RESULTS

Below some basic facts of the firms are presented. Thereafter we describe the different constructs, and their implications in relation to the study.

A. *Basic facts of the participating firms*

Ten of 15 firms are global corporations; the other five are Scandinavian or Swedish firms. All of the 15 firms have a production plant, or an office in the western part of Sweden. A categorization of the firms in terms of number of employees, number of university-educated engineers, type of industry, local or global business, and the presence of their own R&D department is presented in Table 3.

TABLE 2
FRAMEWORK – READINESS FOR
TECHNOLOGY ENHANCED COMPETENCE DEVELOPMENT

Construct	Dimensions
Awareness	• Internal competence mapping (GAP-analysis by HR department) • Define general competence need • Define expert competence need • Define competence strategically in strategic business plans
E-learning maturity	Experience with use of: • IT tools for learning situations • Web conference systems • Learning Management Systems or other social media technology for learning and collaboration Used systems: • Own e-learning platform/education plat-form
Dynamic capability	• To adapt to changes outside the firm like concurrency and knowledge demands • To customize the firm needs to external requirements • To capture organizational learning, both experience based and developmental learn-ing
Co-creativity	• Through collaborative competence initia-tives absorb and integrate industrial and new knowledge • Through networking with higher education institutions and other companies • Through co-creation of knowledge with external partners and use it for effective production and innovation

TABLE 3
BASIC FACTS OF PARTICIPATING MANUFACTURING FIRMS
(IN SWEDEN)

Facts	Firm type/nr of firms
Nr of employees in the manufacturing plants	In the 15 firms a total of approx. 7 200. Two firms with approx. 2 000 (one in aerospace and one in automotive) Two firms with approx. 500 Ten firms with approx. 130-300 One firm with 26
Nr of engineers with an academic degree	In the 15 firms a total of 950, among these approx. 430 are employed by the largest aerospace industry
Branch of industry	Three in aerospace Six in automotive Three in consulting (in both aerospace and automotive) One in medicine Two in other areas
Local or global industry	Ten international corporate firms Three Scandinavian firms Two Swedish firms
Own R&D department	Seven firms

B. *Awareness*

Awareness refers to a firm´s capability to identify and describe internal knowledge need and content, in line with absorptive capacity [9]. The attention to continuously define firm competence needs on different levels, and also

to be aware of and describe expert knowledge needed in critical production, is part of an internal knowledge base. How are firms able to commission the right type of knowledge? What knowledge do the employees have? Many firms ask for the same knowledge areas according to daily production, but what knowledge can a firm capitalize on in the long-term?

Results show that all firms have routines and work flows for internal competence mapping, and can define competence need for operators. Though, only six firms can define expert knowledge on a high level, six firms are on medium level, and three firms were not able to answer the question. These informants' quotations show the variation;

General competence need

High level; "*…in the work performance dialogue, we talk about both formal education and informal learning, how we work with structured work processes (Lean), and then we report in XX's international HR system ... and then we make GAP analyzes at the group level, department level, etc.*" (Manufacturing firm in aerospace, international corp., 300 employees)

Expert competence need

High level; *"We attain the technology management conference in January to see how we can use expert skills ... other activities is the project 'Combination Forces' aiming for meetings between top competences, to build new innovation…"* (Consulting firm in aerospace, 130 employees)

Low level; *"…we are a small unit, so all our skills are critical, it is difficult to have duplicates in such a small organization. When there are problems, we need to call a supplier, so we have the skills outside the plant ...we haven't discussed critical expert skills. At the operator level, there is no problem, but it is harder on the engineering side…"* (Manufacturing firm in automotive, international corp., 130 employees)

Competence development as strategy in business plans

High level; *"…we engage in something called critical and functional competencies… thus we have a mapping within each function. We map our training needs and our activities to close the gaps ... the change process is that we also show the importance of our work with competence challenges ... and continuously we managers request for information internally to strategic goals."* (Manufacturing firm in aerospace, international corp., 2 200 employees)

Low level; *"difficult to get the right staff in the production, in welding jobs... on the other hand, we are not talking so much about organizational learning strategically. We talk about the future, but not stand-alone about competence development in relation to the company development…"* (Manufacturing firm in aerospace, international corp., 180 employees)

C. E-learning maturity

Questions referring to this construct aimed to identify IT, and e-learning, usability and maturity. Also, the internal IT infrastructure for e-learning systems were discussed; which is in line with other authors e-learning measurement tools [16], [17]. Results show that only four companies have a high level of e-learning use including their own e-learning system. Four companies are defined at medium level, i.e. they use some e-learning system but do not have their own system. Seven firms do not regularly use e-learning tools at all for competence development activities.

Experience of e-learning use and own e-learning system

High level; *"… XX Learning Lab and IT is included in our courses. Here, we offer full training concept for business and individual courses… We have chosen to not have any teachers, but our teachers are our own consultants in everyday work..."* (Consulting firm in aerospace, 130 employees)

Low/medium level; *"…we use an internal system for distance collaboration, mostly we use teleconference and just use web conference systems to share displays..."* (Consulting firm in automotive, 130 employees)

Low level; *"… we bring in the teacher, have a center that we use for training, mostly we go away and have education… very little on the web..."* (Manufacturing firm in other branches, 320 employees)

D. Dynamic capability

Dynamic capabilities in the organizational context are complex. Zahra and George describe it as…"we propose a reconceptualization of ACAP (absorptive capacity) as a dynamic capability pertaining to knowledge creation and utilization that enhances a firm´s ability to sustain a competitive advantage" [10]. Other researchers point to a broad set of skills needed to deal with tacit component of transferred knowledge [36], and also to the capacity to learn and to solve problems. Influenced by these definitions, we widened the construct to include the two contradictions; stability on the one hand; and change on the other. Firms can adapt, more or less, to pressure and concurrency in the surrounding world. How inclined they are depends on the ability to adjust to external requirements of market pressure, and to capturing and using new knowledge. How to build knowledge, and at the same time be a flexible organization, varies between industry branches. The first analysis indicates that automotive branches, in comparison with aerospace manufacturers, differ in their abilities to quickly adjust to market pressure and change. The automotive firms in this study seem to be more dynamic and flexible to external pressure than the aerospace firms. Only four firms show high levels of dynamic capabilities. These following quotations illustrate the variations of dynamic capabilities;

Experience based and developmental learning as part of innovative capability

Developmental learning, high level; *"…we discuss a lot about creating innovation and create the right products and production processes..."* (Manufacturing firm in automotive, international corp., 2 000 employees)

Experience based learning, low level; *"… we do not discuss expertise and innovation naturally, I mean what we use the competences for… we might NOT talk about it in that way, rather we talk more about how effective learning we did, in a more reproductive way of learning…"* (Manufacturing firm in aerospace, international corp., 2 200 employees)

E. Co-creativity

This construct refers to collaboration outside the firm, especially with other organizations e.g. research centers/institutes, higher education, and other industry sectors. Co-creation of knowledge is meaningful when the

cooperation is based on differences found between two or more organizations, in which each actor mainly concentrates on its contribution to the project, based on their goals. Herein lie the dynamics, challenges, and potential of collaborative actions conducted in co-creation. There must be trust between the different parties if they will share knowledge, which demands effective co-creativity with the new knowledge all parties will gain. Seven firms are co-creative on a relative high level. These examples give evidence on what we mean by co-creativity:

Co-creation between manufacturing industry and higher education;

High level; *"…when we write the competence plan together. Take it a step further and to have a continuity between our company and your university."* (Manufacturing firm in aerospace, international corp., 2 200 employees)

High level; "*yes last year we lowered production cost with one-third by last year's theses on bachelor level. This year, we the lowered the cost of 450 000 SEK (71 000 US dollars)…"* (Manufacturing firm in other branches, 190 employees)

Medium level; *"I think we need to describe this ourselves first so we can promote it internally, I mean how we work on competence mapping and co-creation of knowledge…"* (Manufacturing firm in automotive, international corp., 2000 employees)

Low level; *"…it is hard with validation of our employees, so we have not been collaborating with the university so much, but the needs we have within production technology must be researched much more in the future…"*(Manufacturing firm in automotive, international corp., 150 employees)

F. Summary of findings

The number of employees with higher education in the firms is generally low; only the largest aerospace firm (2200 employees) has almost 500 engineers with higher education. The other large automotive firm (approx. 2000 employees) only has 50 employees with academic engineering degrees. Their ability to participate in competence initiatives on the university level will, therefore be harder. Thus, the analysis shows that even if most of the firms have a relative low level of formalized highly educated engineers (between 5-10 %), they do have *capabilities for learning*. The level of *awareness* of defining competence needs is high among all firms, but the ability to defining expert knowledge needs is much lower. The *e-learning maturity* also varies. The two largest firms, and the two consultancy firms, have significant e-learning system experiences, and also a high degree of academically educated employees. It could be concluded that highly educated personnel emphasize technology implementation and use.

Another result is that firms within the aerospace sector that do have high competence awareness, their own R&D, are working with competence, and strategically implement competence goals in their business plans, show rather low level of *dynamic capabilities* of quickly adjusting to external market pressures. This is in contrast to the automotive sector that has generally higher dynamic capabilities, meaning that they are faster and more dynamic in relation to learning from external pressures and competition. An explanation could be that aerospace industries usually have long-term orders in a more stable branch; in comparison to the automotive branch. The automotive firms, on the other hand, have a lower level of organized competence work, both for individuals, and strategically in the business plans.

Seven of the firms showed great interest in *co-creation* of knowledge with academia. Among other activities these firms have participated in the co-creation of content knowledge in the first academic e-learning course that took place during April-May 2014, which shows a potential for *co-creativity*.

V. DISCUSSION

As presented in this paper absorptive capacity and e-learning readiness assessment instruments, generally consists of indicators and/or survey questions. Absorptive capacity is mainly applied to an organization's R&D investment's inclusion of innovative activities; such as basic research, adoption and diffusion of innovations, knowledge transfer and status, as well as the overall financial situation. E-learning readiness instruments aim to assess technological-organizational-environmental factors of the whole organization. Since these instruments measure status in the organization, they provide insight and comprehension into *which* routines and processes that exist in firms constitute a propitious knowledge base.

But, the actuality of *how* activities and workflows are acted upon, either in the workplace, or university organizations, versus the depiction of how they are acted upon, will be hard to study from the inside of a firm. Consequently, the same can be said for determining knowledge and learning capabilities. In this study we are exploiting these two research fields to gain knowledge of how to understand the organizational readiness for technology enhanced competence development initiatives. Though we emphasize a qualitative and practice-based approach through the interpretation of industry managers' conversations on competence work and e-learning maturity.

The analyzed framework is not to be understood as constructs that are independent of each other, rather they are interrelated in different modes (Figure 1).

Awareness not only includes competence mapping, but also competence work of how to use individuals' knowledge skills as resources to achieve a competitive advantage [8]. Awareness of how the knowledge acquisition work that is conducted within the firm, can also be considered as a co-creative process. Knowledge sharing between partners and informal promotion of new ideas is a mix of awareness, and the co-creativity of knowledge that strengthens innovative capabilities [28].

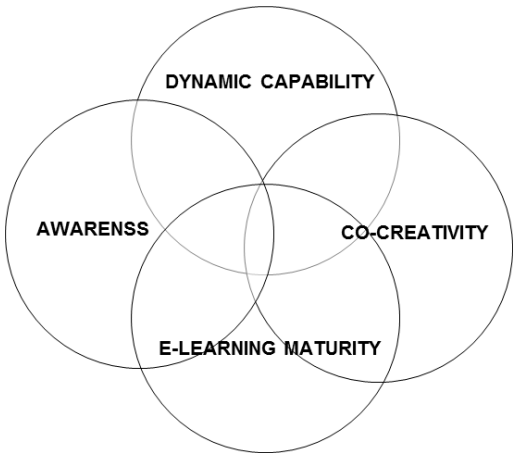

Figure 1. Interrelations between constructs.

Dynamic capability can also be related to both awareness and co-creativity. Managers must support and mobilize internal and external resources to identify, obtain and utilize new knowledge [29]. This process can be explained as a process that includes awareness of internal competence work, support and co-creation of knowledge as capabilities to adapt to changes outside the firm, and to capture organizational learning. But in contrast to co-creativity, dynamic capability is also characterized as being able to act agile with high speed and flexibility to respond to external changes. Though we argue that *co-creativity* is not time dependent. We observe that some firms are highly developed in terms of co-creation networks, but still are less developed in terms of their dynamic capability. This argument is in line with Zahra and George's extended definition of potential absorptive capacity, and realized absorptive capacity [10].

The *e-learning maturity* among the firms is remarkably low; eleven firms have no IT infrastructure for learning, and shows low level of e-learning experience. The readiness for e-learning initiatives conducted in the workplace will therefore call for careful planning and implementation. Furthermore, the firms with low e-learning maturity also show low levels of dynamic capability. Though, they have relatively high level of co-creativity in collaboration with universities. Even though they are not technology ready, their potential for development lies in the intersection between co-creativity and dynamic capability. Through competence initiatives where industry and academia collaborate, the capabilities of technology use has the potential to increase, which also enhances the firms' e-learning maturity. The e-learning courses offered in the MERIT project will primarily use digital media and other production technology systems, such as virtual training tools, so participants can learn and communicate with new distributed technologies [33].

VI. Conclusion

In line with Duchek, and, Jones and Craven, we have used a qualitative approach to our case study aiming at an in-depth understanding of the conditions under which absorptive capacity relates to managers' perceptions of their manufacturing firms [23], [29]. We identified a framework consisting of four constructs through an analysis of the firms' absorptive capacity and e-learning readiness. The framework provides four constructs that collectively explain the e-learning readiness of a firm.

In summary, the results show a broad variation with respect to the constructs. All firms are rated as having a high level of awareness, but only four firms have high level of e-learning maturity; the rest have low. Out of 15 firms, only four show dynamic capabilities. Half of the firms are rated as highly co-creative, but all managers state that they realize that they could benefit from richer co-creative activities, such as technology enhanced competence development projects.

We conclude that, for a firm to have e-learning readiness within the whole organization, all four of the constructs should be on high level. A high level of absorptive capacity and e-learning readiness will constitute a solid foundation for developing technology-enhanced learning for expert engineers.

In conclusion, the framework provides knowledge of the manufacturing industry's e-learning readiness and can inform the design and implementation of e-learning courses conducted in the work.

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