Technology Enhanced Learning in Manufacturing: overview, effectiveness and directions for future research

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Abstract: The increasing skills gap in manufacturing is requiring firms to enhance training strategies in order to maintain their competitive advantage in the modern market. Technology Enhanced Learning (TEL) represents a valuable answer to the problem, giving a unique support both in terms of efficiency and efficacy. Nevertheless, a lot of studies have been focusing on the analysis of the effects of TEL solutions on the Perception and of the Learning of the users, but there are no significant contributions on the comprehension of their impact on the Employee Behavior and on the Organizational Results (according to Kirkpatrick’s four-levels model for training evaluation). In particular, the investigation of the impact of TEL solutions on the performances of manufacturing firms is still completely unexplored. To this respect, in this paper the rationale behind the use of TEL solutions in organizations is explained in detail, as well as its crucial importance for manufacturing domain. Furthermore, the problem of their effectiveness in supporting business results is identified and the potential impact of its better comprehension for manufacturing firms is discussed. Finally, specific directions for future research on this topic are presented.

Keywords: Manufacturing, Workplace Training, Technology Enhanced Learning, Performance

1. Skills gap in Manufacturing

As documented by a survey of over 400 CEOs all over the world managed by Deloitte and the U.S. Council on Competitiveness (2013), talent-driven innovation is nowadays the most important driver of global manufacturing competitiveness. The dramatic importance of the human component for the prosperity of future manufacturing has been also highlighted by McKinsey&Company (2012), which identifies the building of innovative workers’ skills as one of the four key areas to focus on for the empowerment of manufacturing.

Unfortunately, even though manufacturing is still suffering the consequences of a severe crisis, it is facing more than other sectors a deep skill shortage from different perspectives (Perini, et al., 2014), i.e. the countries, facing high unemployment rate despite the increasing number of employers reporting difficulty in filling manufacturing jobs (World Economic Forum, 2012); the different functions within a single organization, with the engineering/technical ones among the most affected (Economist Intelligence Unit, 2012); the educational attainments, with a more critical shortage of high-skill and medium-skill workers rather than low-skill ones (McKinsey & Company, 2012).

The root causes of the skills shortage identified have been widely explored both in literature and in practice, leading to the identification of different elements, e.g. an aging workforce, an outdated strategic workforce planning, a limited efficiency of life-long learning, a poor perception of manufacturing among the young generation, the volatility and rapid transformation of work (Skevi, et al., 2014). According to these factors, the solution to the skill paradox identified above can be found in two possible complementary strategies, i.e. an “external” one, based on the increased recruitment of the brightest young talents to manufacturing, and an “internal” one, based on the development of the new interdisciplinary competencies requested to the current workforce by the market. Both strategies should be considered by manufacturing firms as a priority to maintain and improve their competitiveness in the modern market (Skevi, et al., 2014).

In the light of this situation, it is evident how proper managerial solutions should be implemented in order to address the issue. In particular, when focusing on the “internal” strategy, among the several actions available one of the most powerful is evidently the continuous training of the current workforce (Stuart & Dahm, 1999). Anyway, traditional manufacturing training is nowadays still deficient in providing the right solution to the skills gap identified above, both in terms of ease of access and engagement of the employees to be trained, this resulting in the long term in a serious lack of improvement of the performances and eventually of economic growth (Deloitte, 2007). The present problem is then even complicated by the increasing diffusion of complex technologies (e.g. CNC machine tools, CAD/CAM programs, robotics) that require to the workers a rapid and continuous update of their competencies (Davenport, 2013).

2. Technology Enhanced Learning (TEL)

It is evident that the points identified highlight serious difficulties in manufacturing training both from an efficacy and an efficiency point of view (Deloitte, 2007). As a consequence, a possible solution to those questions has been found in the last years for manufacturing as well as for many other sectors (e.g. banking, healthcare, higher
education) in the pervasive use of ICT technology to support and deliver the training (education) of employees (students) in organizations (Song, et al., 2010). The widely recognized advantages of such kind of approach are indeed both pedagogical and practical. Indeed, in synthesis the use of ICT technology for training has four strengths points. First of all, it can reproduce the ideal conditions of several practices of good teaching in a controlled environment, allowing e.g. small group tutorial discussions, the exchange of realistic feedback on actions and the collection of learner performance for the definition of the best following educational step (Laurillard, 2008). Second of all, it can enable economies of scale, facilitating e.g. the accessibility to tutor’s answer, the identification of common problems and the consequent reproduction of common valuable explanations (Laurillard, 2008). Third of all, it can facilitate the creation, reproduction and continuous improvement of a wide range of content, made available in its turn by means of a great variety of delivery mechanisms (Laurillard, 2008). Finally, it allows the possibility to learn abstract concepts that “are not otherwise directly available to the senses” (Goodyear & Retalis, 2010).

The great variety of delivery mechanisms is a distinctive feature of ICT-based education and training. Under the term “Technology Enhanced Learning” (TEL) a lot of different solutions have been developed, implemented and studied in the past years (Pange & Pange, 2011). With no claim of completeness, we can cite among the others adaptive intelligent tutoring systems, conversation agents, haptic devices, virtual objects, simulations, serious games, virtual and augmented reality applications, collaborative technologies, multiplayer virtual worlds (Laurillard, 2008). Even if there is no common definition or understanding of the concept of TEL in literature, we can reasonably consider it as the extension of the original term “e-learning” (i.e. the use of electronic technology for education and training) with the addition of further elements of interactivity and engagement of the user. Hereafter we will hence consider the general term “e-learning” as included in the more advanced one of TEL, which we can assume as its progressive evolution.

It is some years that researchers have been addressing the problem of understanding the potentialities and limitations of TEL solution in organizations but, at the moment, there are still several dark areas that have not been understood yet in detail. This is mainly due to the fact that the practice of TEL and its applications is nowadays faster than the underpinnings scientific results. As a consequence, it is at the moment quite unrealistic to achieve common accepted knowledge about TEL solutions before their effective implementation in organizations in order to solve specific issues (DeRouin, et al., 2005). Nevertheless, the deep understanding of how TEL interacts with individuals and organizations is fundamental in order to improve its impact on processes and activities (Macpherson, et al., 2005). It is in fact for the final aim of organizational success that TEL solutions should be used for the training of workforce, in manufacturing as well as in the other sectors (Bersin, 2005).

3. Technology Enhanced Learning in Organizations

Currently, several problems related to the design, implementation and use of TEL solutions in organizations can be identified.

There is now common agreement in scientific community that the focus on the learner should have the priority on the focus on the technology (Wisher & Curnow, 1999) (Allen, et al., 2002). Indeed technology should be considered only an enabler facilitating the process of learning (Laurillard, 2008). On the other hand, at the moment there is no common theory widely accepted to represent the underpinnings for TEL design, even if is proved that consolidated learning theories should drive that process (DeRouin, et al., 2005). Therefore, even though the research in this sense should still make considerable progress (DeRouin, et al., 2005), different learning theories are reported in literature as suitable basic blocks for the progressive definition of an integrated framework for learning with ICT, e.g. the behavioral/objectivist theory, the collaborative/cooperative theory (Salas, et al., 2002), the cognitive learning theory (Clark & Mayer, 2003).

Complementary to this research strand about TEL learning theories and design there is another one trying to address from a more operating perspective the principles and best practices for the development of effective TEL solutions. A point of view that has been adopted in such kind of analysis is the study of the differences between classic classroom-based and TEL environments (Brown & Ford, 2002). Elements of discussion in such kind of perspective are mainly the changed role of the teacher/mentor, the understanding of the progress of the learner, the optimal “blended-learning” equilibrium (i.e. the balance between traditional and ICT-based training) and the collaborative aspects of learning with technology (Brown & Ford, 2002). Another perspective is represented on the other hand by the definition and development of specific “design patterns”, i.e. solutions “to a recurrent problem, in a context” as defined by Goodyear and Retalis (2010) basing on the seminal work by Alexander et al. (1977) in architecture. The main purpose of that approach is the systematic identification of the features that allows ICT to actually support education and training (Becker, 1994). In this area, several elements are being addressed by researchers, e.g. the user’s perspective, understanding the dynamics of motivation to learn (Dernstl & Motschnig-Pitrik, 2010), the influence of social interactions (Winters, et al., 2010), the representation of practice (Conole & Jones, 2010), the alignment with organizational structures (Zeniós & Smith, 2010).

Different studies have been done over the last years about the implementation of TEL solutions in organizations. From this perspective, two different research problems can be identified. The former is about the understanding of the organizational “background” where the given TEL solution is going to be implemented, addressing in particular the topics of absorptive capacity and e-learning readiness. The latter is about the analysis of the technological and human barriers to the successful implementation of TEL.
The absorptive capacity of organizations is not specific of TEL studies but is a general concept which represents the “ability to recognize the value of new information, assimilate it and apply it” (Cohen & Levinthal, 1990). This fundamental feature of the organization should be obviously taken into account when studying the implementation issues of TEL solutions, because they help the understanding of the initial situation of the environment, thus influencing the final benefits of the system (Martin, et al., 2003). When talking more in detail about TEL, absorptive capacity should be then associated to the concept of e-learning readiness, i.e. the capability of an organization of exploiting the potential benefits coming from the use of e-learning education and training solutions (Hakan Aydin & Tasci, 2005). Many attempts have been already done in order to provide decision makers with powerful tools for the assessment of that specific feature (Haney, 2002), trying to avoid high investments in infrastructures that might demonstrate not to have the hoped effects.

The analysis of technological and human barriers to the implementation of TEL is well documented in literature, both from the individual and the organizational point of view. Those barriers are only rarely distinguishable between pure technological and human factors and hence can be usually integrated together and resumed in the following elements, i.e. costs (Georgini, et al., 2013), lack of knowledge in potential usage (Georgini, et al., 2013), lack of structure for peer interaction (Obikwelu & Read, 2012), information overload (Sutherland, et al., 2012), inadequacy of social technologies (Knight, 2009), wrong attitudes of organizations (Merchant, 2012), dealing with big data (Fitzgerald, 2012), lack of interoperability (Goktas, et al., 2013), lack of standards (Spada, et al., 2012), lack of knowledge in using devices (Ozuorcun & Tabak, 2012).

Also the study of all the possible applications of TEL solutions in organizations is receiving a lot of attention. The specific purposes of TEL have been resumed in a comprehensive way by Goodyear and Retalis (2010) in the following main points:

- TEL as media for accessing and studying learning material (e.g. Learning Management Systems (LMS), Learning Objects Repositories (LOR))
- TEL as media for learning through inquiry
- TEL as media for learning through communication and collaboration (e.g. Computer-Supported Collaborative Learning systems (CSCL))
- TEL as media for learning through construction
- TEL for learners’ assessment
- TEL for digital and multimedia literacy (e.g. video editing and annotating, image processing)

Furthermore, also the synergy of TEL with existing technologies has been investigated, especially for business environments. To this respect, potentialities to be better exploited should be searched among the others in the interaction with Knowledge Management Systems (KMS) and Competencies Management Systems (CMS). In the first case, it should be still clarified how to integrate TEL with KMS, allowing a more efficient transfer from individual to organizational learning (Charti, et al., 2012). In the second case, more research should be done on how to align TEL and CMS in order to empower the Human Resources Management (HRM) practices in companies (Cerovsek, et al., 2010). Moreover, it is still object of discussion what kind of competencies can be effectively improved thanks to TEL solutions. Even though the detailed harmonization of ICT-based delivery mechanisms and development of competencies seems to be a tricky task, there is still evidence to be collected about the more effectiveness of TEL for training hard rather than soft skills (DeRouin, et al., 2005).

4. Effectiveness of Technology Enhanced Learning (TEL) in Organizations

The effectiveness of TEL solutions both at the individual and at the organizational levels is still one of the biggest issue to be addressed by research. As already mentioned above, the practice of TEL is at the moment more advanced of the related theoretical findings, and therefore even though several implementations of those kind of systems have been reported, further evidence should be provided about the advantages of TEL over traditional training approaches in organizations. In order to understand more in detail the problem highlighted, the general Kirkpatrick’s (1976) four-levels model for training evaluation can be used (Arthur, et al., 2003) (DeRouin, et al., 2005). The four levels of the model are Reaction, Learning, Employee Behavior and Organizational Results, from the most immediate to the most elaborated. The first level (Reaction) represents the perception of students/workers about the training received. The second level (Learning) represents the increase in knowledge/skills usually verified by means of tests. The third level (Employee Behavior) represents the transfer of the knowledge/skills acquired during training to the job, usually verified by means of employees’ performances measurement. The fourth level (Organizational Results) represents the final outcome of the training intervention, usually measured in terms of money and/or improvement in organizational performances. It is evident how this last level should represent also the final objective to be pursued by organizations willing to have benefits from the training of their students/workforce (Tate & Klein-Collins, 2004).

A lot of efforts have been done so far in order to explore the effectiveness of TEL solutions on the Reaction and Learning levels of the Kirkpatrick’s model (DeRouin, et al., 2005). In particular, the evidence suggests that the Reaction of users when using TEL widely vary from one experience to the other, even though reactions of workplace employees seem to be more positive than the students’ ones. Also for the Learning level the several studies that can be found in literature suggest that definitive answers about the less or more effectiveness of TEL methods over traditional training ones can be hardly...
formulated. Anyway, once again results from workplace settings are more encouraging than studies from educational settings (DeRouin, et al., 2005).

On the other hand, very few studies can be found about the effectiveness of TEL on Employee Behavior and Organizational Results. This is true for TEL but even for traditional training programs (Van Buren & Erskine, 2002). This fact support the idea of the extreme difficulty to come to established systems of measure for that kind of purposes, both in traditional and TEL-based training settings (Kirkpatrick & Kirkpatrick, 2005). At this point, two very important topics concerning TEL in organizations can be defined. First of all, the understanding of the impact of TEL on Behavior and Organizational Results, both in terms of dynamics and specific metrics to be used. Second of all, the understanding of the relationships among the four levels of Kirkpatrick model when using TEL for workplace training.

The impact of training on Behavior and Organizational Results is being studied both from the traditional and the TEL-based point of view. Regarding the latter, specific research has tried to address the problem of the transfer of training, i.e. the extent to which workers actually apply the knowledge/skills achieved by means of a training intervention to real situations (Wexley & Latham, 1991). According to the literature review, very few studies have been done so far on the effects of TEL on Behavior. Among the others, the ones of Gopher et al. (Gopher, et al., 1996), Whetzel et al. (Whetzel, et al., 1996), Thomson NETg (NETg, 2003), Skillsoft (Skillsoft, 2004), Park and Wentling (Park & Wentling, 2007) can be cited. In particular, the last research is recognized as to be one of the first attempt to study the particular factors related to transfer of training in TEL environments. Furthermore, even less studies about the effects of TEL on Organizational Results are present in literature. Some attempts are represented by those of O’Leonard (O’Leonard, 2004), Hockstra (Hockstra, 2001), Overton (Overton, 2008). Unfortunately, they mainly represent reports of strategies ideated by companies rather than rigorous concepts. According to the just mentioned results, it appears that TEL can effectively have a positive effect on both Behavior and Organizational Results. Anyway, the clear relationship between the specific features of TEL and those two levels as well as the definition of consistent methodologies to formalize it are still far to being fully understood.

The study of the relationships among the four levels of Kirkpatrick model has received a lot of attention from traditional training’s research. There is currently common agreement in literature about the poor correlation between Reaction criteria on one hand and Learning, Behavior and Organizational Results criteria on the other (Noe & Schmitt, 1986) (Alliger, et al., 1997) (Colquitt, et al., 2000) (Arthur, et al., 2003), while Learning is considered to be a necessary step in order for training to have an impact on Behavior (Tannenbaum & Yukl, 1992) (Arthur, et al., 2003), even though this link has not been completely demonstrated yet (Alliger, et al., 1997) (Colquitt, et al., 2000) (Arthur, et al., 2003). Indeed when passing from Learning to Behavior, the abovementioned problem of transfer arises, with complex environmental elements influencing the linearity of the relationship (Quinones, 1997) (Arthur, et al., 2003). The issue is evidently even amplified when establishing the link between Behavior and Organizational Results criteria. On the basis of this, further research has been then conducted on the specification of the problem identified when addressing the particular features of TEL-based training. This strand of research has been trying to understand the similarities and the differences with the traditional training’s one in the comprehension of the problem of transfer and in general of the correlations among the four levels of Kirkpatrick’s model, developing in parallel original contributions. Even though there are in literature some valuable specific works (Wang, et al., 2007) (Tzeng, et al., 2007) (Roca & Gagné, 2008) (Chao & Chen, 2009), clear and systematic answers to the problems just identified have not been provided yet.

5. Technology Enhanced Learning (TEL) in Manufacturing

As already highlighted, Manufacturing is suffering a severe skill shortage (Perini, et al., 2014) and, among the different possible solutions available, training is widely recognized as the most powerful strategy to mitigate the “internal” issue, i.e. the need for the rapid and efficient development of competencies requested to the current workforce by the market (Skevi, et al., 2014). Anyway, because of the increasing problems of ease of access and engagement of the employees as well as the fast diffusion of complex technologies that require to the workers a continuous update (Deloitte, 2007) (Davenport, 2013), it is some years that Manufacturing training is discovering the benefits of the use of Technology Enhanced Learning (TEL) solutions (Song, et al., 2010). The specific advantages of TEL-based training have been already identified and can be resumed in the following four points, i.e. the reproduction of ideal conditions for learning (Laurillard, 2008), the economies of scale (Laurillard, 2008), the facilitation in the creation and reproduction of content (Laurillard, 2008), the possibility to plasticly represents abstract concepts (Goodyear & Retalis, 2010).

The use of TEL for training of the workforce has had in the last years a great diffusion in Manufacturing (Cerinsé, et al., 2013). Among the solutions investigated, visual learning, ubiquitous learning, virtual reality, augmented reality, serious games, simulations, authoring systems, multiplayer virtual worlds, learning management systems can be mentioned (Intelligent Manufacturing Systems, 2010) (O’Sullivan, et al., 2011). Anyway, the formal study of TEL in Manufacturing is still far behind its actual practice and, therefore, it has even more dark areas than the ones identified addressing TEL in organizations (Hattinger, 2014). In particular, when talking about the specific problem of effectiveness, the lack of commonly accepted answers is extremely high.

Nevertheless, the understanding of the effectiveness of TEL-based training could give to Manufacturing firms an extremely powerful tool to evaluate the benefits of the
introduction and/or upgrade of TEL solutions, whose use is increasing exponentially in these years according to the motivations analyzed above (Capuano, et al, 2008) (Kiritsis, et al., 2013). Indeed it is important to underline that the final objective of a firm is always the improvement of its business results and hence under this perspective also the use of TEL for workforce training should be motivated accordingly (Bersin, 2005). Therefore, it becomes of great importance for Manufacturing to understand in detail the effective impact of TEL on Employee Behavior and Organizational Results (Kim, 2011), and analyzing in particular the peculiarities of this sector, linking the use of TEL solutions to industrial-specific performances.

Unfortunately, to our knowledge this fundamental aspect, as well as the interrelations among the four levels of Kirkpatrick’s model, is for TEL-based training in Manufacturing sector still completely unexplored.

6. Directions for future research

According to the findings of the literature review, some specific patterns for future research in the field of TEL applied to manufacturing can be outlined.

First of all, the relationship between the use of TEL solutions and the effective Behaviors of the employees in the workplace should be investigated (i.e. third level of the Kirkpatrick’s model). In particular, evidence of the mid and long term impact on the performance of individuals and teams should be collected.

Second of all, also the relationship between the use of TEL solutions and the Organizational Results of manufacturing firms should be clarified (i.e. fourth level of the Kirkpatrick’s model). Among the others, the estimation of the Return On Learning (ROL) of TEL in terms of investment can represent a step further in this direction.

Another issue that complements the previous ones is then represented by the identification of the criteria able to explain the link between TEL solutions and the performances of manufacturing firms. Furthermore, the relationship between the levels of Perception and Learning and the effects on the performances should be made evident, understanding to what extent these first two levels can be regarded as predictors of the following two (i.e. Behavior and Organizational Results).

Moreover, it is evident that the concepts of e-learning readiness and absorptive capacity of the organization should also be taken into account. Indeed, they represent variables that can influence the abovementioned elements. Finally, as already identified, the concept of TEL includes a wide range of delivery mechanisms, whose specific effects could be also isolated and specified, thus providing a comparative explanation of the particular advantages and disadvantages of each technology for manufacturing firms.

7. Conclusion

In this paper, the increasing problem of skills gap in manufacturing has been presented as well as the two possible strategies (i.e. the “external” and the “internal” one) that can be adopted to mitigate it. Subsequently, a solution supporting the internal strategy has been identified in the use of ICT technology to deliver the training of employees in organizations. Therefore, the features, advantages and open issues of TEL in organizations have been identified, focusing on the study of its effectiveness on the Employees Behavior and Organizational Results (i.e. levels two and three of the Kirkpatrick’s model for training evaluation). To this respect, the importance of linking its use to the actual performances of individuals and organizations has been highlighted. On this basis, the specific importance of TEL solutions for manufacturing has been made evident, as well as its increasing diffusion in this industry. The big gap between practice and theory in the use of these applications in this domain have been also pointed out, and the problem of the effectiveness of TEL has been identified as even more critical for manufacturing. Indeed, the potential impact of a better understanding of this topic has been underlined. Finally, according to these findings, directions for future research in the field of TEL applied to manufacturing have been listed, reiterating once again the importance of effectiveness at the Behavior and Organizational levels.

8. References


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