Information Sharing to Transformation: Antecedents of Collaborative Networked Learning in Manufacturing

Wee Hock Quik, Nevan Wright

Abstract—Collaborative networked learning (hereafter CNL) was first proposed by Charles Findley in his work “Collaborative networked learning: online facilitation and software support” as part of instructional learning for the future of the knowledge worker. His premise was that through electronic dialogue learners and experts could interactively communicate within a contextual framework to resolve problems, and/or to improve product or process knowledge. Collaborative learning has always been the forefront of educational technology and pedagogical research, but not in the mainstream of operations management. As a result, there is a large disparity in the study of CNL, and little is known about the antecedents of network collaboration and sharing of information among diverse employees in the manufacturing environment. This paper presents a model to bridge the gap between theory and practice. The objective is that manufacturing organizations will be able to accelerate organizational learning and sharing of information through various collaborative approaches. Further, Goodyear et al. [8] refine collaborative learning as a mean to promote interactions between one learner to another; between learners and content experts; between a learning community or workgroups and its learning resources using information communications technology (ICT). In every sense, CNL is a network that is largely autonomous, geographically distributed and heterogeneous, yet it is capable of collaborating complex information to achieve compatible goals [9]. Employees use CNL to proliferate and transform organizational knowledge and learning. This is consistent with Findley’s underlying premise of CNL which is based on consensus among members of a group who mutually search for a general understanding on problem resolutions, product or process knowledge, systems and tools [10].

II. LITERATURE REVIEW

A. What is Collaborative Networked Learning

Collaborative learning is not CNL. While collaborative learning addresses pedagogical issues in educational research, CNL’s primary focus is in organizational learning and sharing of information, which addresses the process of knowledge acquisition and transformation. In CNL, employees develop and maintain shared conceptions of a subject matter [4], then move swiftly to integrate each other’s perspectives and ideas to make sense of a task [11], build new set of knowledge and solve problems [12],[13]. Learning has since evolved from the emphasis on formal training to the experiential learning that is fundamental in CNL. The implementation of lean manufacturing, for instance, has made it necessary for the integration of learning in manufacturing [14],[15].

Some scholars use the term cooperative and collaborative interchangeably to mean employees working interdependently on a common learning task. However, there must be a clear epistemological distinction [16],[17]. Cooperation is accomplished by the division of labour among employees, as an activity where each person is responsible for a portion of the problem solving, whereas collaboration involves the mutual engagement of participants in a coordinated effort to solve the problem together [4],[5]. Both differ by the way in which the task is divided as Camarinha-Matos and Afsarmanesh define cooperation as the aggregated value of the addition individual components each performs part of the job in a quasi-independent manner [9]. In contrast, collaborative shares risks, resources, responsibilities, and rewards in seeking divergent insights, through spontaneity and in an unstructured joint accord [9].
Cooperative learning is not always being embraced because it challenges the established notions of expertise, working identities and relationships based on traditional hierarchies of knowledge [18]. Webb and Palincsar summarize it to say work is ‘cooperation based’ if members shared a divided workload, or ‘collaboration based’ if members develop shared meanings [19]. Knowledge does not necessarily accrue to any individual employee. Instead it is widely distributed across the networks and CNL promotes interaction and sharing of information among diverse members of the manufacturing community.

B. Research Streams in Collaborative Learning

Doherty and Shani identify four broad streams in collaborative research, namely work organization stream, organizational learning stream, learning at work stream and organizational design stream [14]. The work organization stream focuses on organizational workgroups that would enable self-management [20],[21]. Manufacturing is shifting towards greater interdependence among individuals and workgroups to create collective and synergistic products through CNL. The organization learning stream however, addresses the depth and character of the learning process [22],[23], which may be acquired through evaluation, study, experience and innovation. Research approaches such as these examine the conditions under which effective collaborative knowledge building is achieved [24]. Learning at work stream evolved from the emphasis on formal vocational training milieu to the experiential learning of employees and workgroups. Research in the organizational design stream believes that conditions for learning need to be designed and not left to emergence [25]. Others like Cullen et.al [18] and Fuller et.al [26] consider wider span of studies that include regulatory, sectoral environment and characteristics of the operations, e.g. different market conditions, regulations and technology that may influence the way organizations engage with collaborative learning.

C. Collaborative Technologies

CNL leverages on computer technology to provide analytical capabilities, interactivity, and networking support and to organize geographically dispersed teams [27],[28]. In addition, Zakaria, Amelincks and Wilemon in their study on global virtual teams describe how the heterogeneous workgroups used synchronous and asynchronous technologies to collaborate to increase participation and collaboration [29]. The choice of use between synchronous and asynchronous depends on the needs and the stage of collaboration. According to Wasson, before embarking on a project task, the rate of synchronous meetings and frequency of communication were higher than post decision [28]. The asynchronous nature of the post decision work only takes precedence after the need for synchronous meetings had diminished, or members had been reassigned to their respective area of responsibility. It then transforms into more of a cooperative, rather than a collaborative form of work.

D. Asynchronous CNL

Asynchronous communications are more frequent than synchronous because of its flexibility [30] and it does not require employees to be communicating at the same time or in a same workspace. Coordination in asynchronous CNL involves offline data transmission and storage of information, records of interactions and collaborative outcome [31]. This includes use of emails, electronic bulletin boards, wikis, newsgroups, SharePoint, Lotus Notes/Domino, podcasts and discussion forums. Other office applications (including word processor, spreadsheet and presentation) enable CNL with the support of co-authoring and document sharing over the network using Office Web Apps, Google Apps and OneNote to work virtually anywhere with supported browser. While asynchronous computer mediated communication (CMC) tools allow employees to focus on more important tasks and provide freedom to initiate, it poses problem of getting timely information [32]. On the other hand, employees can hold focused discussion with asynchronous conferencing systems about specific issues [33],[34], schedule activities on group calendars [35], track activities through workflow systems [36], post and retrieve documentation comprising a repository of organizational memory and expertise through hypertext [37]-[39]. The enormous capacity and potential in asynchronous CNL are evident.

E. Synchronous CNL

Synchronous CNL has the capability to contract time which makes it particularly appropriate for tasks that require interactivity, spontaneity, and immediate decision. Synchronous CNL also provides a sense of immediacy and communicative presence and offer both intellectual and emotional support to workgroups [40]. Synchronous CNL occurs when single or multiple parties exchange information concurrently. This would include real-time chatting, exchange of information through group interactive sessions like instant messaging (IM), Microsoft’s NetMeeting, audio-video conferencing like Skype and webcast. Other systems which support real-time collaboration include application sharing, groupware, and online presentation tools. While these systems encourage interaction, they also enable sharing of vital expertise through conversation and discussion [41]. Web conferencing is a powerful tool which provides a platform for geographically dispersed workgroups or virtual teams to collaborate, and exchange of ideas and information. Others using synchronous CNL in the virtual help centres, customer support representatives or helpdesk technicians could remotely collaborate, using chat, email, discussion list, or screen sharing to assist and support customers and employees in their homes and offices, taking advantage of the “anytime”, “anywhere” characteristics of the Internet [42].

F. Application of CNL

The needs to adopt CNL in manufacturing organizations arise from three broad trends: 1) widespread interest in organizational learning, 2) the present commonplace use of
ICT for training, and 3) the ubiquitous presence of workgroups within the organization [43]. These contentions are well supported by many studies which conclude that CNL enables organizations to adapt and respond to global demands for rapid change and greater agility [44]-[47]. In the case of product life cycle (PLC) management, employees interact in dynamic virtual teams for the entire phases from product conceptualization, design, build and servicing [48]. Appropriate manufacturing operations can be assigned to the designated personnel or to the best interest of the virtual consortium [49]. In other words, CNL accelerates product realization by reducing developmental costs, improves organizational performance and responsiveness to market needs.

Virtual teams’ collaborations focus on experiential learning that facilitates sharing of knowledge between employees and workgroups [50]. It also helps to develop a culture that fosters learning and open sharing of knowledge and innovations. Best practices and transferable processes can be effectively proliferated across the globe, creating new standards and leveraging successes from other organizations or subsidiaries. Learn by doing and guided methodology for problem solving could transform organizational knowledge [47]. For instance, CNL allows geographically dispersed employees and workgroups to document, disseminate and share product information such as product schematics, bill of materials (BOM) and technical specifications in the networked environment. Product design and modelling workgroups could work concurrently in the design and analyse the workflow [49]. With global virtual teams, operating cost are further reduced due to cost saving in travelling, relocation and avoid expatriation assignments [51].

On individual perspective, employees are concerned about the needs to acquire new sets of knowledge and skills to improve and to simplify their work processes, increase productivity and to reduce costs of reworks [47]. According to Daradoumis and Marquès, it creates the potential for cognitive and metacognitive benefits [52]. It reinforces and improves learning of the subject-matter and engages employees in the learning process. Likewise, employees who are trained on how to use of collaborative tools are able to form new knowledge, enhance their problem solving skills and innovations [47]. CNL also leads to extensive learning opportunity and development in communication and sociotechnical skills.

The issue for discussion is what are the significant antecedents for a Collaborative Networked Learning (CNL) model in manufacturing? Other secondary research questions include: How significant are the relationships between CNL and organizational support, positive interdependence, promotive interaction, and internal-external learning? What is employees’ perception of CNL usefulness and effectiveness in manufacturing?

III. THEORETICAL MODEL

The model below provides a framework for the study of relationships between the independent variables and dependent variable CNL which will lead to the determination of the antecedents for CNL, as depicted in Fig. 1.

A. Organizational support

A support system is part of the organizational infrastructure that facilitates the necessary processes to manage, control, coordinate and improve work [53] which must be aligned with the organizational design [54]. Ideally, employees are self-directed and the organization would support their employees’ learning goals and engagement with others in the learning networks [26],[55]. Therefore, perceived organizational support are positively related to self-efficacy and motivation to learn [56] and strongly associated with affective commitment [57]. The organization is just as important in determining different forms of knowledge creation, and it influences different forms of learning. Conversely, developing a training system, without organizational readiness and support may lead to failure [58]. Organizational support is deemed to be critical for positive CNL outcomes by providing ample opportunities for diverse employees to engage in collaborative work and learning. The greater the extent to which employees perceived that the organization or management is providing support, the more the employees are willing to learn through collaborative network.
**B. Interdependence**

It is not unusual for manufacturing organizations to be segmented into functional workgroups. However, as operational issues become more specialised and complex, solutions will require interdependence on others in the organization. Task interdependence may be embedded in the jobs [59] and required contributions from multiple employees [60]. Positive interdependence also relates to the attainment of individual goals to the success of others in the workgroup [61]-[64]. Moreover, a highly interdependent task would require members of the team to work collectively in meeting the project’s requirements. Task interdependence increased as the work become more complex and requires assistance and support of others [59]. Many studies are focused on self-managing teams, virtual global teams and other cross functional teams in support of joint quality improvement, efficiency and product development that require some form of interdependence for the workgroups to succeed in their goals.

Interdependencies may shift from communication networks, to collaborative networks involving joint technology development or innovation projects with customers, suppliers and partners [65],[66]. In every sense, building a CNL system requires employees to think in terms of organized networks of mutual interdependence and to overcome individual differences [67]. “When goal, task, resource and role interdependence are clearly understood, employees realize that their efforts are required for the team to succeed”[68]. Positive interdependence facilitates the development of new insights and discoveries through promotive interaction [69]. Employees whose job requires less input from others, requires less information access than those who do [70].

**C. Promotive interaction**

Social interaction is the key element in CNL; if there is no interaction then there is no real collaboration [71]. Promotive interaction means close, usually synchronous, purposeful activity and joint decision making [61], where employees participate in workgroups to complete their tasks and goals [68]. Kreijns et al. argue that interaction between the workgroups members will not automatically occur just because the technology used allows social interaction [63]. For CNL to occur, both action and interaction need to be well coordinated within the shared workspace in the manufacturing network. It has to be a deliberate planning by the management or organization to promote interaction. In a review of 168 studies between 1924 and 1997 by Johnson, Johnson and Smith, cooperation among learners improved learning outcomes relative to individual work across the board [72]. Their finding is further supported by Springer et al. review on 37 studies of students in science, mathematics, engineering and technology [73]. Engeström explains that through collaborative activities, employees can focus on re-conceptualizing their own interaction system to create new motives and artifacts [74]. Even interactions with computer-supported social networks [75] should be considered as strong interactive. In addition, effective collaboration increases interconnections between organizations [76], increases interactions [77] and foster learning among employees.

**D. Internal-external learning**

The goal of empirical research is to establish whether and under what circumstances collaborative learning was more effective than learning individually [12]. In a networked organization, the primary activity is participation in collaborative process of sharing and distributing expertise [78]. Effective internal learning requires skill in conducting self-appraisals; ability to use appropriate learning standards and curricula; reflecting the assessment of events and personal goals; and willingness to change learning strategies [79]. However, in a study of dry stone walling by Farrar and Torrey, it was the cooperation and learning with others that was crucial to the success of the learning process [80]. There are cases where employees act as mentors to others and help other employees to see possibilities that were previously inaccessible [58],[81].

Network scholars agree that innovation is a complex process which may require information flow between organizations and employees [82],[83] and innovation could only happen through interaction with external factors [84]. External sources of knowledge are critical to the innovation process and most innovative ideas are learned from either competitor, developers, partners or suppliers. According to Cohen and Levinthal, the ability to learn from external knowledge is mainly a function of skills, language and knowledge of most recent scientific or technological development in the field [85]. This is particular prevalent in technological driven manufacturing organizations that are dependent on their research and development (R&D) teams to capitalize on internal-external knowledge. Wiske, Franz and Breit suggest that “collaboration with others enriches one’s capacity to develop and apply ideas” [86](p.99). Employees reflect on what they learned, consider ideas from multiple perspectives to provide an interpretive framework [86] and share organizationally relevant experiences and information with others in collaboration [87]. Therefore, CNL arises from the needs for employees to share, collaborate and learn both internally and externally in order to achieve their goals.

**E. Perceived Effectiveness**

A study by Murgolo-Poore et al. found significant relationship between perceived effectiveness and the amount of information disseminated through the organization’s intranet [88]. Effectiveness was operationalized as the usability and usefulness of the information in the repository. Gray and Meister also found that employees who performed more intellectual work and who required frequent interactions with others, perceived themselves to have learned more from knowledge sharing networks than those who are not [70]. As such, employees in the CNL organizations are frequently required to interact and collaborate in workgroups as compared to non-CNL organizations. Frequent communications between workgroups create more opportunities for leveraging competencies, increase perceived effectiveness and increase motivation to collaborate and learn [89],[90].
Employees are required to use the network for documenting and accessing vital information for their work. They are more receptive to the collaborative technologies as compared to their counterparts in the non-CNL organizations who have limited resources and mostly rely on tacit knowledge.

F. Perceived usefulness
Employees’ ability to adopt collaborative technology is dependent on their perceived usefulness [91],[92]. Perceived usefulness is defined as “the prospective user’s subjective probability that using a specific application will increase his or her job performance within the organizational context” [91](p.985). If employees perceived that the results gained from using CNL are useful for their work, then employees are more likely to continue using CNL. However, employees bring their own experience and prejudice in adjudging the usefulness of a system and their perceptions are influenced by past experience [92],[93]. Clearly, if CNL does not provide useful information exchanges, it will not motivate employees to collaborate and contribute in the system. At this point, Perkowitz and Etzioni argue that information is useful only if the user considers the information on the network to be accurate, informative and pertinent [94]. Information quality improves the usefulness by enhancing the fit between network content and employees’ information requirements [95]. Ritchie et al. in their empirical study found that greater level of usefulness will lead to higher levels of intentions to use the Angel software [96]. However, it is our conjecture that employees’ perception of usefulness differs between employees in CNL driven organizations and other non-CNL organizations. Employees in CNL organizations may experience more collaborative projects and the complexity of their jobs requires them to share and attain information and knowledge from their peers and workgroups. Therefore, employees in these organizations would most likely to perceive CNL as being useful.

IV. EXPECTED RESEARCH CONTRIBUTIONS
This study aims to contribute knowledge to CNL in manufacturing. Previous study has focused on knowledge management and organizational learning. The lack of study has been observed and discussed in the literature.

A. Bridging the theory and practice of CNL in manufacturing
This model contributes a theoretical exposition on the roles of theory and practice of CNL. It provides a taxonomy of pragmatic antecedents that links sociotechnical theory (STT) to the practice of CNL in manufacturing. The objective is to provide a framework to understand how employees in manufacturing organizations share and collaborate through complex networks of information systems. Employee learning is becoming part of intricate networked systems that are less formalized and unstructured. In the advent of the virtual factory (VF), manufacturing organizations have extended beyond boundaries of face-to-face communication and collaboration.

Therefore, this paper proposes a theoretically well-grounded development of CNL research that can adequately addresses these issues and challenges in the context of a networked manufacturing environment.

B. Development and validation of the proposed CNL framework for manufacturing
CNL is a recent phenomenon for which no coherent theoretical frameworks yet exist in manufacturing. At present little is known about CNL in manufacturing. De Laat and Lally argue that due to complexities in both the theory and praxis, no single theoretical framework is yet capable of offering a sufficiently powerful articulation of description, rhetoric, inference or application of networked learning [97]. The argument is further supported by Paavola, Lipponen and Hakkarainen that while the present theoretical collaborative learning models complement each other, there are many fundamental differences between these models in terms of both focus and power [98]. The majority of theoretical frameworks are based on educational context. This paper, however, is proposing a framework for CNL within the context of manufacturing as depicted in Fig. 1. In addition, this study also supports Redmond and Lock who suggest that “the focus of the framework is to shift from online learning environments into collaborative and interactive space” [99](p.270). The construction of knowledge which is an interdependent process of interaction with social environment [100] should be the emerging force within the framework [99]. This study is hoping to demonstrate such relationships.

C. Development and validation of CNL survey instrument and measurement
Prior studies in collaborative learning merely mirrored the use of computer mediated learning in particularly among participants in learning institutions. It is proposed that a research CNL survey instrument to be developed with measurement scales to study the antecedents of CNL. The survey instrument (see Appendix B) should be complementary to the technology acceptance model (TAM) which is theoretically grounded and posits that perceived usefulness and perceived ease of use are the primary determinants of new technology system adoption.

D. Implications to operational management
Through use of CNL’s framework, it is believed that management will provide the impetus to enhance collaborative learning and knowledge sharing in virtual teams. The expansion of collaborative networks and virtual teams are expected to increase the propensity of interactions among manufacturing employees. This study attempts to demonstrate that employees from diverse roles and responsibilities could work collectively and effectively in any networked organizations. Inevitably, employees and their workgroups may become more interdependent in their new roles, given that individuals roles have been intertwined into complex information network within the organization.
<table>
<thead>
<tr>
<th>Classification of Scale</th>
<th>Related construct(s)</th>
<th>Authors</th>
<th>Sample size</th>
<th>Methodology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implicit knowledge</td>
<td>organizational support, internal external learning, project success and impact</td>
<td>Fedor, Ghosh, Caldwell, Maurer, and Singhal (2003)</td>
<td>754 sample size, 232 responded</td>
<td>qualitative (semi-structured interview), quantitative (survey)</td>
</tr>
<tr>
<td>Knowledge management system</td>
<td>organizational culture, organizational structure, perceived usefulness, interaction, effectiveness, information systems, knowledge sharing, knowledge transfer, knowledge exchange</td>
<td>Chen and Pautarla (2004)</td>
<td>10 companies, 48 teams, 150 members, response rate 62.5%</td>
<td>qualitative (survey)</td>
</tr>
<tr>
<td>Cross-functional teams</td>
<td>organizational support, internal external learning, project success and impact</td>
<td>Vies, Mero, Kowalski, and Bourdon (2009)</td>
<td>10 consultants (response rate 8%), 100 engineers (response rate 20%), 222 professionals</td>
<td>quantitative (SEM)</td>
</tr>
<tr>
<td>Communities of practice</td>
<td>internal and external learning, organizational learning, team learning</td>
<td>Bourdasi (2009)</td>
<td>122 consulting companies, 101 operations managers, 109 quality managers, and 97 production managers</td>
<td>qualitative</td>
</tr>
<tr>
<td>Interdependence (job)</td>
<td>positive interdependence, positive interdependence</td>
<td>Dean and Snell (1991)</td>
<td>38 students (in pairs)</td>
<td>qualitative</td>
</tr>
<tr>
<td>Interdependence</td>
<td>positive interdependence, positive interdependence</td>
<td>Regueras, Verdu, Verdu, and Castro (2011)</td>
<td>13 organizations, 28 teams, 231 members</td>
<td>qualitative (SEM)</td>
</tr>
<tr>
<td>Cooperative learning</td>
<td>internal and external learning, perceived usefulness</td>
<td>Schroeder, Bales, and Jurilla (2002)</td>
<td>164 plants, 65% response rate</td>
<td>quantitative (SEM)</td>
</tr>
<tr>
<td>Continuous improvement</td>
<td>internal and external cooperation, knowledge acquisition and transfer, learning</td>
<td>Schroeder (2003)</td>
<td>3 companies, 158 teams</td>
<td>quantitative (SEM)</td>
</tr>
<tr>
<td>Continuous learning</td>
<td>perceived usefulness</td>
<td>Zellmer-Bruhn (2003)</td>
<td>32 teams, 228 members</td>
<td>quantitative (SEM)</td>
</tr>
<tr>
<td>Organizational learning scales</td>
<td>perceived usefulness</td>
<td>Zellmer-Bruhn (2003)</td>
<td>32 teams, 228 members</td>
<td>quantitative (SEM)</td>
</tr>
<tr>
<td>Knowledge transfer effort</td>
<td>perceived usefulness</td>
<td>Venkatesh, Speier, and Morris (2002)</td>
<td>48% from 31 different countries, response rate 54%</td>
<td>quantitative (SEM)</td>
</tr>
<tr>
<td>Team learning</td>
<td>perceived usefulness</td>
<td>Carver (2011)</td>
<td>222 teams, 228 members</td>
<td>quantitative</td>
</tr>
<tr>
<td>Learning management system (LMS)</td>
<td>perceived usefulness</td>
<td>Rich, Drew, Srite, Andrews, and Carter (2011)</td>
<td>48% from 31 different countries, response rate 54%</td>
<td>quantitative</td>
</tr>
</tbody>
</table>

Note: Since there is no prior study in the antecedents of CNL, no measurement has ever been designed. Measurements from other close related researches will be adapted for use.
### Appendix B – Survey Questionnaire Items

<table>
<thead>
<tr>
<th>ORGSUP perceived organizational support</th>
<th>B1</th>
<th>I have access to a computer workstation to perform my job</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B2</td>
<td>I have access to networked computer/email to work with others</td>
</tr>
<tr>
<td></td>
<td>B3</td>
<td>I have access to training and learning through computer network</td>
</tr>
<tr>
<td></td>
<td>B4</td>
<td>I have access to online shared databases to facilitate my work</td>
</tr>
<tr>
<td></td>
<td>B5</td>
<td>I have support from my supervisor/manager to collaborate with others</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>POSIDP positive interdependence</th>
<th>C1</th>
<th>My job requires me to work in teams</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C2</td>
<td>My job requires me to hold tele-conferences with members from other sites</td>
</tr>
<tr>
<td></td>
<td>C3</td>
<td>My job requires me to share my ideas, work and information with others</td>
</tr>
<tr>
<td></td>
<td>C4</td>
<td>My job can only be completed if other members complete theirs</td>
</tr>
<tr>
<td></td>
<td>C5</td>
<td>My performance depends on the results of my team</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PROINT promotive interaction</th>
<th>D1</th>
<th>I frequently share ideas, work and information with others</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D2</td>
<td>I frequently interact with my peers and members in the team online</td>
</tr>
<tr>
<td></td>
<td>D3</td>
<td>I can easily obtained help and support from my team/peers online</td>
</tr>
<tr>
<td></td>
<td>D4</td>
<td>I frequently share information in online meetings or discussions</td>
</tr>
<tr>
<td></td>
<td>D5</td>
<td>Members in the team help each other to learn and engage</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LEARN internal-external learning</th>
<th>E1</th>
<th>I learn from shared information from the network</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>E2</td>
<td>I received training to enable me to collaborate effectively</td>
</tr>
<tr>
<td></td>
<td>E3</td>
<td>I participate in improvement projects</td>
</tr>
<tr>
<td></td>
<td>E4</td>
<td>I learn from suppliers/customers or external parties</td>
</tr>
<tr>
<td></td>
<td>E5</td>
<td>I learn from my peers and members in the team</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PEREFF perceived effectiveness</th>
<th>F1</th>
<th>I work efficiently through use of information from the network</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F2</td>
<td>I work interdependently using the computer network</td>
</tr>
<tr>
<td></td>
<td>F3</td>
<td>I use computers to share information effectively with others</td>
</tr>
<tr>
<td></td>
<td>F4</td>
<td>My team achieved goals for projects by using information from the network</td>
</tr>
<tr>
<td></td>
<td>F5</td>
<td>My team produces good quality collaborative work</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PERUSE perceived usefulness</th>
<th>G1</th>
<th>The network systems and tools are useful for my work</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>G2</td>
<td>The shared databases are useful for my work</td>
</tr>
<tr>
<td></td>
<td>G3</td>
<td>The online meetings/discussions with external parties are useful</td>
</tr>
<tr>
<td></td>
<td>G4</td>
<td>The network systems are useful for sharing information</td>
</tr>
<tr>
<td></td>
<td>G5</td>
<td>The online learning system and training are useful</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>COLLRN collaborative learning</th>
<th>H1</th>
<th>I accessed knowledge and information through computer system/network</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H2</td>
<td>I updated my work through the computer system/network</td>
</tr>
<tr>
<td></td>
<td>H3</td>
<td>I learned by sharing and exchanging information with others</td>
</tr>
<tr>
<td></td>
<td>H4</td>
<td>I participated in e-learning or online courses</td>
</tr>
<tr>
<td></td>
<td>H5</td>
<td>I participated in workgroups to complete projects or tasks</td>
</tr>
</tbody>
</table>
Network thinking that recognizes the individual elements of the system enterprise and their reciprocal relationships are becoming increasingly important [101]. As a result, organizational design may be tasked to nurture organizational development and other essential networking skills.

V. CONCLUSION

The research on collaborative networked learning (CNL) explores the antecedents to knowledge and information sharing and transformation among employees in manufacturing organizations. It provides a framework for future research on the theory of organizational learning and sociotechnical theory, in particular interest of diverse manufacturing environment which is constantly evolving as a consequence of technological advancement. This research, hope to contribute a sound theoretical knowledge for collaborative networked learning with possibilities to support both comparative and empirical researches in areas of collaborative technologies, employees engagement, online learning, virtual teams and knowledge transformation.

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