Collaborative Networked Learning in Manufacturing

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***Abstract*—This study aims to investigate the antecedents of collaborative networked learning (CNL), to develop an integrative CNL framework and to bridge the gap between theory and praxis in manufacturing. It provides a holistic perspective of CNL within the complexity of the manufacturing environment, including empirical investigation using survey questionnaires. The findings and discussions draw upon socio-technical systems (STS) theory, and present the theoretical context and interpretations through the lens of manufacturing employees.**

Results of the study show the existence of significant positive influences of organizational support, promotive interactions, positive interdependence, internal-external learning, perceived effectiveness and perceived usefulness of CNL among manufacturing employees. The study offers a basis for empirical validity for measuring CNL in organizational learning, knowledge and information sharing in manufacturing.

***Index Terms*—collaborative networked learning, socio-technical systems theory, workplace learning**

I. INTRODUCTION

Collaborative networked learning (CNL) was first proposed by Charles Findley (1988) in his work "*Collaborative networked learning: online facilitation and software support*" as part of an instructional learning design for the future of the knowledge worker. His premise is 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. Although collaborative learning has been at the forefront of educational and pedagogical studies, there is a lack of research in the mainstream of operations management and information systems. This study explores CNL and the sharing of information among diverse employees within the context of manufacturing industries in Malaysia.

In essence, collaboration begins with the identification of a problem and seeking contribution from multiple parties with mutual interest [1], aspirations and purposes to determine which collaboration approach is appropriate [2] in solving operational or engineering tasks. Collaboration has also been defined as a "process of participating in knowledge communities" [3] "in a coordinated, synchronous task to construct and maintain a shared conception of a problem" [4]. CNL transpires when employees and their workgroups learn or attempt to learn through organizational networks and work interactions. CNL transforms knowledge, experiences and perspectives into a coherent shared understanding and engages employees in knowledge construction [5],[6].

II. THEORY DEVELOPMENT

Research on information systems examines more than just the technological system, or just the social system, or even the two side by side. It investigates the phenomena that emerge when the two interact [7]. The central principles of socio-technical systems theory were first elaborated by Trist and Bamforth [8]. Luhmann [9] advances the approach in discussing modeling collaborative work combining new epistemological concepts with system theory. The term socio-technical systems (STS) relates to systems that combine social and technical sub-systems and interactions between complex system infrastructures and human behavior. In socio-technical systems research, behavior is often studied using an ethnographic approach, case studies, social network analysis and surveys [10].

According to Herrmann et al. [11], social systems are defined by: the phenomena of communications and cooperation between employees; emergence of systems; self-referential development of systems, structures and processes; self-descriptions; and responsible autonomy. Technical systems are defined by artifacts, control and anticipation, state-transitions, and pre-programmed adaptability [11]. It is assumed that the degree of integration between manufacturing organizations and the CNL infrastructures is closely interrelated. Variation in the socio-technical context does have an effect on group experience [12]. The conditions affect the success (or failure) in the adoption of collaborative technologies. Socio-technical information systems can be designed to support storage and distribution of data as a basis of knowledge sharing within the organization [13]. In addition, Powell et al. [14] reviewed 47 studies of virtual teams, and suggested that the development of virtual teams is complex, multivalent and requires extensive study to determine the design based upon the social technical mechanism.

III. RESEARCH FRAMEWORK

This study is driven by the determination to test a provisional supposition about the phenomena of CNL and propositions which state that there is a causal relationship between the dependent variable and independent variables.

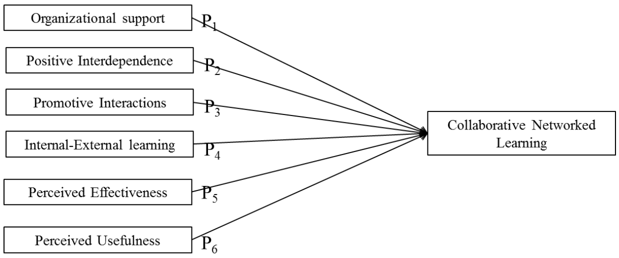

Figure 1. Research framework of CNL

A support system is part of the organizational infrastructure that facilitates the necessary processes to manage, control, coordinate and improve work [15] and in the case of CNL, the organization would support their employees' learning goals and engagement with others in the learning networks [16],[17]. Therefore, perceived organizational support is positively related to self-efficacy and the motivation to learn [18] and is strongly associated with affective commitment [19]. Thus, it can be postulated that organizational support through the provision of opportunities for diverse employees to engage in collaborative work and learning is an important antecedent to achieve positive CNL outcomes. Likewise, the greater the extent to which employees perceive that the organization or management is providing support, the more the employees are willing to learn and engage through collaborative network. This leads to P_1:

P_1 Organizational Support is an Antecedent of CNL

CNL occurs in interactive groups in which participants actively communicate and negotiate meaning with one another. In a complex problem solving situation, employees are required to collaborate with each other [20] resulting in positive interdependence between learners [21]. Although manufacturing organizations may be highly segmented into departments, as operational knowledge becomes more specialized and complex, solutions to problems will require interdependence of employees working together. Positive interdependence refers to the degree to which the performance of a single group member depends on the performance of all other members [22]. Positive interdependence also relates to the attainment of individual goals to the success of others in the workgroup [23],[24],[25],[26],[27],[28]. Building a CNL system requires employees to think in terms of organized networks of mutual interdependence and to overcome individual differences [29]. Conversely, employees whose job requires less input from others, requires less information access than those who do [30]. Positive interdependence facilitates the development of new insights and discoveries through promotive interaction [31],[32]. This leads to P_2:

P_2 Positive Interdependence is an Antecedent of CNL

Social interaction is the key element in CNL. An interaction in CNL encompasses interactivity between employees and their workgroups, from information sharing to task-oriented discussions, to achieve shared understandings and knowledge construction. Promotive interaction means close, usually synchronous, purposeful activity and joint decision making [25] where employees participate in workgroups to complete their tasks and goals [32]. 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 [27], cooperation among learners improved learning outcomes relative to individual work across the board. Their finding is further supported by Springer et al.'s [33] review of 37 studies of students in science, mathematics, engineering and technology. Interactions with computer-supported social networks [34] should also be considered as strongly interactive. In addition, effective collaboration increases interconnections between organizations [35], increases interactions [36] and fosters learning among employees [37]. This leads to P_3:

P_3 Promotive Interactions is an Antecedent of CNL

Wiske, Franz and Breit [38] also assert that "collaboration with others enriches one's capacity to develop and apply ideas" (p.99). Employees reflect on what they learned, consider ideas from multiple perspectives to provide an interpretive framework [38] and share organizationally relevant experiences and information with others in collaboration [39]. By leveraging intra-organizational knowledge sharing, a network of interdependent relationships can link the success of an organization with the success of other organizations [40], [41]. Intense global competition and increasing technological dynamism promote the importance of external learning as an element of organizational success [42]. External knowledge is critical to the innovation process and most innovative ideas are learned from competitors, developers, partners or suppliers. Innovation requires knowledge and information flow between organizations and other employees [43],[44] and can only happen through interaction with external factors [45]. Therefore, CNL arises from the need for employees to share, collaborate and learn both internally and externally in order to achieve their goals. This leads to P_4:

P_4 Internal-External Learning is an Antecedent of CNL

Effectiveness is operationalized as the usability and usefulness of the information in the repository or through interactivity with other members. A study by Murgolo-Poore, Pitt, Berthon and Prendegast [46] found a significant relationship between perceived effectiveness and the amount of information disseminated through the organization's intranet. Gray and Meister [30] also found that employees who perform more intellectual work and who require frequent interactions with others, perceive themselves to be learning more from knowledge sharing networks than those who perform less intellectual work and required less frequent interactions. Frequent communications between workgroups create more opportunities for leveraging competencies, increasing perceived effectiveness and increasing motivation to collaborate and learn [47],[48]. Employees who are required to use the network for documenting, accessing vital information and using that information for their work are more likely to have a perceived notion about the effectiveness of CNL as compared to those who are not provided with collaborative technology. This leads to P_5:

P_5 Employees' Perceived Effectiveness is an Antecedent of CNL

Perceived usefulness is defined as “the prospective user’s subjective probability that using a specific application will increase his or her job performance within an organizational context” [49]. If employees perceive that the results gained from using CNL are useful for their work, then it is quite likely that employees will continue in using CNL. In other words, employees’ ability to adopt collaborative technology is dependent on its perceived usefulness [50],[51]. However, employees draw on their own experience and prejudice when judging the usefulness of a system [50],[52]. Clearly, if CNL does not provide useful information exchanges, it will not motivate employees to collaborate and contribute to learning. Perkowitz and Etzioni [53] argue that information is useful only if the user considers the information on the network to be accurate, informative and pertinent. Employees who have positive experiences in collaborative projects and are able to work through the complexity of their jobs are more likely to share and attain information and knowledge from their peers and workgroups. This leads to P_6:

P_6 Employees’ Perceived Usefulness is an Antecedent of CNL

IV. METHODOLOGY

A. Research Method

The mixed methods approach is appropriate for this study which has both exploratory and confirmatory questions [54],[55] and employs both inductive and deductive logic [56],[57]. Similar areas of study in collaborative learning increasingly apply mixed method strategies [58],[59],[60],[61],[62],[63],[64],[65],[66],[67], [68],[69]. CNL reflects a complex reality where multiple variables interact and influence each other in a rich empirical and ecological setting [70]. The approach is likely to produce a complete study of networked learning and CNL [66],[67],[70]. It has the ability to reveal high quality and complex inferences [71], it is valuable in capturing individuals’ experiences and beliefs [72] and it opens new ways of contextualizing and building up understanding of CNL activities that participants are engaged in [70].

B. Unit of analysis

A unit of analysis is the primary entity or element for collecting and analyzing data [73]. The unit of analysis for computer-supported cooperative learning (CSCL) and computer-supported collaborative work (CSCW) is the collective social network level or activity system [74]. Dillenbourg et al. [75] claim that “the group itself has become the unit of analysis and the focus has shifted to more emergent, socially constructed, properties of interaction” (p.1). In this study, the researchers seek for major themes that could explain the CNL antecedents with individual employees’ engagement in CNL as the focus for the unit of analysis.

C. Sample and questionnaire design

The qualitative findings from the interviews were corroborated with a 246 quantitative survey of multinational companies (MNCs) and small-medium enterprises (SMEs) in Malaysia. SPSS software was used for statistical analysis and NVivo for content analysis. Participants were randomly recruited from various manufacturing organizations using snowball sampling.

The questionnaire was made available through a Qualtrics web-based survey and through mailed out hardcopies. The questionnaire solicited self-reported background, and information pertaining to perceptions and experiences in using CNL. Compared to conventional mail surveys, the cost of Qualtrics web-based surveys for sending questionnaires and coding data is relatively low, and has a short turnaround time. Potential errors due to data transfer and codification are eliminated [73]. The Qualtrics generated electronic dataset from responses were pre-coded in SPSS format. Both types of questionnaire (online and hardcopy) consisted of 44 questions categorized into 3 sections: type of manufacturing organizations (item A1), experience with CNL (items B1 to H5), and number of hours using CNL systems and tools (items I1 to I4) and demographic data (items J1 to J4).

D. Mitigating *Research* Bias

Bryman [54] describes various factors that could affect the reliability of a test. A self-administered web-based survey and anonymous administration lessen socially desirable responding (SDR) bias involving an individual’s self-description but not self-deceptive bias [76],[77]. To mitigate the risk of SDR, the following questions were designed to complement others:

i. Item C1 “My job requires me to work in teams” with item C5 “My performance depends on the results of my team”.
ii. Item G2 “The shared database is useful” with item I2 “Numbers of hours using a shared database or network information per week”.
iii. Item G3 “The online meetings with external parties are useful” with item E4 “I learned from suppliers, customers or external parties”.
iv. Item H4 “I participated in e-learning or online courses” with item I1 “Numbers of hours using e-learning or online learning per year”.

In order to reduce duplicate submissions from the same respondent, the researcher conducted verification on the IP addresses which prevented any repeated or duplicated responses. The Qualtrics web-based survey automatically prompted the participants, should any of the questions not be answered. Hardcopies of the survey were checked for accuracy before they were entered into the Qualtrics online database.

E. Survey Response

The main study was conducted from July 2012 until the end of November 2012 and 292 responses were obtained. Of the 63 potential participants identified for the initial stage, 12 were unreachable due to change in employment. This reduced the sample size of the initial target group of participants to 51. After the cut-off date of November 22, 246 usable responses were attained, out of which 150 were from the web-based survey and another 96 replied through hardcopies. Forty six potential participants declined to participate giving a non-response rate of 14% (46 of 338). In total, 292 participants responded to the survey, of which 246 completed responses were usable. With 63 survey invitations and 400 hardcopies printed and distributed, the overall response rate was 63% (292 of 463), and the usable rate was 84% (246 of 292). The majority of the participants were aged between 30-39 years (52.0%, n =128), followed by those aged between 20-29 years (35.0%, n =86), and possessed at least a diploma or a bachelor degree (58.9%, n =145).

F. Data Analysis and Scale Purification

From the analysis, the researchers also sought to increase the reliability of the Cronbach's α. Field [78] recommends that items with low values of α should be deleted from the scale in order to improve its reliability. Deletion of item B4 only increased α from 0.928 to 0.933 and item G3 from 0.935 to 0.945. These increases were not deemed to be significant and thus these items were not deleted.

The Cronbach's α reliability test in the pilot study was repeated to ensure consistency in the measurement with the results previously indicated in the pilot study. The result from the main study ranged from 0.90 to 0.96 (Table 2) and as this was >0.7, they were considered to be reliable.

The split-half reliability was also used to further validate this result, since "Cronbach's alpha would calculate the average of all possible split-half reliability coefficients" [79] to clearly dictate the measurement instrument is both reliable and valid. Cronbach's Coefficient Alpha, using the split-half reliability test further proved the scales to be effective (see Table 3) with results ranging between 0.73 to 0.95 (level > 0.7). The closer the correlation coefficient is to 1.0 the more reliable it is [73].

TABLE I.
CRONBACH ALPHA

Constructs	Cronbach's Alpha	N of Items
Organizational Support	0.90	4
Positive Interdependence	0.91	4
Promotive Interactions	0.93	5
Internal-External Learning	0.90	4
Perceived Effectiveness	0.96	5
Perceived Usefulness	0.94	5
Collaborative Networked Learning	0.93	5

TABLE II.
SPLIT-HALF RELIABILITY

Constructs	Cronbach's Alpha 1st Half	N of Items	Cronbach's Alpha 2nd Half	N of Items
Organizational Support	0.90	2	0.73	2
Positive Interdependence	0.84	2	0.87	2
Promotive Interactions	0.93	3	0.77	2
Internal-External Learning	0.90	2	0.80	2
Perceived Effectiveness	0.94	3	0.92	2
Perceived Usefulness	0.88	3	0.87	2
Collaborative Networked Learning	0.93	3	0.83	2

V. RESULTS

All the predictors were entered into the regression to determine which predictors contributed significantly to the CNL model. Predictors that had low significance (p>0.05) were identified for removal. This study adopts Field's [78] recommendation to rerun the analysis to include only the important predictors and use the resulting parameter estimates to define the regression model. The result is used to build the models H1-H5 in Figures 2-6.

The independents variables and constructs were identified and they strongly supported dependent variable CNL for model H1. Predictors B2 (sig. =7.95), C1 (sig.=1.65, C4 (sig. =0.18), C5 (sig. =0.82), D2 (sig. =0.11), E3 (sig. =0.16), F2 (sig. =0.05), F3 (sig. =0.17), and G3 (sig. =0.74) were removed because of low significance (p> 0.05). Independent variable C3 "Job requires to share ideas, work and information" (β = 74%, t= 17.26, sig = 0.01) was the strongest predictor for H1 "Access information online".

The independents variables and constructs were identified and they moderately supported CNL for model H2. Predictors B5 (sig. =0.05), C4 (sig.=0.13), C5 (sig. =0.38), D3 (sig. =0.24), D5 (sig. =0.05), E3 (sig. =0.17), F1 (sig. =0.33), F2 (sig. =0.22), F4 (sig. =0.25), F5 (sig. =0.06), G1 (sig. = 0.17), G2 (sig =0.05), and G3 (sig. =0.09) were removed because of low significance (p > 0.05). Independent variable F3 "Use of computer to share information" (β = 77%, t= 19.06, sig = 0.01) was the strongest predictor for H2 "Work using online system or network".

The independent variables and constructs were identified and they strongly supported CNL model H3. Predictors B2 (sig. =0.79), C1 (sig.=0.19), C4 (sig. =0.37), C5 (sig. = 0.12), D1 (sig. =0.21), D3 (sig. =0.51), E3 (sig. =0.09), F2 (sig. =0.42), F3 (sig. =0.28), F4 (sig. =0.26), G1 (sig. = 0.16), G2 (sig =0.09), and G3 (sig. =0.66) were removed because of low significance (p > 0.05). Again, the independent variable C3 "Job requires to share ideas, work and information" (β = 75%, t= 17.49, sig = 0.01) was the strongest predictor for H3 "Share and exchange information online".

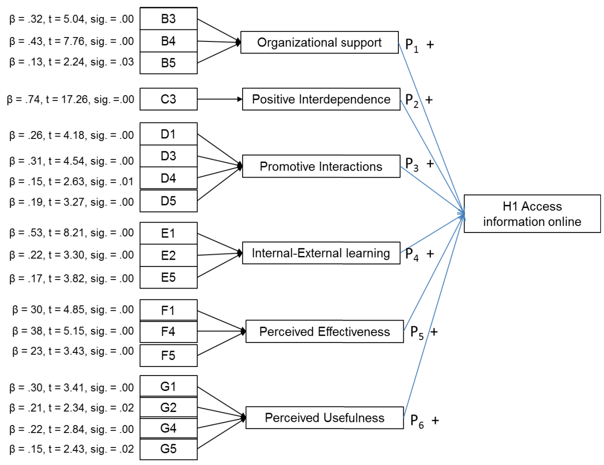

Figure 2. Model H1 Access to information online

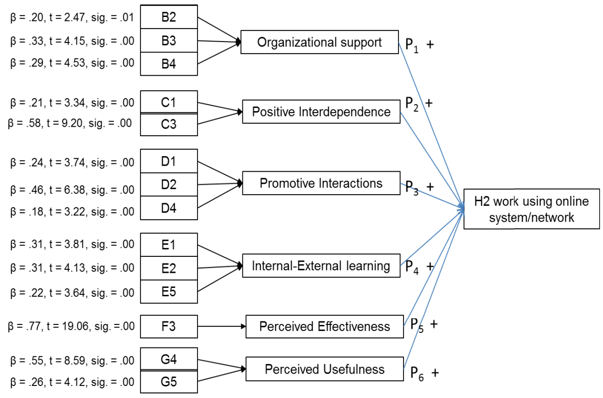

Figure 3. Model H2 Work using online system or network

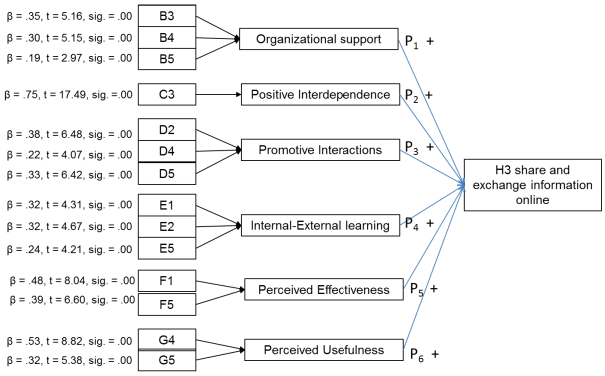

Figure 4. Model H3 Share and exchange information online

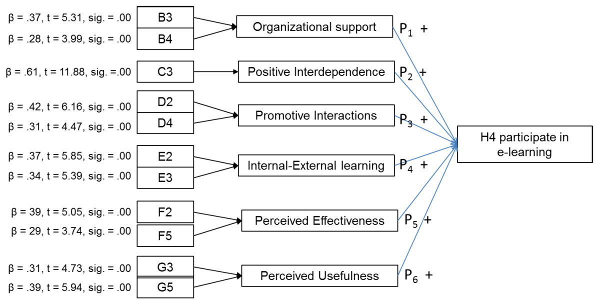

Figure 5. Model H4 Participate in e-learning

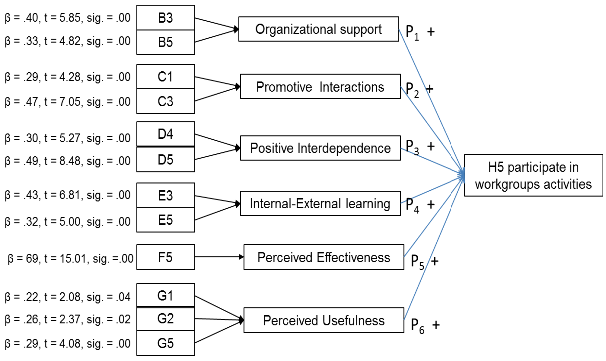

Figure 6. Model H5 Participate in workgroups activities

The independent variables and constructs were identified and they moderately supported CNL model H4. Predictors B2 (sig. =0.97), C1 (sig.=0.78), C4 (sig. =0.21), C5 (sig. = 0.16), D1 (sig. =0.35), D3 (sig. =0.64), D5 (sig. = 0.51), E1 (sig. =0.06), E5 (sig. =0.53), F1 (sig. =0.19), F3 (sig. =0.77), F4 (sig. =0.46), G1 (sig. = 0.93), G2 (sig =0.38), and G4 (sig. =0.24) were removed because of low significance ($p > 0.05$). Again, independent variable C3 "Job requires to share ideas, work and information" (β = 61%, t= 11.88, sig = 0.01) was the strongest predictor for H4 "Participate in online learning". However, the construct 'organization support' with adjusted R^2=35% and the observed value of 0.60, and 'promotive interactions' with adjusted R^2=36% and the observed value of 0.61 indicated that both constructs would predict poorly for online learning participation.

The independent variables and constructs were identified and they moderately supported CNL model H5. Predictors B2 (sig. =0.11), B4 (sig.=0.06), C4 (sig. =0.14), C5 (sig. = 0.32), D1 (sig. =0.45), D2 (sig. =0.30), D3 (sig. = 0.76), E1 (sig. =0.12), E2 (sig. =0.05), F1 (sig. =0.72), F2 (sig. =0.69), F3 (sig. =0.14), F4 (sig. =0.36), G3 (sig. = 0.51), and G4 (sig =0.48) were removed because of low significance ($p > 0.05$). Independent variable F5 "Team produces quality collaborative work" (β = 69%, t= 15.01, sig = 0.01) was the strongest predictor for H5 "Participate in workgroup activities".

VI. DISCUSSION AND CONCLUSION

A. *Organizational Support*

Employees are provided with access to a computer network to communicate and collaborate with others. The network plays an important role in enabling employees to access, learn and share information. Management support is pivotal in providing the facility and infrastructure as well as learning support to collaborate. Likewise, other researches also recommend a supportive organizational context and supportive interpersonal climate, as well as the positive effects of facilitative leadership [80],[81]. Most organizations provide both asynchronous and synchronous tools for communication and collaboration as well as workspace for sharing information. Management is supportive of employees in ways that facilitate the accomplishment of their tasks, for example, removing barriers, developing standards and coordinating activities [82]. Similarly, Chiaburu et al. [18] and Fedor et al. [83] also found that perceived organizational support is positively related to self-efficacy and the motivation to learn. It is also related to team members' ratings of their project success and expectation of a project's impact on the organization.

B. *Positive Interdependence*

This study has proven that positive interdependence is an antecedent of CNL. Employee's mutual dependency is focused on shared tasks and working collaboratively to accomplish the deliverables set forth by the management or organization. Jobs that require employees to work in teams or to share ideas, work and information are more likely to develop into CNL. Moreover, task interdependence requires assistance and support from multiple teams to work collectively [82],[83]. However, it is not possible to ascertain the extent of collaborative effort in this study as MNC employees are widely distributed across different countries. A positive interdependence is produced among employees, since they are aware that other members are working together with them towards a common outcome [28]. Therefore, co-creating of new knowledge is defined by its genesis process that knowledge has to be shared and is often dependent on joint task performance or a merging process between individual thought networks [84]. The study further supports Grant and Baden-Fuller's (2004) argument that self-managing teams, virtual global teams and other cross-functional teams that support joint improvement activities and new product development (NPD) require positive interdependence for the groups to succeed.

C. *Promotive Interaction*

This study has proven that promotive interaction is an antecedent of CNL. Employees who frequently interact with peers or teams are more comfortable in working in teams and engaging in CNL. CNL requires employees to frequently share ideas, work and information with others through the use of a computer network. Extensive interaction is required for employees to communicate and solve problems with other internal knowledge peers and network with external experts [85]. This is clearly evident in the study which has shown that participation in a workgroup (in Model H5) requires frequent information sharing and the ability to help each other out. Interaction between people in networked learning environments can be synchronous, asynchronous or both and this forms an essential part of networked learning. It requires both technical and interactive skills from parties in collaboration [86]. The intensity of interactions may also help to support other constructs, for example, positive interdependence and internal-external learning. Similar research by Fedor et al. [83] also found that knowledge generation in both internal and external forms positively relates to team members' rating of their project's level of success and positive expectation of the project's impact on the organization.

D. Internal-External Learning

Employees learn to obtain shared information from the network and train to collaborate effectively with their teams (in Model H1). Equally important is the ability to learn from peers and teams in all aspects of CNL whether to access information online, work online, share and exchange information, participate in online learning or even work in groups. To participate in workgroup activities, employees have to learn from their peers and participate in improvement projects. Teams perform best when engaged iteratively in reflecting on their action of learning [87],[88]; reconstruction and involvement in learning transfer processes [89]; and internal and external learning processes. The study further confirmed the findings from other researches on external learning. For instance, Bierly and Daly [90] found that learning from customers is a predictor of innovation speed, learning from suppliers is a predictor of operational efficiency, and learning from other industries is a predictor of superior process technologies. The learning experience forms a positive reputation, which in turn motivates more employees and external experts to participate in the knowledge network [90].

E. Perceived Effectiveness

This study has found employees' perceived effectiveness is an antecedent of CNL. Similarly to Murgolo-Poore et al. [46] this study found a significant relationship between perceived effectiveness and the amount of information disseminated through the network. The frequency at which employees access information online is influenced by employees' perception about the system's ability to generate information for them to work efficiently and as a result, the team's ability to attain goals and produce high quality collaborative work. Likewise, for employees to work online using CNL, the system has to be effective in sharing information. To share and exchange information online, employee must perceive that the information that they obtain from the network will help them to work efficiently and produce high quality collaborative work. In fact, in all aspects of CNL, the ability to generate high quality collaborative work outperforms all other factors. Employees have high expectations that CNL should be highly effective.

F. Perceived Usefulness

This study has found employees' perceived usefulness is an antecedent of CNL. Like perceived effectiveness, the study also borrows the construct of perceived usefulness from TAM to measure the antecedents of CNL. In general, employees expect the online learning system or programme to be useful in order for CNL to be successful in all aspects. To participate in workgroup activities (Model H5) and a network system, a shared database and online learning has to be useful for work. Likewise, to work online (Model H2) and share and exchange information online (Model H3), the network system has to be useful for sharing information, as well as online learning. In another empirical study, Ritchie et al. [91] found that a greater level of usefulness will lead to higher levels of intention to use application software.

G. Academic contribution

This study contributes significantly to the theoretical exposition on the roles of theory and praxis of CNL in the manufacturing environment. The proposed set of pragmatic antecedents validated through knowledge transfer and information sharing in manufacturing examined employees' perceptions and motivations to share and collaborate. Employees' learning is interwoven into intricate networked systems that are less formalized and often unstructured. This study amplifies the relevance of socio-technical systems (STS) theory and bridges the gap between social and collaborative technologies, and interactions between complex CNL system infrastructures and manufacturing employees. The findings are that for CNL to be effective, it is imperative to provide information that is relevant for employees to perform their daily work activities. Collaborative tools have to be strategically planned, designed, purposeful and supported by management to facilitate learning and sharing of information.

This study presents a framework for CNL in manufacturing. As suggested in the literature, previous theoretical frameworks are based on an educational context [65]. Arbaugh and Benbunan-Fich [92] also recommend research on the application of theoretical frameworks in the study of networked learning and supports. Redmond and Lock [93] suggest that "the focus of the framework is to shift from online learning environments into collaborative and interactive space" (p.270). The co-construction of knowledge, which is an interdependent process of interaction with the social environment, should be the emerging force within the framework [93]. CNL is used to integrate information sharing and transformation into collaborative business processes. Drawing from the findings, the study recommends organizations and managers to adopt an integrative CNL framework for design and development of a more complete networked learning system. The focus expands from online learning or e-learning to a much broader scope encompassing collaborative and interactive workspaces. Unlike educational collaborative learning models which are restrictive, the CNL framework provides a holistic perspective for workplace learning that is unbounded, engaging and accounts for users' perceptions about technology.

H. Research Limitation

This study examined factors elicited from the literature, but also identified other variables such as "quality of information" and "employees' roles and responsibilities" as antecedents. Several studies postulate that the quality of online information may affect the sustainability of a system and quality to be identified and understood [94],[95],[96],[97],[98]. As this study was limited to the Malaysia manufacturing environment, the findings can only be generalized to other contexts. The sample size for the quantitative analysis limits generalization of the results beyond the specific sample used in this study. A study with a larger sample size would allow more focus on the use of different collaborative technologies in other industries. A larger sample would facilitate the testing of more complex models, with the focus on group dynamisms and could relate CNL with performance and operational outcomes.

I. Future Research

Although the adoption of CNL is mainly determined by organizational and leadership strategies, its effectiveness is highly dependent on the members' acceptance (managers and workers), nuances and in-depth application of collaborative technology in all organizational work systems as well as in project or workgroup oriented tasks. Although suitable infrastructures as well as information and communication technologies (ICT) exist, especially web-based tools to facilitate and enable the process of knowledge transfer [99], technology itself does not resolve all the challenges of learning and collaboration. As such, the research on the selective use of collaborative technology in organizational learning, information transmission and knowledge transformation needs to be further explored. Similarly, Rittgen [100] cautions that those engaged in collaboration not only bring their different organizational cultures but also different, often incompatible, information systems. This is particularly crucial for large manufacturing organizations that require information exchange between multiple sites, suppliers, customers and developers. Future research could examine how organizations address this gap and develop an integration process for the diverse operating systems and collaborative technologies, in support of learning environment using appropriate pedagogic theory [101].

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