Jurnal
Teknologi

Full Paper

# HANDLING EMERGENCE OF DYNAMIC VISUAL REPRESENTATION DESIGN FOR COMPLEX ACTIVITIES IN THE COLLABORATION

**Article history**
Received:
*15 August 2015*
Received in revised form
*15 October 2015*
Accepted
*10 June 2016*

Suraya Ya'acob*, Nazlena Mohamad Ali, Norshita Mat Nayan

Institute of Visual Informatics, National University of Malaysia, Bangi, Malaysia

*Corresponding author
suraya@intanbk.intan.my

## Abstract

In recent years, we observed a general trend in organization toward emerging information items in the complex cognitive activities (CCA). Since CCA occur in decision making, problem solving and sense making more in the collaborative settings, it becomes essential for business to response and act according to emerging information items to stay relevant in the market. However, the emergence of information which has been known as an 'uncontrollable entities' are hard to be determined from information system perspectives. Thus, the management team is having difficulties in utilizing the emergence information to become valuable outcomes for both organization and stakeholders. This paper aims to show how visualization can play an important role to facilitate this challenge. First, we present the emergence challenges from the perspective of relative isolation between the information, mental and representation spaces. Then, we highlight the importance of dynamic concept as a fundamental approach to handle emergence. We attempt to pin the second order cybernetic as an underlying theory for dynamic interactivity between visual representation and users' mental space. By having this, we are able to construct the information evolvement during the cognitive process and manage their cognitive burden. Finally, we report the findings from qualitative analysis of experimental case studies within a collaborative setting dealing with complex activities (decision making) process. Our findings show the positive outcomes to centralize collaborators' mental model, bring clarities and foster innovative thinking during the process of complex activities in the collaboration. Through this research, we have found the potential of dynamic visual structure to bring better values, practical and sufficient in handling complexities of information emergence during the collaborative CCA in the organization.

*Keywords:* Visual design, visual representation, complex activities, collaboration, emergence, dynamic approach



## 1.0 INTRODUCTION

Collaboration is an essential for innovation and productivity in organizations. Collaboration implies a team to perform a task jointly, thus requiring interaction and coordination of cognitive effort. Collaborative activities often require high level of cognitive [1]. Moreover, as an organizational management system is increasingly complex and dynamic, the collaboration especially between the higher level executives and top management have to deal with more complex cognitive activities such as decision making, problem solving, sense making, analytical forecasting and strategic planning in order to come out with valuable innovation and outcomes for an organization [2].

Visualization-computational based has been used to support the organization in performing complex cognitive activities in the collaboration (from hereafter, we simplify the term as 'collaborative CCA'). From basic presentation aids like Power Points, Prezi and Keynote to more sophisticated tools like Business Intelligent and Big Data application. However, we also observe the shortcomings of visual representation design to handle the process of collaborative CCA, especially to facilitate the general trend in organization towards an emerging information. This is because teams within organization need to have flexible visualization that are open and able to align themselves with emergent information. Designing such visualizations can be challenging. Although there has been some realisation of the need to cater the visualizations for collaborative CCA, reserach in this area is still at the early stages [3, 4].

Literature shows the use of visualizations has been expanding rapidly, and as the amount and complexity of data keeps growing, so is the sophistication and complexity of their corresponding visual representations. The field of visualization is inter-disciplinary, one that incorporates scientific, technological and cognitive aspects. Visualization basically focuses on amplifying human cognition to promote efficiency in well-defined tasks [5-7], and more recently, visualization has been used as a communication mediator to build common understanding, insight and decision-making [8-11]. After more than 20 years of evolutions, computer-supported visualizations have become very important and are used in many application domains [12, 13]. However, we found most of the viusalization tools are based on the same determination approach locks the process of facilitating the collaborative CCA into a course that disregards any input other than information provided by the application. It cuts off the prossibility of improvisation, deviation and the chance to adapt new input. Whereas, the management team need to have more flexible and open ended visual representation to handle their constructive knowledge and allign the emergence information with their cognitive goal while performing the collaborative CCA. Hence, there is still no suitable, comprehensive approach of emergence to be found in communicating complex visualizations in the collaboration. Since current visualizations need to handle this kind of complex matters in the collaboration, we believe it is timely that we explore the approach further in providing solution according to the complex and emergence conditions. Using research from other areas to help us, we propose to shift the visualization design paradigm for handling collaborative CCA through Second Order Cybernetics theory. We tend to propose more dynamic interactivity approach in handling the performance of collaborative CCA.

This paper is presented according to the following structure. Section 2 describes the working background of this research, where we present some discussion about conception and challenges in the collaborative CCA from the visual structure perspectives. In section 3, we discuss the dynamic approaches and derivation in order to bridge the necessities of emergence condition. In section 4, we propose the contextual of visual structure as the dynamic approach for the representation space. Section 5 presents the validation through experimental class with case studies. The result shows the benefits of the approaches and the potential to foster innovation. Finally, section 6 provides a summary and some future research directions.

## 2.0 BACKGROUND OF STUDY

To understand the background of visual representation, we intend to follow the categorization of different spaces similar to [14, 4]. Categorizing visualizations according to different spaces can help examine each space in relative isolation while still keeping in mind their necessary relationships. When dealing with the visual representation to support the interactivity between the users' mental model and the information environment, we need to consider three spaces namely information, mental and representation space. Each space and the relationship between them will be discussed in more detail in the following sections.

### 2.1 Information Space

An information space is an environment, source, domain, place or area of containment from which a body of information originates. According to [14], while research has recently been focusing on the human side of the user-visualization discourse, there is not much attention given to conceptualize the information side. Many researchers in visualization science refer to body of information with which users engage in discourse as 'information space'. However, aside from sporadic contributions, not much effort has been placed on the development of general models, theories or characterizations of information space within the visualization literature. The source of massive, messy, diverse and ever changing volumes of information [15] can be many [16], and they can be from concrete realms, existing within a physical space (e.g. oceans), or abstract (e.g. stock markets), originating from a non-tangible and non-perceptible sources.

For ease of conceptualization and discussion, we refer all components within information space as information items (data, conceptual entities, properties, structures, processes, relationships and temporal properties). In organization, information items derived from internal (e.g knowledgeable workers, R&D findings, strong financial) that could become the strengths or weaknessess of an organization. Moreover, information items also derives from external (e.g trends for users demand and competitors) to become opportunities or threats. The information items that derive from the internal are mostly in their complicated manners. They are messy, massive and diverse. This kind of data is still manageable to be handled with sophisticated and determined manner. It has been taken care under interchangeable name of knowledge management, business intelligent and big data.

Nevertheless, we also observe a general trend in organization towards an emerging information items (mostly from external organization) and not within their control. It is essential for an organization to respond and act according to an emerging information items to stay relevant in the market. Thus the management teams need to process an emergent information items, aligned with their organization vision and mission and to produce outcomes that bring values to both the organization and the stakeholders. Emergence is the creation of a new level organization through the coming into existence of one or more selfsustaining systems or agents. The agents often co-exist in populations of other agents which are more or less similar to one another. Basically, emergence refers to the ability of low-level components of a system or community to be self-organized into a higher-level system of sophistication [17]. There are differences in understanding emergence – some view emergence from the perspective of synergies, concept, process, perception, structure and enigmatic. However for this particular research, we refer to Roger Sperry and Donald Campbell that clarified the significance of emergence in mental and cognitive perspectives. Basically, we identified two types of emergence elements from this perspective: i) the input - information to feed the cognitive process and ii) the output - new interpretation from the cognitive process that is evolving during the performance of collaborative CCA.

#### i) The Input – Information to Feed the Cognitive Process

Hodgson [18] emphasized the homomorphism of the mental model becomes the subconscious assumption of the world as it really is. Thus, the transaction between users' mental model an information space is important during the cognitive induction. From the collaborative perspectives, the induction is known as convergence phase - the process of analyzing and organizing the information shared in a group. According to Kolfschoten and Brazier [1], there are three phases of collaboration process which are divergence, convergence and decision making.

During the divergence, the users rapidly gather, share or brainstorm the information from varying relevance, across multiple levels of abstraction and of varying granularity [19]. In consequences, collective information from the information space evolves during the process and continually emerges since the interpretation during the cognitive process required relevant information. This happens because when the impact of the uncertainties is at its optimum level, the users are willing to entertain alternate views. Thus, from visualization structure perspectives, new situations require new cognitive rules of interpretation, hence, it require the emerging of new information from information space to deepen the understanding, and further to compare, apply, analysis, relate and finally induce new knowledge that must be relevant to accomplish the collaborative CCA goal.

#### ii) The Output – New Interpretation from the Cognitive Process

Besides the evolving of information from the information space to feed the cognitive process, the collaborators also face the emergence challenge of a new knowledge from the induction of their own cognitive process. New knowledge results from the constructive alignment of the new information along with the current knowledge in the mental model. For the induction process, each of the interpretation from the mental model contributes as a new knowledge (for instance: ideas, suggestion, analysis and recommendation) for alternation.

From collaboration of cognitive, the information that shared and created by a group during the divergence phase need to be converge to a manageable size to create an overview of its content in order to make it useful for further analysis, evaluation or decision making. According to Kolfschoten and Brazier [1] , the transition from the phase of divergence to convergence causing the cognitive overloaded among the users since they are having multiple tasks. For the first stage, they need to capture and memorize the information from the information space. Then, the process of preparation and analysis is required during the transition from the phase of divergence to convergence. Through these activities, the cognitive elements of reductionism, shared understanding, classification and overview are essential to process the collective information to be outcomes for collaborative CCA. Moreover, the cognitive load are getting heavier since the collaborators need to catch up for newly emerge information from time to time during the performance of collaborative CCA.

### 2.2 Mental Space

Mental space refers to the space in which internal mental events and operations (e.g. interpretation, apprehension, induction, deduction, memory encoding, memory storage, memory retrieval, judgement and classification) take place. It is mediating reality from people's mind and brain. According to Goswami [20], mental space is a core to guide how people handle everything in life. Hence it is where the process of cognitive performs. In the collaboration of the management teams – usually between experts and decision makers, the mental space become more complex since each of the team members have different mental model that need to work together in order to accomplish the same goal of collaborative CCA [21, 22, 23]. Thus it is essential to create an environment where those mental spaces will continually guide, grow and develop [24]. Therefore, an appropriate environment will guide the process of making the shared mental model between the collaborators. Here is where visual representation can play a role to facilitate the environment in performing the collaborative CCA. According to Senge [24], visual representation is the best way to table up the mental model that everybody can look on it. Being an explicit and structural, the visual representation is able to guide and clarify the process of collaborative CCA with clearer picture – with that, the users have the opportunity to deepen their own knowledge and conscious in producing the output.

Basically, cognitive process is a dynamic process and capability to carry out any cognitive activities, according to Kolfschoten and Brazier [1], when groups collaborate they often go through a goal oriented cognitive process with roughly three phases which are diverged to gather, share the information and later converge the information. It is important to create meaning and share understanding and the outcomes are valuable for decision making. From here, we can observe that the mental space have three important elements in the cognitive process which are: i) Goal – understand the task or function that the mental try to accomplish, ii) Input to accomplish the divergence phase according to CCA goals (an input is come from information space that will be discussed further in the next paragraph. iii) Output as the outcome from the convergence phase that is valuable for making decision.

On a larger context, cognitive overload during the transition from divergence to convergence phase is due to the evolving information from the emergence of uncertainties. It causes effects such as impaired performance and decision making, stress, difficulty to retrieve knowledge, impeding creativity, and difficulty to analyze and organize knowledge, impeding schema building and learning [25]. Since mental model is the cognitive patterning for the users, the moment we improve our effectiveness in the environment, we have made a step of improved correspondence between the mental model and the evolving of information during the cognitive induction [18]. Thus, by having representation space that capable to structure and construct the emergence of information, we facilitate better correspondence between the mental model and the evolving of information during the collaborative CCA.

Since we have a huge amount of visual representation diagrams, techniques and methods, it is difficult to provide specific visual representation that is suitable for all cognitive process. For instance, the visual representation for strategizing business development might differ from analyzing the competitor advantages. Therefore, as a prerequisite, it is important to understand the context usage to determine the goal for mental space. One approach to reveal the context usage is by understanding why and how the users need to use visualization [7]. By understanding the entire contextual situation and to provide input (from information items) to specifically address open-ended questions by focusing on the user's goal and information needs [26].

### 2.3 Representation Space

Representation space acts as a mental interface that could connect the human mind to the information space. Thus, the design of representation space fundamentally influences how users perceive the information space. Although the representation space gives information a tangible form by making it accessible at the interface level, they seldom encode the totality of an information space. With limited capabilities of visual representations, display technologies, and user's cognitive load, it is essential to make sure the presented information is sufficient to fulfil the user's information needs.

According to Sedig *et al.* [27], current visual design for representation space supported information items are encoded and stored internally and are not directly accessible to users. The only access that users have to the information is through the representation space, at the visually perceptible interface of a tool. To handle collaborative CCA, it is often not possible to provide a single representation space design that sufficiently meets the user's information needs especially for large, multi-faceted, and constantly changing information. While the representation space is a component that contains the abstract and detailed information but without the interactive component, content in the form of visual representation is simply a static image with exploration constraints. Thus, the interactive elements play an important role in the cycle of forming expectations and insights. However, Sedig and Parsons [4] has done a comprehensive job to fulfil the needs for interaction space design for complex cognitive activities.

While interactive design has taken care of constructive visual interaction where actions are performed and consequent reactions occur—that is, it is an additional layer added to visualizations, we are still lacking of representation space that is applicable for dynamic information feeds, real time visualizations will emerge as a new set of elements come in as time transpires. Therefore we intend to focus more on representation space design for the collaborative CCA. In a larger context, we hope the outcomes from both studies will complement each other to form a comprehensive guideline to consult the visualization design for the collaborative CCA.

The prime challenge for representation space in the collaborative CCA is basically to answer one question - how to handle the emergence of information during the collaborative CCA? Here, we intend to further investigate how current visual design in the representation space handles the emergence of information challenge. Despite discussing of numerous new tools, mechanism and techniques introduce in the visualization field, without understanding why and how people interpret, communicate and reason with representation space will limit our ability to have relevant design according to the collaborative CCA needs [7, 28]. Therefore, we attempt to further understand the challenges of emerging information due to collaborative CCA. Accordingly, we intend to propose an appropriate approach to handle the challenges focusing on visual design for representation space.

At a glance, we found that the determination approach is pinning the underlying thinking of the visual representation design. The information being represented in passive and determine manner to the users (e.g power point, prezi and Keynote) locks the collaborative CCA into a course that disregards any input other than information provided by the computer space. Pre-selected set of information and visualization to support users viewing static without interactivities with or annotate the information is obviously irrelevant for discourse. Whereas, from the collaborative perspective, we found the study by Isenberg [3] and Hodgson [18] have shed some light on the importance of engagement between the users' mental model and the information environment. According to Isenberg, for the higher level of interactivity between users and information environment lead to higher level of engagement of social interaction, from viewing, interacting/exploring towards sharing and creating. Thus, the visual design should be capable of actively uploading and sharing the input from the users during the collaborative CCA. However, based of classic space-time matrix settings and five application of real world example for collaborative scenario [3] as we can see - the collaborative visualization is more in solving complicated instead of complex challenges. Interactivity capabilities in these studies are relevant for creating new visualization and prediction from the database is clearly inadequate to handle the evolving information from emergence of uncertainties as discussed in previous section 2.

Moreover, we do realize that the visualization-computational based is rooted from computer science field, hence computer supported concerns more on the accuracy and integrity of the data, thus limit any new input elements without integritry to be in the representation space. Whereas, it is in contrast with the needs for collaborative CCA. Since complex cognitive process is exploring alternatives, it diverge new interpretations of ideas, suggestion and abstraction that might be wrong and far from integrity to be gathered, shared and brainstormed. At this point, accuracy and integrity might cut off the possibility of improvisation and deviation and the chance to adapt new input. At some extent, the dynamic visual representation make it more flexible for the new input elements, however they are still in need some improvement on the elements of modifiability and perceived finishedness [29] and [30]. These elements are crucial in the collaborative process. Modifiability is a level of capability of visual representation to dynamically react according to any changes in the collaboration process. Modifiability encourage the participant to offer contribution, enhance the prossibility of interaction and ammend the visual representation. Meanwhile perceived finishedness is a level of visual representation resembles a final and polished product. By providing the visual representation that seems incomplete might encourage the users to modify and contribute to the representation space during the collaboration process. It gives confidence to the users that the visual representation still needs improvement for perfection. In the contrary, giving the polished and perfect looks on visual representation might hesitate the users to make any alteration or changes. In sum, we identified TWO gaps of visual design in handling the challenges of evolving information of uncertainties in collaborative CCA:

- Visual design need to be more dynamic (flexible, open for changes, responsive, react and amenable) to handle close interactivity between users mental model and information in their environment. From visual structure perspective, we need to have a better design for representation space that act as the mediator between mental space and information space.
- Visual design needs the elements of modifiability and perceived finishedness to encourage and motivate the users to become more engaged and motivated during the social interaction.

## 3.0 THE DYNAMIC APPROACH FOR VISUAL DESIGN

Although determined approach is practical and bring benefit for rational analysis in some domain of relative predictable, somehow it reduce the considerations of options that lead to the lost of flexibility and anticipation. Effective decision in the 'uncontrollable world' needs an approach to deal with the missing unruly half to match between the cognitive process and the information space [18]. Therefore, it is important to implement the theory of second order cybernetics that can provide the dynamic feedback loop in the close interactivity between the mental space and the representation space. Due to response and stimulus from the mental and representation space in the feedback loops will affect the users' behavior and information construction during the cognitive process.

### 3.1 Second Order Cybernetics

Second order cybernetics highlights the importance of the users being investigators, who are always engaged cyberneticaly with the representation space (system) being observed. In the case of collaborative CCA for the management teams in the organization, when the representation space facilitates the collaborators' mental space, they affect and are effected by it. According to [18], the decision maker is not simply an observer but is also a participant who cannot abdicate from personal ethical considerations and ultimate responsibility even in the face of uncertainty. It is similar to constructivism model of cybernetics system where the output from the collaborators depends upon his or her background and contextual. Basically, cybernetics is a transdisciplinary approach in exploring regulatory system, their structures, constraints and possibilities. Cybernetics is applicable when the representation space as a system being analyzed is involved in a closed signaling loop: that is where action by visual representation generates some changes to the collaborators and vice versa.

Since our research emphasizes more on the process of collaborative CCA, we need to be more sensible to engage the users during the communication process. Therefore, we need to extent the perspective of interaction to the perspective of interactivity and communication in the feedback loop. This attempt on communication and interactivity values for the emergence has been greatly influenced by the works of Eppler and Bresciani and Flensburg [31-33]. Thus, the visual design for the representation space must convey the underlying users cognition and perception. Moreover, according to [8], visual representation design within communication perspectives should be able to: i) help to coordinate collaborators in the communication process, ii) get and keep attenting by identifying patterns, outliers and trends, iii) improve memorability, remembrance and recall, iv) motivate, inspire, energize and activate collaborators, v) foster elaboration of knowledge construction in the collaboration and iv) support the creation of new insights by embedding details in context showing relationships between objects.

By embedding second order cybernetics theory for visual representation space, the users will be able to construct and refine their knowledge iteratively [9, 4]. Thus, the information as the content of visual representation will be constructively evolved according to the collaborative CCA process. The emergence of information can be added, merged and deleted according to the transition process of collaboration from divergence to convergence and up to the decision making phase. Through the visual design we hope to achieve a concise reconstruction of the information in the representation space.

### 3.2 The Dynamic Interactivity

We propose the dynamic yet guided visual structure as a basis for visual representation to handle evolving information due to emergence of uncertainties. Thus we need the dynamic feedback loop to pin the underlying visual representation design for better interactivity between users' mental space and the information space. According to Hoque and Baer [2], having a feedback loop will sustain the system and act as the basis of interactivity between the mental and representation space. By providing the basis visual structure that allow modifiability for the content, we intend to give the element of perceived finishedness to the users. Further than that, collaboration need cooperation from multiple users. Thus, it is important to engage their cognitive activities together. Accordingly, by having the dynamic feedback loop, the users are free to amend and add new input in the representation space. During the cognitive process, the amendment is according to current update based on the emerging of the information. Since the concern of visual design for this research is performing collaborative CCA, thus the input needed by the users is to spark or motivate the communication. It is to make sure users are clear, understand and engage in the process of cognitive and communication. Thus, accuracy on the emerging elements is less on the priority, it will gradually refine and modify through the process.

The concept of dynamic in the closed feedback loop is closely related to the concept of epistemic cycle by Sedig *et al.* [14] to accomplish the mental space's goal. In this cycle, the mental space repeatedly process and align the incoming input to accomplish the goal and come out with the cognitive output of it. Thus, from interactivity perspectives, the users will perform the actions upon the representation space and perceive its reactions as shown in Figure 1. An epistemic cycle is carried out between users' mental space, internal to them, and the visual representation as an external environment. As with many cognitive activities, users will need to exert some kind actions to externalize their thought process and, along the way, alter the representation space to support their mental operations in a distributed manner [4]. Through such process, users manage to dynamically interact between higher level mental abstractions and lower level details in the external representation space, and this level of support is needed for them to explore a problem or phenomena.

Important conclusions drawn from this work have shown that the dynamic approach towards the constructive of visual representation space has the potential to facilitate the cognitive process, guide the users and unfold the emergence information from moments to moments during the cognitive process.

We identified four benefit of dynamic visual representation space, which are as follows:

- To act as the shared mental model to centralize the differences among the collaborators for the evolving of emergence information.
- The explicit guidelines to enhance clarity.
- The visual structure that enable the elements of modifiability and perceived finishedness to engage and motivate users to contribute
- The references to extend the mental space limitation.

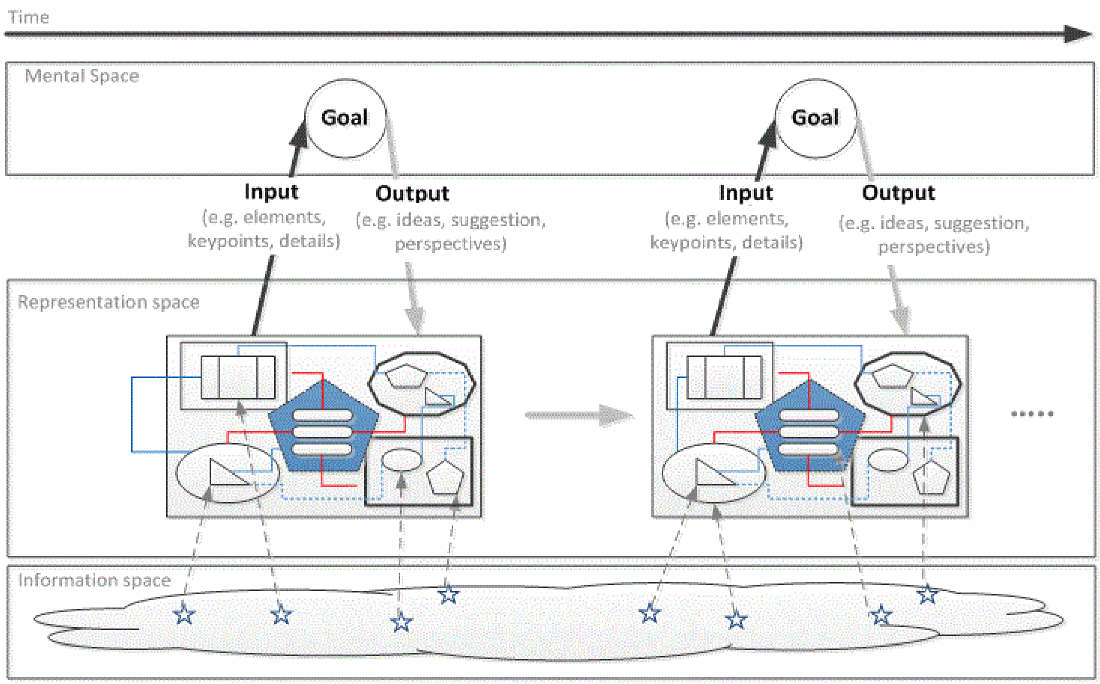


**Figure 1** The process of users performing epistemic actions upon the representation space

## 4.0 DYNAMIC CONTEXTUAL DESIGN SOLUTION

We propose to concentrate on the contextual of representation space for the dynamic design solution. According to Eppler [22], structure and guidance are required to frame and focus thought during the process of sharing, creating and integrating information across epistemic boundaries. Therefore, our study seeks an importance of visual structure as the contextual of representation space to centralize, guide and extend the mental space dynamically during the process of collaborative CCA. In designing the visualization based on complex cognitive processes, the study of [1, 6, 26, 34, 35] explains that the structure is the critical element in the foundation of semantic relationship in representating visualization and solving complex cognition activities to a more detailed tasks and activities is essential for visualization interaction [4, 6, 36, 37].

Previous studies have shown how visual structure was used to reduce the cognitive load, especially for the higher level cognitive process. Mengis [38] justified that the visual structure facilitate experts and decision makers and give benefit towards knowledge integration. Earlier than that, the study of Albers [26] has developed user-recognizable structure that is capable to map between mental model with the current situation. Whereas Kalfschoten [1] proposed a pre-structure framework as a basic convergence of knowledge in the complex collaboration process and Vitiello & Kalawsky [39] justified that the interactive visual structure is capable to collect systemic insight in emergent behaviours.

The underlying theories about visual structure are mostly based on Cognitive Load Theory and Cognitive Architecture [40, 41]. It enlightened the visual structure in supporting the cognitive architecture to reduce extraneous load. They also highlighted the essential of pre-structure framework as a basis for knowledge understanding. Apart from that, distributed cognition theory has emphasized the visual structure as a basis for external representation to interactively couple the internal human mental model [37].

Ziemkiewicz [35] described the process of how people interpret the visualization as 'the cycle of forming expectation' process. Basically, to interpret visualization, the process between making hypotheses at a higher level structure and later confirming the hypotheses through checking the relevant details at a lower level. Thus, we can see the potential of visual structure at a higher level to act as the contextual while the relevant details at a lower level is the content of representation space. The cycle of forming expectation will recur iteratively until the users are satisfied and get the fuller understanding of the problem or the phenomena for collaborative CCA. Ziemkiewicz [35] proposed visual metaphor to be at a higher level visualization structure in handling higher level cognitive. While Tergan *et al*. [42] applied concept mapping to explicit and structure the relationship between knowledge concepts and Berstchi [11] proposed the storytelling concept as a basis structure in visualizing knowledge. Therefore, we propose the visual structure as the contextual will centralize, extend and share mental model in order to manage the content. Following the contextual as the guidelines, the content will then dynamically evolved according to the emergence of information during the collaborative CCA.

## 5.0 DYNAMIC CONTEXTUAL VALIDATION

We intend to demonstrate and later validate how dynamic contextual of representation space is capable to facilitate the collaborative users to handle emergence of information. The unit of analysis for this research is the interactivity process between the users and the visual representation design. Based on the need to understand the interactivity process, we need to observe the phenomenon throughout the collaborative process [3, 36]. The method requires events must be in the natural settings and to perform better within the real context. Thus, the qualitative method is the most relevant of all methods [43]. However, since we are validating the framework, the qualitative analysis will be carried out deductively. Through deductive approach, our research questions will become more specific – what are the capabilities of dynamic contextual for representation space in facilitating collaborative CCA?

For this particular paper, we would like to see how it gives impact to the novice users and later on the expert users [44] and the differentiation is according to the management skills criteria. So far we have conducted two experimental classes for the novice category. We categorize and select the novice respondents, who are still new in the business domain and basically didn't have much experience, training and skill to handle management tasks. Thus with the help of Young Entrepreneur Programmes by Malaysia Agricultural and Research Development Institute (MARDI), we manage to approach two novice groups from the Small and Medium Enterprise (SME) category to be our respondents. In order to observe the interactivity process in natural way, we intend to run the experimental class by applying the case study. Since the validation is a case study basis, the experimental class seems to be more flexible and open-ended to adapt the real case necessities [36, 45]. We adapt the steps from Lengler and Eppler [46] as the guidelines to demonstrate the dynamic contextual for visual representation design. After understanding the users' context usage, we discussed and agreed for the CCA type and subject domain that is relevant to the respondents' context to be our case studies through experimental class (please refer Table 1).

**Table 1** The group, type of CCA and subject domain for the experimental class of case studies

| Group | Type of CCA | Subject Domain |
|---|---|---|
| Novice 1 (4 respondents) | Product Development Strategy | Agriculture investment for 18 acres land at Nilai, Negeri Sembilan |
| Novice 2 (5respondents) | Business Developement strategy | Business investment in 2500 squarefeet land at Kuala Lumpur |

During the experimental class, we only provide two main elements for the validation. First is the goal of the complex cognitive activities to be performed (based on our early agreement with the respondents during understanding the context usage phase). Second is the dynamic contextual of visual structure to facilitate the respondents during the collaborative CCA. Since the validation is case study basis, the experimental class seems to be more flexible to adapt the real case necessities, the respondents, points for discussion and the environment of the discussion are based from the real case. Using this method, we have invited a group of management teams from the organization to perform the CCA in the mode of face to face collaboration (e.g: meeting, discussion and workgroup). The class experiments took around 90-120 minutes. During the experiments, the respondents in the group of 4-6 people were gathered in the meeting room. Based on the goal, we suggest the group to discuss as in the normal meeting or discussion as long as they refer and utilize the provided visual representation. We then observe the interactivity process on how the dynamic contextual of visual structure design is capable to facilitate the collaboration of 4-6 people to perform complex cognitive activities.

We bear in mind that the main goal for validation is to see how the dynamic contextual of visual structure design is able to facilitate the users in handling the emergence of information while performing the CCA. Thus, the data collection must capture the data related to the dynamic contextual of visual structure design. In doing so, we intend to triangulate the analysis from three sources of data collection to capture the interactivity process. Three data collection methods were applied during the experimental class observation, which are: i) audio recording for discussion among the collaborators, ii) video recording for action observation during the experiment and iii) content record in the visual representation structure [43]. Accordingly, thematic analysis was carried out after the transcription for the two cases. Analysis was conducted based on the deductive qualitative analysis.

In order to perform thematic analysis, we read and capture the relevant quotation from the script. Each quotation will be grouped according to the similarities and the new subthemes will emerge from the group. The collection of subthemes should then support the theme. Since we are validating the visual structure, triangulation is essential to complement each of the quotation along with video on action and observation that are related to visual representation instruments. From the analysis conducted, we found the contextual of representation space is capable to dynamically handle the emergence of CCA contents. Through the interactivity process between the users and the representation space, we found that contextual of representation space was capable to centralize the mental model between collaborators. Thus, it gives clarity during the performance of complex cognitive activities collaboratively. The unit and subthemes emerge from the deductive qualitative analysis support the contextual of representation space as shown in Table 2 follows:

**Table 2** Unit and Subthemes for the contextual representation space themes

| Unit | Subtheme | Theme |
|---|---|---|
| • Constructing other's knowledge<br>• Explicit the abstraction. | Breaking silo | Centralized Mental Model |
| • Understanding other's roles<br>• Adapting other's expertise and knowledge | Leverage roles during the process | |
| • Reduce duplicating<br>• Highlighting explicit content<br>• Showing interconnection between elements<br>• They know that they don't know | Avoid blurriness | Clarities |

One of the interesting findings from the case study, we identified the potential of dynamic contextual visual structure to foster innovative thinking. The capabilities for the users to pick up the evolving content and assimilate it to the previous content in the structured and organized context are capable to produce new interpretation that is valuable for business. This finding is inductively analysed once we identified a few emerging of subthemes throughout the analysis as shown in Table 3 below.

**Table 3** Foster Innovation Theme

| Unit | Subtheme |
|---|---|
| • Content evolvement<br>• Pull pieces of puzzle together<br>• Cross system (Interconnection) | Constructive process |
| • Adaptation (new information into current information) | Sustainability |
| • Practical outcomes<br>• Understanding why and how for each of the interpretation. | Value for business |

## 6.0 CONCLUSION AND FUTURE WORKS

Throughout this paper, we show the potential of dynamic element to handle emergence information for CCA especially in the collaborative settings. Looking from the lenses of collaborative visualization, we have found that the challenges arise because in emergence case, visual design need to be more dynamic and at the same time, the element of modifiability and perceive finishedness are important to engage collaborators during the process of CCA. Besides the fact that this study has validated the benefits of dynamic visualization in handling the emergence in collaborative CCA, we also found that it is sufficient to handle the basis of collaborative issues – conflict resolution and collective problem solving [22]. Further than that, we found that second order cybernetics theory is able to frame the idea of open ended visual representation, it provides dynamisms and flexibility to knowledge construction and extension for collective mental model development among collaborators. It is also interesting to find that the overall findings lead to the potential of visual structure as the foundation to spark the innovative thinking during the cognitive process.

The evaluation's core findings have justifies the benefits of dynamic contextual visual structure to handle the emerging information. The deductive qualitative analysis has identified the subthemes of breaking silo and leverage roles during the cognitive process support the theme of centralize mental models. Moreover, the subthemes of avoiding blurriness and smooth progress justified the benefit of contextual visual structure to bring clarities during the performance of collaborative CCA. It is also interesting to find the potential of dynamic approach as the foundation to spark the innovation during the cognitive process. As observed, the contextual structure is capable to guide and organize the new emergence element to assimilate with the previous content. The explicitness of assimilation process brings clarities on the interconnection and construction of information in the representation space; hence bring clarities on the interconnection and construction of knowledge in the human mind. As a result, the collaborators are able to grab the real understanding on how and why for each of the cognitive interpretation. According to Keeley [47], understanding the real question of how and why is the key to spark for valuable innovation.

Through this research, we also demonstrate how to 'connect pieces' between interdisciplinary fields in solving the emergence information for collaboration in the CCA. The integrative approach is able to bring values form academic field to benefit the practice in the organization. By demonstrating the use of the dynamic contextual of visual structure in the real settings of organizations, it can be viewed more practically which the collaborative CCA occur. The value of visual design should be more concerned with the benefits to the teams which are definitely context dependent and deal with emergent information dependent issues.

## References

[1] Kolfschoten, G. L., & Brazier, F. 2012. Cognitive Load in Collaboration- Convergence. 2012. *45th Hawaii International Conference on System Sciences*. 129-138.

[2] Hoque, F., & Baer, D. 2014. *Everything Connects: How to Transform and Lead in the Age of Creativity, Innovation, and Sustainability: How to Transform and Lead in the Age of Creativity, Innovation and Sustainability*. McGraw Hill Professional.

[3] Isenberg, Petra, Niklas Elmqvist, J. S. 2011. Collaborative Visualization: Definition, Challenges, and Research Agenda. *IEEE Symposium on Information Visualization*. 10(4): 310-326.

[4] Sedig K., & Parsons, P. 2013. Interaction Design for Complex Cognitive Activities with Visual Representations: A Pattern-Based Approach. *AIS Transactions on Human-Computer Interaction*. 5(2): 84-133.

[5] Schneiderman, B. 1996. The Eyes Have It: A Task By Data Type Taxonomy For Information Visualizations. In Visual Languages, 1996. *Proceedings. IEEE Symposium*. 336-343.

[6] Amar, R., & Stasko, J. 2004. A Knowledge Task-Based Framework For Design And Evaluation Of Information Visualizations. *Information Visualization, 2004 (INFOVIS 2004) IEEE Symposium*. 143-150.

[7] Huang, W. 2014. *Handbook of Human Centric Visualization. In Human Centric Visualizaton*. Springer New York.

[8] Burkhard R. A. & Eppler. M. J. 2004. Knowledge Visualization Towards a New Discipline and its Fields of Application. USI Research Note (July).

[9] Burkhard, R., A. 2005. Knowledge Visualization: The Use of Complementary Visual Representations for the Transfer of Knowledge: a Model, a Framework, and Four New Approaches. Doctoral dissertation, Swiss Federal Institute for Environmental Science and Technology.

[10] Bresciani, S., *et al.* 2008. A Collaborative Dimensions Framework : Understanding the Mediating Role of Conceptual Visualizations in Collaborative Knowledge Work. *Proceedings of the 41st Hawaii International Conference on System Sciences*. 1-10.

[11] Bertschi, S., & Bresciani, S. 2011. What Is Knowledge Visualization? Perspectives On An Emerging Discipline. *Proceedings of the 2011 IEEE Symposium on International Conference of Information Visualization*. 329-336.

[12] Masud L., *et al*. 2010. From Data To Knowledge-Visualizations As Transformation Processes Within The Data-Information-Knowledge Continuum. *In IEEE Information Visualisation (IV), 2010 14th International Conference*. 445-449.

[13] Meyer, R. 2009. Knowledge Visualization. *In Media Informatics Advanced Seminar on Information Visualization*.

[14] Sedig, K., Parsons, P., & Babanski, A. 2012. Towards a Characterization of Interactivity in Visual Analytics. *Journal of Multimedia Processing and Technologies.* 3(1): 12-28.

[15] Thomas, J. J., and Cook, K. A. 2005. Illuminating the Path: the Research and Development Agenda for Visual Analytics. Los Amitos, CA: IEEE Comput. Soc.

[16] Bates, M. J. 2005. Information And Knowledge: An Evolutionary Framework For Information Science. *Information Research*. 10(4).

[17] Johnson, J. 2010. Embracing Design In Complexity. In T. Z. (Eds) Katerina Alexiou, Jeffrey Johnson (Ed.). Embracing Complexity in Design. 193-203.

[18] Hodgson, A. 2009. Decision Integrity and Second Order Cybernetics. Cybernetics and Systems Theory in Management: Tools, Views, and Advancements. 52.

[19] Briggs, R. O., Kolfschoten, G., Vreede, G. J. D., Albrecht, C., Dean, D. R., & Lukosch, S. 2009. A Seven-Layer Model Of Collaboration: Separation Of Concerns For Designers Of Collaboration Systems. *ICIS 2009 Proceedings.* 26.

[20] Goswami, B. 2004. *The Human Fabric: Unleashing the Power of Core Energy in Everyone*. Aviri Publishing.

[21] Mengis, J., & Eppler, M. J. 2008. Understanding And Managing Conversations From A Knowledge Perspective: An Analysis Of The Roles And Rules Of Face-To-Face Conversations In Organizations. *Organization Studies*. 29(10): 1287-1313.

[23] Yaacob, S., Ali, N. M., & Nayan, N. M. 2013. *Understanding Big Picture and Its Challenges: Experts and Decision Makers Perspectives. In Advances in Visual Informatics.* Springer International Publishing. 311-322.

[24] Senge, P. & Jaworski, J. 2011. *Synchronicity: The Inner Path Of Leadership*. Berrett-Koehler Publisher.

[25] Eppler M. J., Hoffmann, F., & Bresciani, S. 2011. New Business Models Through Collaborative Idea Generation. *International Journal of Innovation Management*. 15(6): 1323-1341.

[26] Albers, M. J. 2004. Analysis for Complex Information : Focus on User Goals, Information Needs, and Information Relationships. Coping with complexity. University of Bath, London.

[27] Sedig, K., Parsons, P., Dittmer, M., & Haworth, R. 2014. Human-Centered Interactivity of Visualization Tools : Micro-and Macro-level Considerations. (W. Huang, Ed.) New York: Springer Science Business Media. 717-743.

[28] Hundhausen, C. D. 2014. *Evaluating Visualization Environments: Cognitive, Social, and Cultural Perspectives. In Handbook of Human Centric Visualization*. Springer New York. 115-145.

[29] Hundhausen, C. D. 2004. Using End User Visualization Environments to Mediate Conversations : A Communicative Dimensions. *Journal of Visual Languages and Computing*. 16(3): 158-185.

[30] Bresciani, S., Blackwell, A. F., & Eppler, M. 2008. A Collaborative Dimensions Framework : Understanding the Mediating Role of Conceptual Visualizations in Collaborative Knowledge Work. *Proceedings of the 41st Hawaii International Conference on System Sciences*. 1-10.

[31] Eppler, M. J. 2006. Knowledge Integration in Face-to-Face Communication and the Moderating Effect of a Collaborative Visualization Tool (August). 1-93.

[32] Flensburg, P. 2009. An Enhanced Communication Model. *The International Journal of Digital Accounting Research*. 9(15): 31-43.

[33] Eppler, M. J., & Bresciani, S. 2013. Visualization In Management: From Communication To Collaboration. A Response To Zhang. *Journal of Visual Languages & Computing*. 24(2): 146-149.

[34] Adnan, W. A. W., Daud, N. G. N., & Noor, N. L. M. 2008. Expressive Information Visualization Taxonomy For Decision Support Environment. Convergence and Hybrid Information Technology, 2008. ICCIT'08. *Third International Conference*. 1: 88-93.

[35] Ziemkiewicz, C. 2010. Understanding The Structure Of Information Visualization Through Visual Metaphors (phD dissertation). University of North Carolina, Charlotte.

[36] Liu, Z., Nersessian, N., & Stasko, J. 2008. Distributed Cognition As A Theoretical Framework For Information Visualization. *IEEE Transactions on Visualization and Computer Graphics*. 14(6): 1173-80.

[37] Liu, Z., & Stasko, J. 2010. Mental Models, Visual Reasoning And Interaction In Information Visualization: A Top-Down Perspective. *Visualization and Computer Graphics, IEEE Transactions*. 16(6): 999-1008.

[38] Mengis, J. 2007. Integrating Knowledge Through Communication: An Analysis Of Expert-Decision Maker Interactions. Doctoral dissertation, Institute of Corporate Communication.

[39] Vitiello, P. F., & Kalawsky, R. S. 2012. Visual Analytics: A Sensemaking Framework For Systems Thinking In Systems Engineering. *In Systems Conference (SysCon), IEEE International.* 1-6.

[40] Paas, F., Renkl, A., & Sweller, J. 2003. Cognitive Load Theory And Instructional Design: Recent Developments. *Educational Psychologist*. 38(1): 1-4.

[41] Paas, F., Renkl, A., & Sweller, J. 2004. Cognitive Load Theory: Instructional Implications Of The Interaction Between Information Structures And Cognitive Architecture. *Instructional Science*. 32(1/2): 1-8.

[42] Tergan, S., Tanja, K., & Mitchell, J. C. 2005. *Knowledge and Information Visualization: Searching for Synergies (LNCS 3426.).* Verlag Berlin Heidelberg: Springer.

[43] Yin, K. 2010. *Qualitative Research From Start To Finish.* Guilford Press.

[44] Craft, B., & Cairns, P. 2005. Beyond Guidelines: What Can We Learn From The Visual Information Seeking Mantra? In Information Visualisation, 2005. Proceedings. *Ninth International Conference on IEEE*. 44-50.

[45] Dickie, M. 2000. Experimenting On Classroom Experiments: Do They Increase Learning In Introductory Microeconomics. University of Southern Mississippi Working Paper.

[46] Lengler, R., & Eppler, M. J. 2007. Towards A Periodic Table of Visualization Methods for Management. In M. Alam (Ed.), GVE '07 Proceedings of the IASTED International Conference on Graphics and Visualization in Engineering. 83-88.

[47] Keeley, L., Walters, H., Pikkel, R., & Quinn, B2013. *Ten Types Of Innovation: The Discipline Of Building Breakthroughs.* John Wiley & Sons.