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COLLABORATIVE VISUALIZATION FRAMEWORK FOR CROSS-FIELD WORKING GROUP: ANALYSIS THROUGH SMART PLS

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ABSTRACT

This study is conducted to develop a collaborative visualization framework in the cross-field working group. The goal of this project is to provide a proper framework that can be used to develop a platform to allow collaborative visualization to be implemented inter-disciplinary groups, in two different settings: university students and research groups in research and development companies and institutions. The study begins with preliminary works to define the collaborative visualization published in the previous research. It focuses on the factors to develop an effective collaborative working environment through visualization and shared understanding among the staff/users from inter-disciplinary backgrounds. In addition, this study also investigates the interaction between human cognition, collaborative factors, and ICT attributes of visualization in developing an efficient working group to achieve common goals and objectives. To conclude, the framework will be tested to validate its possible contributions to the targeted collaborative working groups. The study is hoped to contribute to the identification of factors that connect the application of collaborative assisted tools in visualization with the development of human cognition and shared understanding towards achieving efficiency especially in a multi-disciplinary working environment.

Keywords: *Cross-Field Working Group, Collaboration Visualization, Human Cognition, Structural Equation Modelling, Smart-Pls*

1. INTRODUCTION

Collaboration is deemed to be one of the essential factors that will lead to the success of the business, as well as to improve operational efficiency. That is one of the reasons why most industries have now begun to realize the importance of nurturing the culture of collaboration to stay relevant in the market. Taking example of oil and gas industry (which was hit by a major economic recession since 2015); 95% of the operators in the industry agreed that collaboration has been an integral part of their day-to-day business [1]. This figure shows a major improvement towards the acceptance of collaboration among the operators, rather than the last recorded figures for the previous two years; 86% in 2016 and 74% 2015.

The concept of bringing together people from different sets of skills and expertise to achieve a common objective might sound feasible; but this process is doubted to be much harder as it sounds. Together with the rapid development of technology assisted tools in business and commercial sectors, collaboration is thought to be the most sought-after mechanisms to ones that involve directly in the decision-making process, project management as well as business operations. This however comes with a whole new set of different challenges (that may hinder, or limit collaboration in a cross-field work group): (1) conflicting goals – a person from sales department might or might not have the same aspiration, motivation, and goal than his/her other counterparts in operations or logistics department. (2) lack of understanding on coworkers' roles, responsibilities, and terminologies – the word 'volume' is easily misinterpreted as it carries two different meanings in sales (sales volume counted as quantity), and in production (calculated in matrix like liters or ounces). (3) Unaware of coworkers' works and contributions, and the mindset of working together is too time consuming.

Effective communication is essential to establish a cohesive understanding in a cross-field working structure. Moreover, effective communication is also important to facilitate fast decision-making, thus improving productivity [2]. Traditional types of communication (physical communication) like those that involve listening, talking, and writing could no longer carry the needs of collaboration like mentioned above. Visualization is thought to be one of the most suitable tools to be added on top of the traditional communication and believed to be a better way to promote proper understanding among the team members despite the disparities in ideas and vocabulary used in multiple domains and sub-divisions.

This has brought us to the ideation of this study, which is to understand the relationship between visualization and collaboration and how can the elements of media used in visualization could help in improving the effectiveness of collaboration in a cross-field/cross-functional working group /environment.

2. LITERATURE REVIEW

According to [3], visualization is a set of image representation that is used to convey complicated ideas clearly, precisely, and efficiently. Besides that, it also possesses certain kinds of mechanisms to allow knowledge and information sharing in more impactful but simpler way [4]. Collaborative visualization is another sub-discipline of visualization which uses computer-supported visual representations to establish inter-disciplinary communications that allow people for different backgrounds to work together, share, sort and find information to achieve a common goal [5].

The merger between the ideas of collaboration and visualization promotes several techniques and approaches to connect human cognitive skills of analysis and computer technology.

2.1 Cross-field Collaboration

Based on research conducted by [6], the involvement of employees and managers in collaborative activities pertaining to their roles and functionalities has increased by 50% in these past two decades. This figure has shown organizations and companies' seriousness in embracing the collaborative endeavors especially in breaking the wall of conventional hierarchical business practice, which involved series of decision-making procedures into a long chain of operational process.

Most of the organizations that opted to this conventional working practice usually divide their operational process into smaller divisions; that will carry out specific roles and functionalities. Each of these divisions will then work independently to complete their part and then hand over the activity to the next division driven by the series of long decision-making procedures.

To counter the flaw of this traditional method, cross-field collaboration (also known as cross-function collaboration) has been introduced by fostering the idea of bringing together array of specialists that were once separated according to their roles and functionalities, into one group, which thru it they can jointly work, think, and develop new ideas and solutions in conjunction with the organization's operational process. Besides that, cross-field collaboration is also thought to be one of the most relevant mechanisms that could help in reducing the likelihood of rework, redundancy, and other unnecessary activities; that usually causes delays in the process of transferring knowledge and information as what has been implied thru the conventional hierarchical methods [7].

A paper published by [8] has also stated that cross-field collaboration could have a major impact in enhancing efficiency of a particular cross-field working group, especially thru the processes that are important in stimulating the motivation, self-regulation, synergistic output, and confident level of the group's members.

2.2 Knowledge Integration Mechanism

A study by [9] has suggested that an organization that wishes to adopt cross-field collaboration practice in their operation must first develop a refined structure mechanism, in order to address the aforementioned challenges and differences. According to [10], structure mechanism is necessary for effectively integrating knowledge intensive work like the one involved in multi-disciplinary works and discussions. This supposition is basically made upon research conducted by [11], which stresses on the importance of structural mechanism reformation to process multidisciplinary information due to changing of environment and setting.

In this kind of structural mechanism, members of cross-field collaborative working group are benefited from the formal structural specification setting created in the collaborative working group, to stimulate member's ability to coordinate their

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activities, thinking and practices in accordance with their shared environment and common objective [12].

In simpler words, this mechanism emphasizes how structural composition plays a role in shaping the way the knowledge is integrated, thus resulting in more synchronized work practices among collaborative group members. This structural mechanism is called knowledge integration mechanisms and was initially pioneered by [13]. which instigates the importance of any organization to implement these mechanisms in their operation, to embrace the overwhelming amounts of information shared and later being produced, out of the collaborative working environment.

According to the study by [9], knowledge integration mechanisms involve several formal processes and structures that are essential in the process of delivering, accepting, and synthesizing different types of knowledge among group members. These processes include a series of information-sharing meetings and discussions to support common understanding among the group members. Through these activities, group members can also contribute to the process of recombining intelligent resources in such a way to help the organization to exploit the knowledge for the sake of future innovations and advancements.

2.3 Shared Mental Model

In overall, human cognitive system is said to be contained of individual mental model, which is responsible in organizing knowledge structures, that are illustrated based on reality in accordance with human's capability in interpreting and interacting with their surroundings [14]. However, in a group setting, every member's mental model must be integrated to project a single knowledge structure, thus creating common understanding among them. This has led us to the theory of shared mental model that can be expressed based on two elements: task and team mental models.

Based on earlier research related to mental model, it could be deduced that mental model acts like a "gatekeeper" that will guide an individual to either process, or neglect the information based on what they perceive in the world surrounding them [15]. The concept of the mental model has since been applied in many sectors particularly business and organization management, knowledge transfer processes, human-technology interaction, and even decision-making procedures. The coordination between multiple mental models will then form what is called the shared mental model. The shared mental model is often regarded by previous researchers as one of the most effective tools in promoting an effective collaborative working practice among group members, without the need of having too much communication.

This is because, the theory of shared mental model emphasizes in the process of creating similar knowledge structure among the group members, which is in reluctance of their personal perceptions, and interpretations that they created in their individual mental models. This theory is basically acted as "binding mechanism" that will uphold tightly the individual mental models and subsequently provided a cognitive map on where and how information and knowledge should be organized to complete a similar task [16].

The shared mental model also comprises of two different components which are, tasks mental model and team mental model. Research by [17] has underlined that task mental model consists of task content and equipment, while team mental model consists of team content, and team interaction.

She then put it into simpler explanation as task mental model is consistent with the idea that teams need to perform activities related to the task (task work) and team mental model reflects how well the team works together (teamwork). Previous research conducted by [18], has also indicated that these two components technically coexist even though numerous researchers chose to separately treat these components as a separate entity.

This is because [18] believed that the group members should first develop task mental model, as a sense of familiarization, and eventually forming team mental model, once they are well understood on their tasks, works, all other requirements that will allow them work together as a team. This process is undoubtedly will require some time as the process of familiarization might take a little while to facilitate more space for the group members to develop their understanding before they can form their own interpretations and perceptions to the task that they were assigned to.

Once the group members abled to comprehend these two components of shared mental model, they can then transform the information that they have mutually contributed into sets of meaningful models, thus increasing the efficiency of the group towards achieving the same goal. Conclusively, shared understanding that they have created out of the implementation of shared mental model will somehow hasten the exchange of meaningful communication that is important in creating new knowledge.

2.4 Collaborative Visualization

Visualization is deemed to be one of the supporting tools that can provide a natural and beneficial way to elicit difference in the perceptions and interpretations that someone holds as part of their individual mental model [19]. With a proper techniques and approaches, visualization can contribute to enhancing comprehension, memory, thus facilitating the process of decision-making as well as widening an opportunity for the group members to further involved in the exploration of new knowledge and analysis [20].

By stimulating the process of expressing mental models through visualization can postulate greater degree of freedom to express concepts in ways that the members aren't usually be able to. This will somehow help the members to gain confidence and subsequently improve their willingness to contribute towards a shared commonplace, as what the shared mental model suggests. This is because, the pictorial representations that consist in the visualization can help in supporting the evidence that are somehow more complicated to be deduced based on verbal explanations.

The term collaborative visualization was first expressed by [21] as the "subset of CSCW applications in which controls over parameters or products of the scientific visualization process is shared". From this point of view, collaborative visualization is developed as part of CSCW that emphasizes collaboration with interactive, manipulable visualizations for the scientific visualization community. This definition however has been opposed by [5] as they believed that the definition is overly restricted by limiting the power to control or manipulate the visualization only to the scientific visualization community. For this reason, they have proposed a broader definition of collaborative visualization, that also considers the elements of CSCW and by emphasizing on the shared use of interactive visual representations and information processing to help amplifying the cognitive factors involve in the development of collaborative visualization.

> *"Collaborative visualization is the shared use of computer supported, (interactive), visual representations of data by more than one person with the common goal of contribution to joint information processing activities."*

Figure 1: The general definition of collaborative visualization drew by [5].

From the definition, it can be deduced that collaborative visualization is a set of interactive visual representations that would allow users (regardless expertise and communities) to joint viewing, interacting with, discussing, or interpreting the representation. On the other hand, the term "information processing" is used to acknowledge the contributions of several theories related to cognition which describes the situations of which users belonged to different groups and expertise come together to jointly think, provide, and discuss to achieve one final consensus result or understanding [22]. Besides that, the broad definition of collaborative visualization would also make significant use of the groupware matrix developed by [23] through a vague distinction between each group or categories, that will allow any systems or applications for collaborative visualizations to cross boundaries and utilize both synchronous and synchronous elements of the classifications.

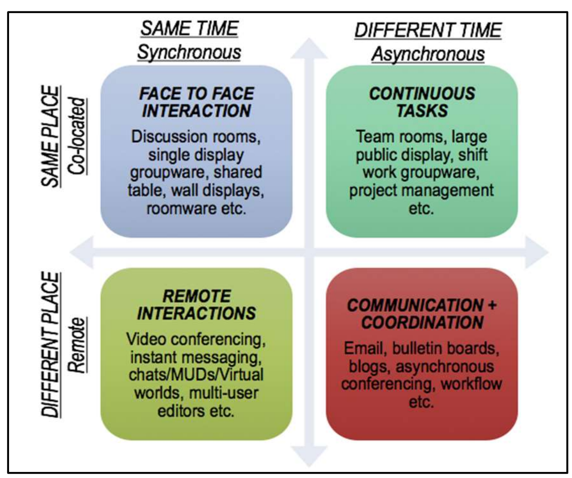

Figure 2: Time/Space Matrix proposed explaining four major scenarios in collaborative work.

Space-time matrix of collaboration specifies a couple of potential collaboration scenarios. Note that a system does not have to fall exclusively inside one

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of the four categories, e.g., online visualization websites where users can cooperate both in real-time and asynchronously. Level of understanding between people from various groups (cognition) can't be classified as sole indicator to determine the performance or quality of a collaborative visualization system; instead, other contributing factors like levels of engagement between users and the system must also be considered to provide a broader perspective to the available visualization approaches.

Once again, [5] has contributed to defining a proper categorization on how levels of engagement could assist users to correlate between the intervention of technology and computer-supported system to the possibilities of creating new analysis on the data or information that they shared using collaborative representations. Levels of engagement can properly be addressed through these three categories:

Table 1: Level of Engagement

Level 1	Viewing	Visualization system that assists the users to view static or animated visualization without proposing any interactive platforms that will allow users to engage with the system or annotate the represented information. This level of engagement is commonly used in scenario like classroom, lectures or meetings that involve only one presenter to teach or explain for his/her counterparts that belong to a larger group of people. This kind of visualization might help in discussing or interpreting pre-selected set of information.
Level 2	Interacting and Exploring	Users from various settings are given freedom or ability to choose and select alternative views of the data that can be used for personal or collaborated interpretation, analysis and discussion. For remote or distributed settings, several forms of communications are implemented in the system including chats, comments, emails or video/audio links. A face-to-face communication can also be done in collocated settings, which is to discover and explore different and wider aspects of the data, accounting alternative interpretations among the users involved and to discuss within a bigger context.
Level 3	Sharing and Creating	At this level, user-generated contents are implemented into the system. Users are given ability to create, upload, and share new datasets and visualizations. This level of visualization is becoming more attractive especially in catering larger group of people as well as to promote some kind of awareness of which inputs and views from multiple parties is highly regarded.

The combination of three major factors; time/space dimension (groupware matrix), cognition and level of engagement into a collaborative visualization system will open more possibilities in developing an advanced collaborative visualization system. Besides that, [25] also explains that collaborative visualizations must consider elements of computer graphics, perception, software development, interaction, cognitive and social psychology, etc., to achieve the final goal.

2.5 Media Synchronicity Theory (MST

Media Synchronicity Theory (MST) has been used to further elaborate the connection between human cognition and visualization. A review wrote by [26] emphasized the importance of Media Synchronicity Theory (MST) in the development of visualization system. MST comprises of five different principles, that would reflect media richness and characteristics in the process of creating shared understanding and cognition among the audiences through visual assistance.

Five principles of MST are: reprocessability, transmission velocity, symbol sets, parallelism and rehearsability. The diagram below shows the basic concept of SMM in relation with MST:

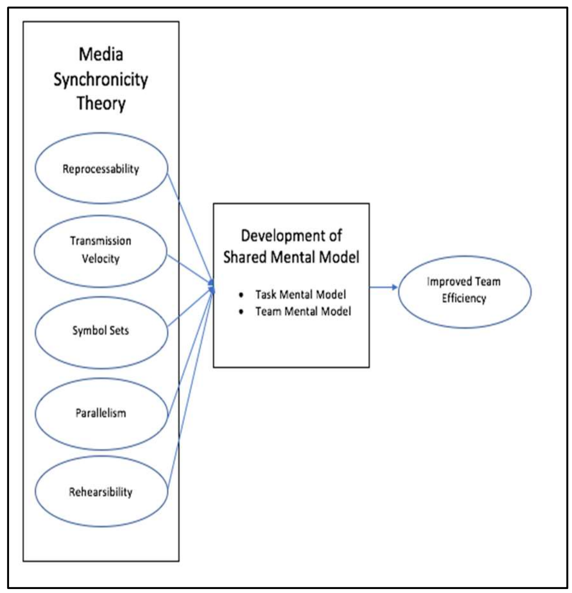

Figure 3: The initial model that shows the relation of MST and SMM.

As was aforementioned in the introduction, this study aims to solidify the foundation laid out in previous research/studies that independently investigated collaboration, knowledge integration mechanisms, shared mental model as well as media synchronization. This has left us with a gap to fill in, which in a way is hoped to be beneficial for us to explore on how could all of these elements are related to each other, why some of them might or might not necessarily be related to the whole equation and what could be a possible impact if one of them is enhanced or dropped from the whole equation (situation), especially in facilitating collaboration in the cross-field/ cross-functional work groups or settings.

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3. METHODOLOGY

This study is designed based on quantitative research method, which utilizes the usage of questionnaire, tailored to test every construct (element), and variables involved in testing the hypotheses used for the study. The quantitative research method was picked because of its nature, which stimulates deductive reasoning that allows researchers to form hypotheses, collect data and conduct analysis which allows the hypotheses to be proven right or wrong. In this study, a survey was conducted to establish a correlational analysis between the variables used in this study, to best verify the hypotheses that were initially proposed in this study.

3.1 Research Methodology Framework

The framework was carefully lined out to direct this research study to achieve its initial aims. Figure 2 depicts the breakdown of the research methodology adopted for this study.

To summarize, the methodology was laid across four consecutive phases; background study and research topic discovery, conceptual framework development, questionnaire development and deployment (data collection), data analysis (validation of results) conducted via PLS-SEM techniques and its evaluation.

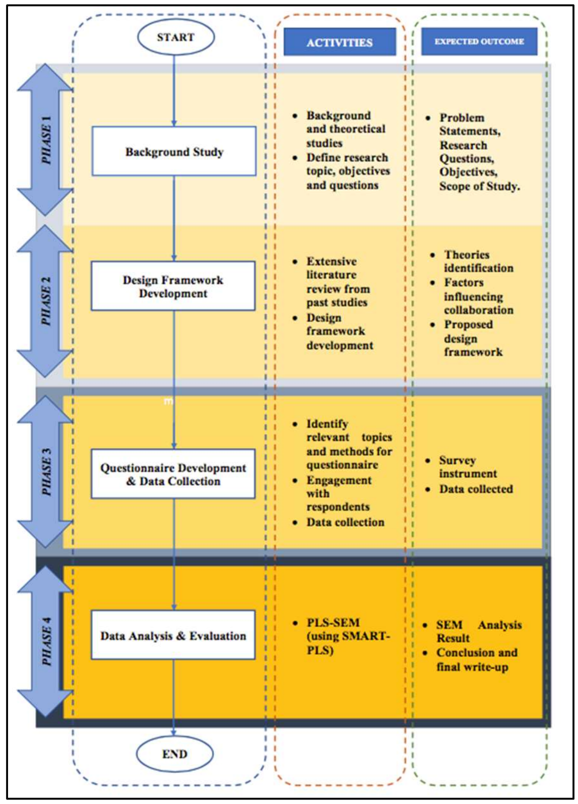

Figure 4: Research Methodology Framework.

Results analyzed and validated at the fourth phase would later determine the relationship of each of the variables/factors tested and would be the basis for proposing the final framework to be presented at the end of this research study. Each phase was represented with its own deliverables, which would also be the bases for the later phases.

3.2 Background Study and Research Topic Discovery

Extensive literature study was conducted to construct the problem statements from the research gap found in the targeted field of study. It was initially discovered that there wasn't any research study specifically investigated the connection between a successful cross-field collaborative working group, with any relatable theories that came as the basis to create a visually assisted collaboration tools (visualization tools) like dashboards etc.

Once identified, the formulation of research objectives and the development of research questions were carried out to strategically delineate the research scope and boundary while feasibility of completing the study within a given timeline.

3.3 Conceptual Framework Development

A conceptual framework was developed by conducting another round of literature review to select the most suitable models proposed in past research studies. At this stage, there are two major components that will be highlighted in the development of the framework, and they are represented as below:

a) Visualization components that consist of ICT or technological aspects or attributes that will help in enhancing collaborative working environment and group's efficiency.

b) Collaborative components that consist of human or individual aspects that will influence the collaboration and subsequently group's efficiency.

To comply with the aim of this study, the integration between these two components (MST and Collaborative Factors) was further extended to include the process of creating shared mental model, in the process of stimulating a common understanding among the members of the collaborative working group. This is an important indicator to determine the success of any collaborative working groups, especially of those that consist of multi-disciplines members.

3.4 Questionnaire Development and Data Collection

The development of conceptual framework will lead the study to phase 3, Questionnaire Development and Data Collection. At this stage, the identification of available research questionnaire is conducted to be adapted during the execution of phase 3. Besides that, as for survey sampling, the process of identifying sample size and unit is also being conducted to match the purpose of the study. Engagement to targeted participants and respondents prior to survey activities was also established to ensure the smooth process during data collection. This will also be part of the data collection administration section in this phase.

The proposed targeted participants can be grouped as two, the amateurs and the professionals. The reason for dividing these participants into two major groups is mainly due to the findings from [27], [28], and [17] that stressed on the importance of cognition maturity in determining the performance of a team. Based on their study, it is found that group members might take sometimes to develop a collective understanding and action towards any situational implications, as it is found that the interaction between two types of shared mental model (task and team) exist in a unique representation that will result in a distinctive consensus outcome. For this reason, the targeted participants are grouped into two:

a) **Amateurs**
Consisted of undergraduate students from Universiti Teknologi PETRONAS, who was then involved in multi-disciplinary projects, like Engineering and Technology Project (ETP). This group of students were regarded as amateur because of their limited experience in engaging with cross-field collaborative working group, thus giving up the opportunity to create better understanding on the process of developing shared mental model in a less matured cognitive environment.

b) **Professionals**
Consisted of group of people from various background who have been working in a cross-field collaborative working group for some significant amount of time. The targeted participants include members of Exploration Research study Teams, in oil and gas upstream sectors, as well as research groups available in the university that work in multi-disciplinary principles, to achieve a common objective.

3.5 Evaluation

Evaluation of the design framework is done by using Partial Least Square - Structural Equation Modeling (PLS-SEM). SEM is well known as one of the most hypothesis testing tools that has been widely used to understand the concepts of ease of use, user acceptance and even appropriateness of technology. As for this research, this method is thought to be suitable due to the nature of the research itself, of which this research is conducted based on exploratory research principle. As explained in the previous steps of the methodology, findings from the preliminary study had finally resulted in the conceptual framework that sums up most of the theories proposed by previous researchers in their works.

Developed by [29], PLS-SEM is designed as one of two branches of SEM that focuses on the iterative approach that maximizes the explained variance of endogenous constructs. There are two main characteristics of PLS-SEM that makes it adaptable to the purpose of the research is the ability to validate model based on small sample sizes and formatively measured construct:

a) **Small sample size**
Sample size can affect several aspects of SEM including parameter estimates, model fit, and statistical power [30]. As compared to another branch of SEM, Covariance-based SEM (CB-SEM), PLS-SEM is more useful and found to be more effective towards much smaller sample sizes, regardless the complexity of the models that it is meant to test. According to a study by [31], it can be deduced that PLS-SEM shows greater levels of statistical power and is able to practice better convergence behavior rather than its peers.

Among the most popular indicators used as a guideline to set the minimum sample size for the usage of PLS-SEM are indicated as below:

- Ten times the largest number of formative indicators used to measure one construct, or
- Ten times the largest number of inner model paths directed at a particular construct in the inner model.

Despite of smaller sample size and more lenient requirement, Hair et al. (2014) insisted that the technique must also be treated as any other data analysis tools, of which attention must be done on the sample size, as it will have major influence on model complexity and data characteristics.

b) **Small sample size**
One of the distinctive features of formative indicators is the ability to represent instances in which the indicators caused the construct. This could be identified through the way the arrows are pointed away from indicators into the construct as what is supposed to show in the model. PLS-SEM has been recognized by previous research as to be more relevant in determining the effects of formative indicators rather than CB-SEM [30].

Research by [30] have proposed a multi-stage process in developing and accessing PLS-SEM. The processes are generally divided into two parts, namely, inner (structural) and outer (measurement) models. Besides that, there are also other processes like data collection and examination, model estimation and finally, the evaluation of results.

3.5.1 Model Specification

This process involved the identification of the inner and outer models. The inner model basically be developed to highlight the relationships between each construct. The outer model on the other hand is responsible for evaluating the relationship between indicator variables and the corresponding construct. The most important thing while prior to constructing these models is the creation of path model that connects each variable and construct based on the proposed theories.

a) **Measurement Model (Outer Model) Evaluation**
The following step after model specification is to run PLS-SEM algorithm [31]. While measuring the reliability and validity of the constructs, researchers need to clearly underline the reflective and formative measures that are involved in the study [32].

b) **Structural Equation Model (Inner Model) Evaluation**
Once the outer model is tested on its reliability and validity, the process proceeds with the evaluation of the hypothesized relationships within the inner model. At this stage, the assessment of model's quality is done by testing its ability to predict the endogenous constructs. This process is unique to PLS-SEM as CB-SEM uses sample data to gain parameters that are most suitable to predict the endogenous constructs.

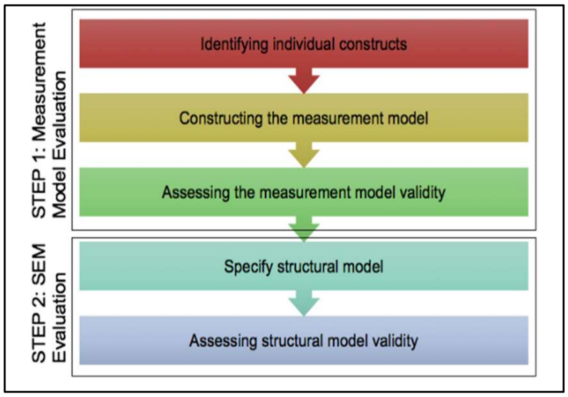

Figure 5: The Partial Least Squares – Structural Equation Modeling (PLS-SEM) Procedures

3.6 Documentation and Final Write-up

The last phase of the research study put into focus the strategies to devise the conceptual framework that was initially tested in the earlier phases. A final framework was proposed with a hope to best explain the relationship between Media Synchronicity Theory (MST) and collaboration factors in facilitating the workflow of cross-field collaborative groups, especially in improving their mutual understanding, and to achieve greater productivity.

4. RESULTS AND DISCUSSION

To reach a common understanding as what the shared mental model suggests, the use of appropriate amount of both types of media (synchronous and asynchronous) is essential to avoid cognitive overload, that in the end preventing the process of achieving common understanding [33]. From these justifications, the first hypothesis is drawn:"

H1: All the five attributes of ICT (elements of" MST) have a significant relationship with the process of developing shared mental model."

4.1 Human Factors as Collaborative Attribute

To explain the relationship between collaborative attributes and the development of shared mental model in human shared cognition perspective, an analysis from a study conducted by [34] has been done. From their study, its understood that a team is made up of individuals that are engaged in shared tasks (task mental model) with a common goal, and committed to a common purpose, performance goals, and approach for which they hold themselves mutually accountable. There are three major components that should be listed under human factors, that can be regarded as part of the collaborative attribute: trust, roles and skills and relationship."

H2: Human factors in the collaboration attributes" "have significant relationship with the process of" "developing shared mental model."

4.2 Organizational Factors as Collaborative Attribute

A study conducted by [35] has underlined a few organizational behaviors that may hinder the process of cross-field collaboration. Both team leader authority and goal congruency are associated with collaborative leadership, that should be formed in the process of creating cross-field collaborative group. This element of organizational factor is worth highlighting in this study because of the fact the proposed visualization framework is developed to address the need of cross-field working groups. In this kind of environment, leadership is thought to be one of the most important elements in minimizing the impact of technical disparities that possible be occurred in a team.

H3: Organization factors in the collaboration" attributes have significant relationship with the" "process of developing shared mental model."

4.3 Shared Mental Model on Group's Effectiveness

In research by [26] they have proposed a relationship between the overlapping of both team and task SMM that will lead to greater team effectiveness. This somehow indicates a significant or positive relationship between team shared cognition and effectiveness. A proposition by [26] that similar SMM research findings of face-to-face settings can also be applied to the distributed and virtual settings of which this research is focusing on. Regardless of the collaborative setting, the same tools of developing shared understanding are used, which is through the development of both types of

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Shared Mental Models (SMM). And for this, another hypothesis can be deduced, which is:"

> ***H4: The convergence of both types of shared mental" "model will have impact on team effectiveness.***
> "

4.4 Proposed Theoretical Framework

Based on the explanations above, the research framework is proposed as below:

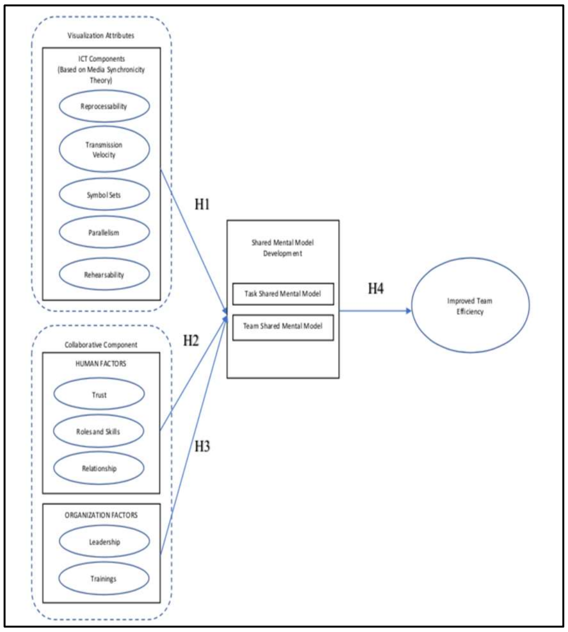

Figure 6: The proposed theoretical framework."

4.5 PLS-SEM Result

Following the results from the questionnaire sent out to two groups of respondents, amateur and professionals, a model is created using SMART-PLS. The structural model was created following each construct representing the variables that were tested in the model. In total initially there were 46 constructs that were tested, and summarized according to codes e.g., TV, PS, TSK etc.

From the first-round test, the reliability and validity tests were conducted by using SMART-PLS. In this section there are three readings to be considered, they are: Convergent Validity, Discriminant Validity and Composite Reliability. In Convergent Validity, one major statistical reading that is going to be included is Average Variance Extracted (AVE). It is important that AVE readings for each construct to be above 0.5, for it to be considered valid, for the model.

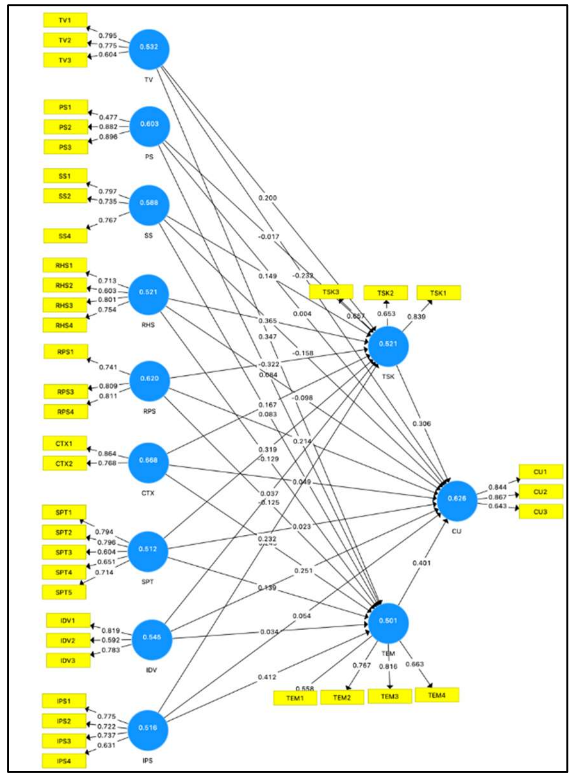

Figure 7: The structural model (post items removal). Values indicated in the circle indicate the AVE readings which are now above 0.5.

Initial reading of the model has identified several constructs with lower than 0.5 AVE reading. To mitigate this issue, low loading items need to be eliminated/removed from the model, to help the constructs achieve its validity reading. It is important to note that 4/46 indicators have been removed from the model, which is around 8.7% of the whole indicators, significantly lower than 20% items removal marked for the model to be considered valid. To check reliability of the model, SMART-PLS utilizes Composite Reliability readings versus the traditional Cronbach's Alpha readings commonly used in SPSS. For the model to be considered reliable, the minimum threshold reading for composite reliability is 0.700, of which all the constructs in the model have significantly passed.

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	Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)
CTX	0.614	0.610	0.795	0.564
CU	0.709	0.718	0.821	0.536
IDV	0.582	0.609	0.779	0.545
IPS	0.688	0.700	0.809	0.516
PS	0.704	0.808	0.812	0.605
RHS	0.691	0.693	0.811	0.520
RPS	0.695	0.700	0.831	0.621
SPT	0.765	0.790	0.839	0.513
SS	0.653	0.655	0.811	0.589
TEM	0.659	0.678	0.797	0.501
TSK	0.531	0.552	0.762	0.520
TV	0.550	0.550	0.771	0.533

Figure 8 shows the table containing Composite Reliability and AVE readings of the model.

For the following type of validity test, the model was tested to get the values of Discriminant Validity. For the constructs to be considered to pass the Discriminant Validity test, the reading must not exceed 0.85. Items are considered invalid due to their overlapping behavior which could indirectly indicate that the items could be used to measure more than one constructs/variables.

	CTX	CU	IDV	IPS	PS	RHS	RPS	SPT	SS
CTX									
CU	0.756								
IDV	0.577	0.974							
IPS	0.532	0.897	1.041						
PS	0.539	0.531	0.802	0.473					
RHS	0.401	0.425	0.858	0.363	1.058				
RPS	0.849	0.621	0.690	0.622	0.790	0.799			
SPT	0.639	0.747	0.936	0.752	0.705	0.466	0.692		
SS	0.560	0.440	0.612	0.687	0.622	0.755	0.719	0.718	
TEM	0.856	0.983	0.871	0.972	0.581	0.438	0.638	0.903	0.659
TSK	0.753	0.949	1.094	0.897	0.869	0.906	0.659	1.043	0.922
TV	0.476	0.483	0.678	0.436	0.719	0.601	0.724	0.891	0.462

Figure 9 shows the table containing Heterotrait-Monotrait Ratio Discriminant Validity of the model.

From the readings, it could be indicated that some of the items in the model have been exemplifying "red" values – above than 0.85. The way to solve this issue is by also using items removal method, however too much items removal could also affect the validity of the model. This is the issue encountered in the model as of this time, as these DV values will somehow impact the readings of our P-Values, in the bootstrapping test later.

From the initial result of testing (until the point when the paper was written), some constructs used to determine the hypotheses in this study were generally considered to be possessing significant level of similarities – which somewhat affected the way how one variable would reflect the change of the other variable. It was initially proposed that the usage of media assisted tools which contain several elements of MST like Symbol Set and Rehearsablity would positively influence the creation of Task Mental Model, that subsequently impact the common understanding among team members. From the discriminant validity test conducted based on the results of the questionnaire, it was statistically deduced that these elements were deemed to be off the same in nature, which the Smart-PLS couldn't identify the correlational basis that was supposed to be made up in explaining the relationship between these constructs.

In the research model used for the hypotheses testing, Task and Team mental model were placed in the same position, which both ways they were written to be influenced by the other lower-ordered constructs, and at the same time were also impacting each other. The study also suggested that these relationships between the two types of mental model would somehow affect the common understanding of team members, as a result to measure effectiveness of the cross-field working groups. This, however, was also challenged by the result of the discriminant validity test, as again they were deemed to be too significantly alike for them to have had the causal-relational relationship proposed earlier in the study.

From these results, the study would then need to revisit the proposed model to look for the necessity for it to be revised, for the constructs and variables to pass the discriminant validity (DV) test. Once the solutions are found, the evaluation of the model is hoped to be completed within the expected time, with a result that is more accurate, and could best describe the relationship between the constructs, and the hypotheses used in the study.

5. CONCLUSION

From the initial results presented in the earlier section, the study could conclude that some of the hypotheses were directly affirmative of what was initially proposed by the previous literature. Common understanding (which was used to measure team's effectiveness) was proven to be influenced by the factors of collaboration (human and organization) as well as the elements of Media Synchronicity Theory (MST). This could somehow tell us that, to create a proper visualization tool, to support collaborative work environments in a cross-field settings, the tool must've included these elements (collaboration and MST).

This conclusion, however, couldn't concisely represent the complete result of this study, as some of the constructs needed to be reviewed and tested again. This conclusion also didn't fully or objectively answer the research question on what and how these factors of collaboration and MST impact the effectiveness of cross-field working groups.

Upon completing this study later, a collaborative visualization framework will be

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developed with a focus to provide a guideline to a proper visualization system especially in promoting collaborative working environment among cross-field working group in both professional and amateur settings.

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REFERENCES:

[1] Black, W. (2017). *Collaboration becoming new reality as oil and gas industry index returns highest score of 7.1*.

[2] Aseeri, A., & Wongthongtham, P. (2011). *Community-driven ontology evolution based on lightweight social networking in oil and gas domain*. In IEEE International Conference on Digital Ecosystems and Technologies (pp. 197–202). https://doi.org/10.1109/DEST.2011.5936625

[3] Khan, M., & Khan, S. (2011*). Data and information visualization methods, and interactive mechanisms: A survey*. International Journal of Computer Applications, 34(1), 1–14. https://doi.org/10.5120/4061-5722

[4] Milojević, S., Hemminger, B. M., Priem, J., Chen, C., Leydesdorff, L., & Weingart, S. B. (2012). *Information visualization state of the art and future directions*. Proceedings of the American Society for Information Science and Technology, 49(1), 1–3. https://doi.org/10.1002/meet.14504901155

[5] Isenberg, P., Elmqvist, N., Scholtz, J., Cernea, D., Ma, K. L., & Hagen, H. (2011). *Collaborative visualization: Definition, challenges, and research agenda.* Information Visualization, 10(4), 310–326. https://doi.org/10.1177/1473871611412817

[6] Cross, B. R., Rebele, R., & Grant, A. (2016). *Collaborative overload*. Harvard Business Review.

[7] Henke, W. J., Krachenberg, R., & Lyons, T. (1993). *Cross-functional teams: Good Concept, poor implementation*.

[8] Robertson, N., Robertson, N., Bishop, R., & Bishop, R. (1999). Kaupapa Maori Research: An Indigenous Approach to Creating Knowledge. Maori and Psychology: Research and Practice - The Proceedings of a Symposium Sponsored by the Maori and Psychology Research Unit Hamilton, 0

[9] Tsai, K. H., & Hsu, T. T. (2014). *Cross-Functional collaboration, competitive intensity, knowledge integration mechanisms, and new product performance: A mediated moderation model*. Industrial Marketing Management, 43(2), 293–303. https://doi.org/10.1016/j.indmarman.2013.08.012

[10] Ben-Menahem, S. M., von Krogh, G., Zynep, E., & Schneider, A. (2016). *Coordinating Knowledge Creation in Multidisciplinary Teams.* Academy of Management Journal, 59(4), 1308–1338. https://doi.org/10.5465/amj.2013.1214

[11] Tushman, M. L., & Nadler, D. A. (1978). *Information Processing as an Integrating Concept in Organizational Design*. Academy of Management Review, 3(3), 613–624. https://doi.org/10.5465/AMR.1978.4305791

[12] Bresnan, H., & Zellmer-Bruhn, M. (2013). *The Structural Context of Team Learning: Effects of Organizational and Team Structure on Internal and External Learning*. Organization Science, 24(4), 1120–1139. https://doi.org/10.1287/orsc.1120.0783

[13] Galbraith, J. R. (1973). *Designing Complex Organizations. Organization development*. https://doi.org/10.2307/248839

[14] Carley, K. M. (1997). *Extracting Team Mental Models Through Textual Analysis* [Doctoral dissertation, Carnegie Melon University]. Center for Computational Analysis of Social and Organizational Systems (CASOS). https://onlinelibrary.wiley.com/doi/abs/10.1002/%28SICI%2910991379%28199711%2918%3A1%2B%3C533%3A%3AAID-JOB906%3E3.0.CO%3B2-3

[15] Rydén, P., Ringberg, T., & Wilke, R. (2015, August). *How Managers' Shared Mental Models of Business-Customer Interactions Create Different Sensemaking of Social Media*. ResearchGate. Retrieved February 13, 2023, from https://www.researchgate.net/publication/280092250_How_Managers'_Shared_Mental_Models_of_Business-Customer_Interactions_Create_Different_Sensemaking_of_Social_Media

[16] Jonker, C. M., Van Riemsdijk, M. B., & Vermeulen, B. (2011). *Shared mental models: A conceptual analysis.* In Coordination, organizations, institutions, and norms in agent

systems VI (pp. 132–151). https://doi.org/10.1007/978-3-642-21268-0_8

[17] Santos, C. M., Rensburg, J. J. van, Uitdewilligen, S., & de Jong, S. B. (2022, January). *The Five-Factor Perceived Shared Mental Model Scale: A Consolidation of Items Across the Contemporary Literature.* ResearchGate. Retrieved February 13, 2023, from https://www.researchgate.net/publication/357865740_The_Five-Factor_Perceived_Shared_Mental_Model_Scale_A_Consolidation_of_Items_Across_the_Contemporary_Literature

[18] Mathieu, J. E., Heffner, T. S., Goodwin, G. F., Salas, E., & Cannon-Bowers, J. A. (2000). *The influence of shared mental models on team process and performance.* Journal of Applied Psychology, 85(2), 273–283. https://doi.org/10.1037/0021-9010.85.2.273

[19] Yang, H. D., Kang, H. R., & Mason, R. M. (2008*). An exploratory study on meta skills in software development teams: Antecedent cooperation skills and personality for shared mental models*. European Journal of Information Systems, 17(1), 47–61. https://doi.org/10.1057/palgrave.ejis.3000730

[20] Basole, R. C., Russell, M. G., Huhtam¨aki, J., Rubens, N., Still, K., and Park, H. (2015). *Understanding Business Ecosystem Dynamics: A Data-Driven Approach.* ACM Transactions on Management Information Systems, 6(2):1–32

[21] Johnson, G., & Elvins, T. T. (1998, May 2). *Introduction to collaborative visualization.* ACM SIGGRAPH Computer Graphics Volume 32 Issue 2 May 1998. Retrieved February 13, 2023, from https://dl.acm.org/doi/abs/10.1145/282037.282039

[22] Yusoff, N. M., & Salim, S. S. (2015). *A systematic review of shared visualisation to achieve common ground.* Journal of Visual Languages and Computing, 28, 83–99. https://doi.org/10.1016/j.jvlc.2014.12.003

[23] Applegate, L. M. (1991). *Technology support for cooperative work: A framework for studying introduction and assimilation in organizations.* Journal of Organizational Computing, 1(1), 11–39. https://doi.org/10.1080/10919399109540148

[24] Isenberg, P., Elmqvist, N., Scholtz, J., Cernea, D., Ma, K. L., & Hagen, H. (2011).

[25] Cernea, D. (2015). *User-Centered Collaborative Visualization.* Technical University of Kaiserslauten. Retrieved from https://d-nb.info/1069938807/34

[26] Maynard, M. T., & Gilson, L. L. (2013). *The Role of Shared Mental Model Development in Understanding Virtual Team Effectiveness.* Group & Organization Management, 39(1), 3–32. https://doi.org/10.1177/1059601113475361

[27] Wildman, J. L., Salas, E., & Scott, C. P. R. (2014). *Measuring cognition in teams: A cross-domain review*. Human Factors. https://doi.org/10.1177/0018720813515907

[28] Mohammed, S., Hamilton, K., Sanchez-Manzanares, M., & Rico, R. (2017). *Team Mental Models and Situation Awareness*. In The Wiley Blackwell Handbook of the Psychology of Team Working and Collaborative Processes.

[29] Wold, H. (1982). Soft Modeling: *The Basic Design and Some Extensions*, in Systems Under Indirect Observations: Part II, K. G. Jöreskog and H. Wold (eds.), North-Holland: Amsterdam, pp. 1-54.

[30] F. Hair Jr, J., Sarstedt, M., Hopkins, L., & G. Kuppelwieser, V. (2014). *Partial least squares structural equation modeling (PLS-SEM).* European Business Review, 26(2), 106–121. https://doi.org/10.1108/EBR-10-2013-0128

[31] Henseler, J., Fassott, G., Dijkstra, T. K., & Wilson, B. (2012). *Analysing quadratic effects of formative constructs by means of variance-based structural equation modelling.* European Journal of Information Systems, 21(1), 99–112. https://doi.org/10.1057/ejis.2011.36

[32] Sarstedt, Marko & Ringle, Christian M. & Smith, Donna & Reams, Russell & Hair, Joseph F., 2014. *"Partial least squares structural equation modeling (PLS-SEM): A useful tool for family business researchers,"* Journal of Family Business Strategy, Elsevier, vol. 5(1), pages 105-115.

[33] Valaker, S. (2017). *Breakdown of Team Cognition and Team Performance Examining the influence of media and overconfidence on mutual.*

[34] Patel, H., Pettitt, M., & Wilson, J. R. (2012*). Factors of collaborative working: A framework for a collaboration model*. Applied Ergonomics. https://doi.org/10.1016/j.apergo.2011.04.009

[35] Wang, L., Cheng, M. Y., and Wang, S. (2016). *Carrot or stick? The role of in-group/out-group on the multilevel relationship between authoritarian and differential leadership and employee turnover Intention.* J. Bus. Ethics 1–16. doi: 10.1007/s10551-016-3299-z