Personal and Extended Intelligence in Collective Emergence

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Abstract— **Humans are biological agents that communicates formally and informally to execute task and solve problem. Seemingly, this collective composition of cognition and behavior formulates efficient solution thus optimizing problem solving techniques. However, there are limited systematical studies conducted to examine whether group effort is better than individual effort. In a study consisting of 240 people, working in groups of three and individually, we find that the collective effort derives a much more positive outcome in problem solving. In this paper, we explain the method of the experiment conducted and expose the outcome through a detailed analysis.**

Keywords-component; Collective Intelligence; Group Intelligence;Personal Intelligence; Extended Intelligence; Intelligence;

I. INTRODUCTION *(HEADING 1)*

The twigging on the concept of Collective Intelligence (CI) has been evident for almost a century of time. Indeed, the perspective that captures the notion varies through many dimensions, namely: psychology, sociology, entomological, computer and science [8][9]. Though its definition manifests the area from which it has been researched upon, it relatively incorporates more than one substance of cognition and behavior. Literally, these substances are formed through the collective demeanor of living entities in the quest of optimization in problem solving [10][11].

Specifically, humans are living beings with exquisite social capabilities [1][2][3][4][5][6][7]. Their ability to communicate through formal and informal mechanism places them at the highest level of the social pyramid. Socializing involves the process of conversing and interacting between two or more parties. It may be in various environments that incorporates different purposes. In organizations, the important facet of socializing is evident through formal and informal meetings.

In these meetings, each individual with various backgrounds, specializing in various areas comes into close encounter to brainstorm on ideas or plans that ultimately improves the well being of the organization. Each of these individuals portrays different levels of personal intelligence. Personal Intelligence, PI is the ability of an individual to understand the capacity of governing and managing their inner abilities and mobilizing it to work within the social structure to meet ones goal [12].

Incredibly, PI is one of the important entities that contribute to a successful decision that ultimately comprehend the concept of the preliminary CI model. As an instance, in the Climate Collaboration project, a brainchild of Malone, the principle idea was to obtain the best entry to improve the world climate condition. As the Climate CoLab. was a web-based project, entries were obtained from various participants with different backgrounds. These participants were environmentalist, researchers, students majoring in environmental studies, housewives who were concerned over the environment and many more. These participants were specialist on environmental/climate issues based on their personal knowledge and experience. By them sharing their ideas and plans in forms of proposals, a variety of inputs were being gathered from a wide range of perspectives that ultimately embodies a formalized structure of idea that is used to overcome issues pertaining climate change worldwide. As such, in 2011 the first launch captured the ideas of the winners to be discussed to the UNFCC for further task execution on climate issues. Fig. 1 and Fig. 2 below describe the Climate CoLab. model and the approach that were geared in the project.

Figure 1. Climate CoLab Model
(http://climatecolab.org/web/guest/about)

Figure 2. Climate Collaboration Project Approach
(http://climatecolab.org/web/guest/about)

While PI as an entity to the preliminary CI model, mobilizes multifaceted ideas to be discussed, the relevancy of these ideas to solve the problems will require an affirmation point. This situation is prevalent as occasionally, when an idea is put forth, the issues on lack of confidence and ambiguity on that idea may arise. In such circumstances, a validation of ideas will be required. Such requirement calls for the assistance of Extended Intelligence (EI), i.e. normally AI-based systems that are used to provide knowledge discovery, optimization, probabilistic or advisory inputs to human decision-making process.

In this paper, we propose the idea of Extended Intelligence (EI), as the support entity that effectively executes the preliminary CI model based on the human interaction performed in group activities. The idea is supported through a study with the intention of discovering the four hypotheses stated below:

Hypothesis 1: Group collaboration in task execution maximizes the utilization of individual expertise and knowledge (PI).

Hypothesis 2: An individual with a higher level of experience and knowledge commands higher authority in the discussion process.

Hypothesis 3: Group of individuals that discusses issues in the same domain, would generate intersections of experience and knowledge, thus forming the basis of CI.

Hypothesis 4: The application of EI allows validation of ideas thus optimizing the efficiency of decision making.

II. THE RESEARCH OBJECTIVES

This research aims to identify the influence of PI during a problem solving process that occurs in groups. This investigation is carried out further to understand the emergence of EI and its contribution in determining the effectiveness in decision making in the preliminary CI model. To achieve the aim of the research, the following objectives are proposed:

1. To evaluate the efficiency of performance level between individual and group task execution.
2. To identify the existence of additional support that can enhance the performance level during the problem solving process.

III. RELATED WORK

A. Collective Intelligence

Collective Intelligence (CI) systems have aroused the interest of many researchers due to its (i) adaptivity in uncertain environments, (ii) ability to organize themselves autonomously, and (iii) emergent behavior. Among others, multi-agent, adaptive, swarm intelligence, and self-organizing systems are considered to be CI systems. However, while the growth of research in CI systems continues, it has yet to lead to a systematic approach for model design of these kinds of systems [13]. Understanding the emergence of intelligent collective behaviors in social systems, such as norms and conventions, higher level organizations, collective wisdom and evolution of culture from simple and predictable local interactions has been an important research question since decades [14][15]. Agent-based modeling of complex social behaviors by simulating social units as agents and modeling their interactions provides a new generative approach to understanding the dynamics of emergence of collective intelligence behaviors.

Here, we attempt to draw a conceptual theory of collective intelligence through detailed observation and recordings carried out on seven general meetings and two design meeting. The methodology details can be further examined in [24]. This research attempts to study and analyze the emerging collective intelligence among humans and to formulate a collective intelligence model which could be redeployed in agent-based systems. Fig. 3 below describes the proposed preliminary CI theory.
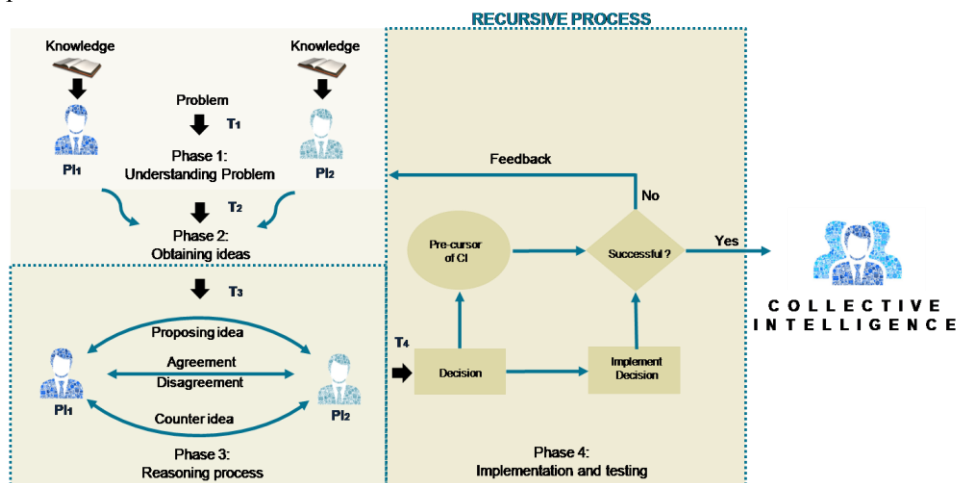

Figure 3. The Conceptual Theory of Collective Intelligence

B. *Personal Intelligence*

Learning about oneself is generally about gaining information on yourself, knowing who you are and what you are, thus enabling you to oversee and organize your mental subsystems, such as motives, thoughts and self control [16]. This correlates very much to the concept of personal intelligence. This term that has been around for as early as the mid-19th Century which is then used to describe an author's talent at capturing a person's character with a few lines of prose thus soon became the title of magazine columns that reported on notable characters of the time [17][18].

Consequently, the concept of PI evolved to be influenced by the hot group [19] of intelligence in which it involves reasoning about information that is personally relevant and that often elicits painful or positive reactions. [20][21]. Soon, PI followed suit the theory of multiple intelligence[23] where specifically it describes the pair of intelligence, known as intrapersonal and interpersonal intelligence. Intrapersonal intelligence is about understanding one physical and neurological capabilities and Interpersonal Intelligence is about channeling the first to encapsulate the sociological aspects of a given scenario. Both these intelligence are in parallel to self-knowledge discovery [24] and social ignition.

Subsequently, all these various concept and theories draws to the idea of PI as the ability to use or redeem past experience in helping to sort future tasks in a more structured and planned manner noticeably reducing the chances of errors and accomplishing a higher success rate in achieving one's goal.

Fig. 4 below describes the relationship between the intrapersonal and interpersonal intelligence that embodies the concept of personal intelligence.
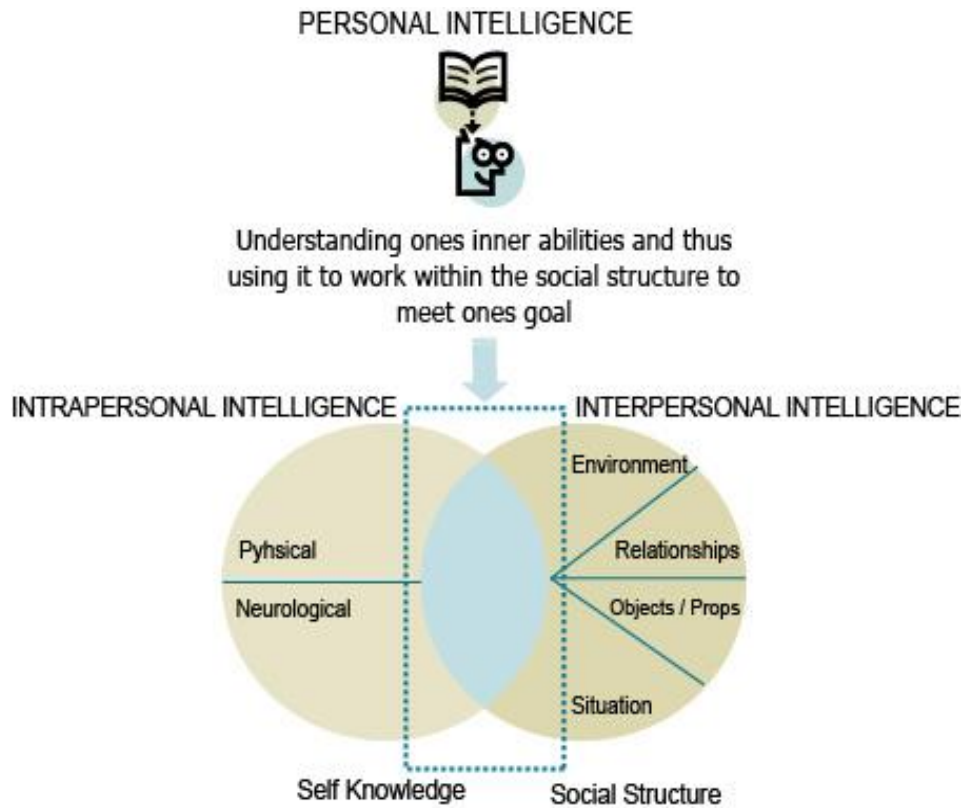

Figure 4. Personal Intelligence Structure

C.   Extended Intelligence

While two or more people discuss issues related to a complex problem, they occasionally encounter a situation of uncertainty, in which they are not sure or confident enough to agree upon the ideas, data, or information (collectively we called it intelligence data, or ID) put forth by any member of the group. When such situation occurs, the ID need to be validated, or data or information related to the ID need to be sought to verify the truth of the ID.

Such requirement calls for the assistance of Extended Intelligence (EI), i.e. normally AI-based systems that are used to provide knowledge discovery, optimization, probabilistic or advisory inputs to human decision-making process. The type of extended intelligent systems needed will be influenced by the knowledge and expertise of the members of the group by identifying the actual AI-based system that is relevant to the problem at hand or, the experts that is able to advice on the required system.
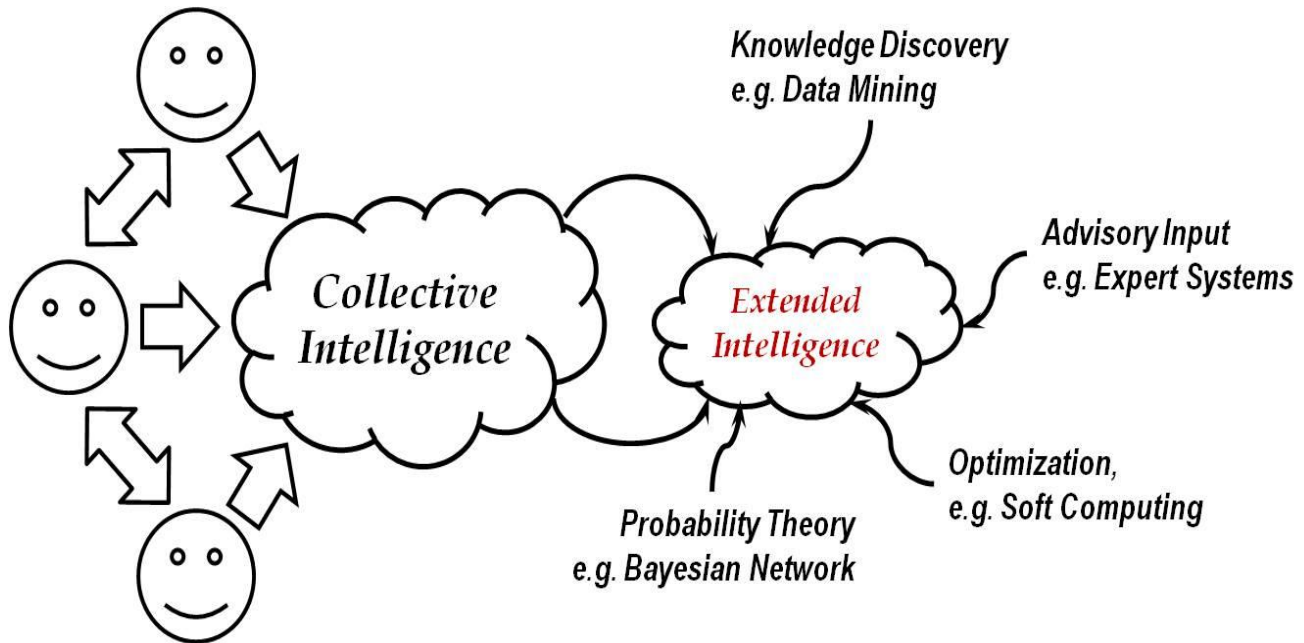
Figure 5. Extended Intelligence

IV.   METHODOLOGY

A study was conducted in the beginning of 2013 to understand the efficiency of group work and the influence of EI in problem solving. A total of 240 students were selected from University Tenaga Nasional, (UNITEN). These students were undertaking the subject, "Statistics for computing". This was the subject of choice as the nature of the subject dictated more problem solving type questions. As a foundation subject, it comprises eight mind stimulating chapters. Prior to this study, these students had completed a total of six chapters in which they had undertaken five quizzes. At this point, the students were fit to undergo the study. This confirmation was given by their lecturer.

The study involved three mathematical tests in which, all students were subjected to. The three tests, specifically an individual test, a group test without the aid of calculators and a group test with the aid of calculators were formalized. The test questions were distributed

across the six chapters. Concurrently, the questions were prepared upon constant verification with the subject lecturer. Each test comprises of 15 objective questions. The duration to complete each test was specified to   30 minutes. The 240 students were scheduled for the exam according to their class section, which comprises of section A, 1A, B and 2B. Each section respectively consists of 60 students. The tests were conducted for the duration of four weeks, where the tests were scheduled respectively on Mondays, Tuesdays, Wednesdays and Thursdays. These tests were conducted in four trials to ensure the accuracy of the results. In each trial, the questions were reconstructed, which indicates that there were altogether 12 sets of questions to accommodate to each trial.

In the first test, all students were subjected to an individual test. At the end of the 30 minutes duration, the test papers were collected and marked with constant verification from the lecturer. In the second test, the

students were grouped in threes randomly. There were 20 groups representing each section. The students were required to complete the test without the aid of calculators. At the end of the 30 minutes duration, the papers were collected and marked with constant verification from the lecturer. In the third test, again the students were grouped in threes, but this time the students were allowed to use calculators as an aid. At the end of the 30 minutes the papers were collected and marked with constant verification from the lecturer. Table 1 below shows the distribution of questions based on the chapters.

Table 1. Chapters and question distribution based on chapters

Chapters	Questions
Graphical Data Representation	3
Numerical Data Representation	3
Measures of Centers and Variability	3
Principles of Probability	2
Probability of Event Relations	2
Probability Of Random Variables	2
Total	**15**

The results were calculated based on the sections. First, each test script is marked and the total correct answers were written on the front page of each script. Then, all the scripts with the same total marks were grouped together. A table was created with a vertical column comprising the questions from 1 till 15 and horizontal columns comprising the sections, from A, 1A, B, and 2B. In each section, three columns were created corresponding to the three separate test. Each column is calculated by tabulating the mean value of the overall correct answers. The mean value is used because it indicates the central distribution of the highest average score of correct answers scored by the participants.

V. RESULTS AND FINDINGS

Fig. 6 below shows the mean - μ value tabulated from the test scripts that have been marked. The μ value tabulated is across four different sections specified for three different tests. Based on the graph, the study shows two definite outcomes. The first indicates that group effort generates better results in the test compared to individual efforts. In this case, respectively, there were an increase of (38%) and (48%) in the correct answers tabulated between the individual test to both the group test. The second outcome indicates that with the aid of calculators, the students' performance increased by (10%) in the correct answers tabulated. This comparison is made between the group test without the aid of calculators and the group test with the aid of calculators. This tabulation gives a (100%) success rate for the later outcome.
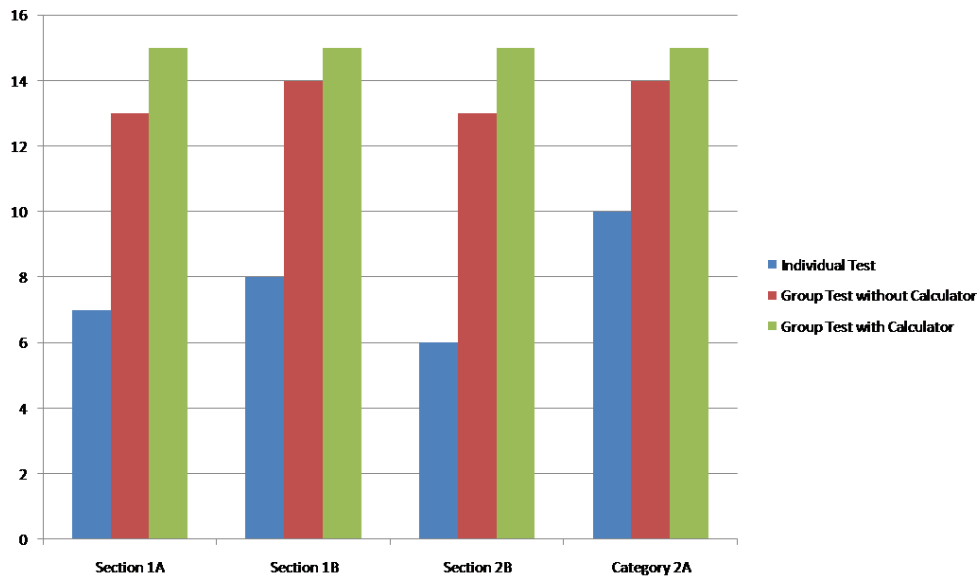

Figure 6. Differences results based on three test using μ value to represent the score

Assurance on the outcome is further deliberated through identical test in the course of four given trials. Fig. 7 below shows a graph indicating the percentage of correct answers tabulated with regards to the four trials. In the first, third and forth trial, the results have been consistent in supporting the two outcomes mentioned above. However, in trial two a slight discrepancy emerges where the group test with calculator steeped a reduction of (12%) of the overall correct answers

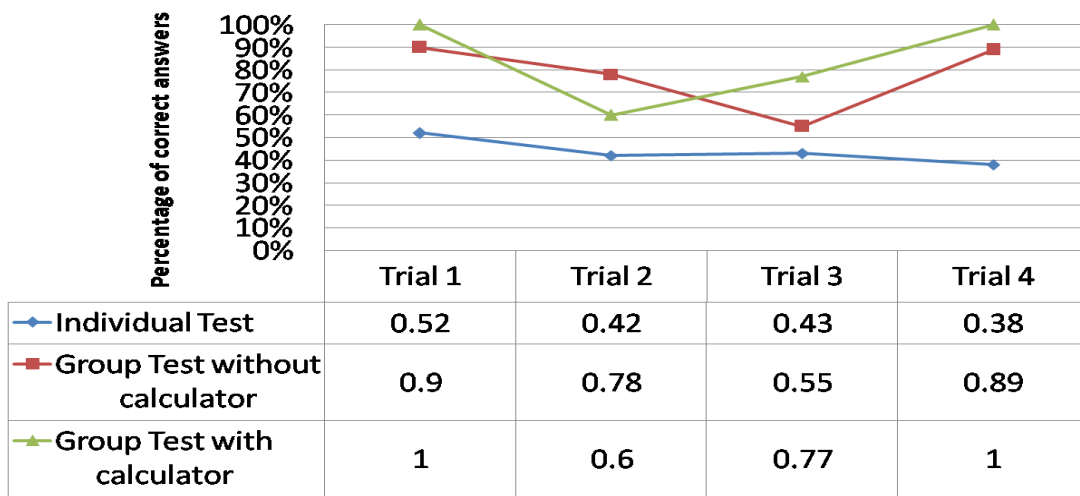tabulated compared to the group test without the   calculator.

Figure 7. Percentage differences between four trials

	Trial 1	Trial 2	Trial 3	Trial 4
Individual Test	0.52	0.42	0.43	0.38
Group Test without calculator	0.9	0.78	0.55	0.89
Group Test with calculator	1	0.6	0.77	1

This situation is evident for two main reasons. Firstly, the participants experienced mental fatigue due to overloads of assignments and the anticipation for the soon emerging semester break. Secondly, the prior reasons have had a major influence on the majority of the participants thus reflecting on their reconciliation of personal distraction that ultimately disperse inefficiencies in task execution when working together.

Consequently, it is pertinent to note the inevitable existence of PI and its influence. Evidently, PI exists within all the participants but at diverse levels. In this study, PI is measured based on the correct answers tabulated in the individual test. Some participant exhibited higher PI level when their scores were above the μ score of seven and to add, the scores were fairly distributed throughout the chapters in which an average mark is scored for each chapter. Others fall at an average level and a few were at the low level when their scores were below the μ score. The differences in the various level of PI are influenced by their knowledge capacity and experience that they have had in learning the subject. Fig. 8 below shows the ratio between knowledge and experience that influences the PI level of a participant.
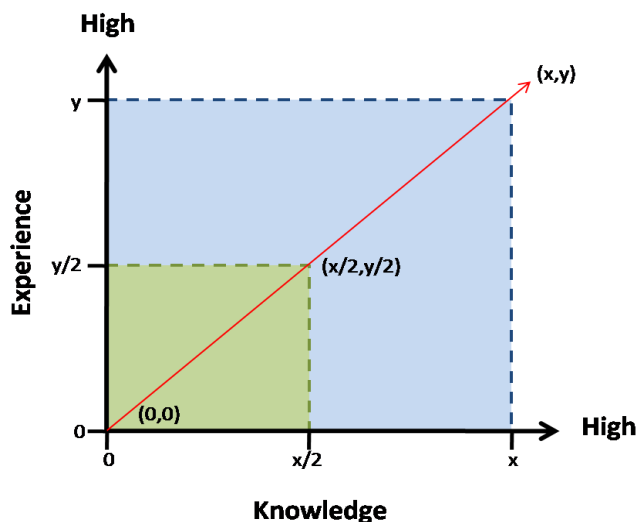

Figure 8. Knowledge and Experience Ratio

In this case, knowledge is represented by their depth in understanding each chapters and experience is dictated by the exercises and other practical methods that they have performed to improve their understanding on the chapters. Seemingly, all 240 participants scored reasonably well in the first three chapters. The participants felt that they were well prepared in terms of knowledge and experience as the first three chapters were a continuation from their high school syllabus. Generally, they rekindle and enhance their past knowledge with

added additional exercises to better grasp the chapters. Noticeably, only half of the participants felt that the last three chapters were doable. These participants felt that they succeeded in answering the questions because they have done more exercises and viewed more question samples from other resources besides the ones provided by the lecturer. Fig. 9 below shows the µ value of the correct answers obtained with regards to the chapters for the individual test. This result is based on an average of 7 scores for correct answers.
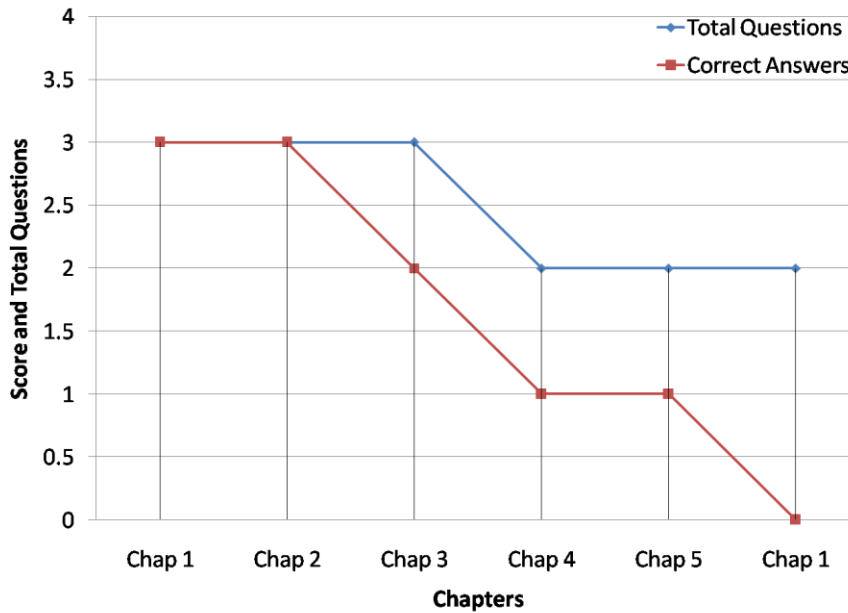

Figure 9. µ Correct answers based on chapters

This proves that from fig. 8, a participant's score is influenced by their degree of knowledge and experience. The knowledge and experience ratio refines constantly throughout the process of problem solving. As participant becomes more experienced on a chapter, their knowledge tends to accelerate as well. Thus, high experience level commands high knowledge level and ultimately resulting in high PI influence.

Respectively, when these individual participants are grouped together, their diverse level of PI capabilities is maximized to the fullest potential as each participant contribute their knowledge and experience in the best way possible as their overall ultimate goal is to complete the group test in order to obtain the best score.

In this process, two observations which are related to PI are made. Firstly, when a participant is more versed in a particular question, they tend to display a higher level command of authority. Relevantly this is the case because a participant, who is able to understand the question consciously and at the same time has had the experience solving similar problem, would tend to display a higher

level of confidence. This participant takes charge to refine the solution to the corresponding problem. In many occasions, such action accelerated the problem solving process.

In the second observation, all three participants in each group brainstormed their ideas by each contributing solutions that resides within the same domain during the problem solving process. The execution of this iterative cycle prolonged until achieving the most accurate solution to the problem. In this situation, it is prevalent to note that when a discussion is done within the same domain, the intersection of ideas that emerge through various levels of PI create a venue for a collective effort. In fig. 10 below there are two uneven shaped boxes that represent two variant levels of PI by two individuals. A point of intersection is achieved when the two PIs complement the body of knowledge and experience that supports the domain of discussion. The process to achieving this intersection goes through a series of negotiation and discussion.
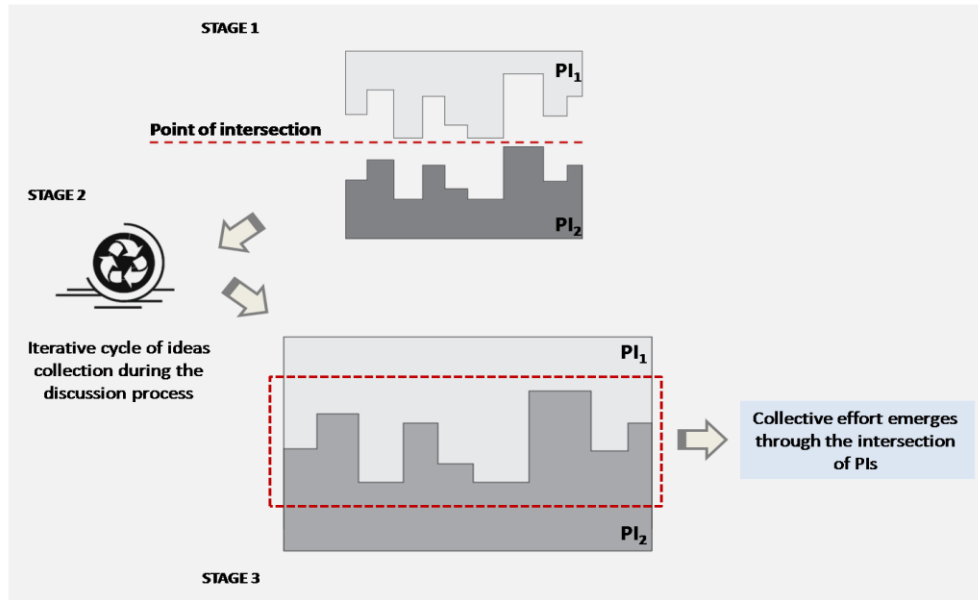
Figure 10. PI intersection model

Ultimately, this recursive cycle requires a point of affirmation to conceal accurate ideas. As such, during the execution of the two different group tests, it is evident through two observations that the students that use calculators exhibited higher confidence level towards their answers. In the first observation, the students displayed shorter lengths of arguments with more accurate answers during the problem solving process. In the second observation, the students were able to complete the test at a faster rate and similarly scoring better. These students use calculators to accurately perform the necessary calculation in the problem solving process. Hence, upon tabulating their answers, they re-verified the answers using this device which is specifically designed to perform accurate mathematical calculation.

This device contains simplified arithmetic algorithm which scientifically allow the tabulation of simple and complicated mathematical operations. Here, the influence on the usage of the calculator is prominent in ensuring the accuracy of the answers. It is a device with a certain degree of intelligence that aided in the problem solving process and students did relied on its expertise to occasionally refine their solution. The calculator is evidence that EI is necessary in validating the accuracy of an idea. EI is very much prominent in ensuring that the idea generated contributes to the success rate in decision making in the preliminary CI model.

VI.   CONCLUSION

Instinctively, in the preliminary CI model, the influence of PI is prevalent. Though the diversity of PI level is governed by the variant in the knowledge and experience, the emergent of a common line of intersection between the various PI levels can eventually generate ideas that create an atmosphere for a CI discussion for as long as it resides within the same domain. The nature of such intersection can only be manifested through a continuous recursion process of negotiation and discussion that involves the events of proposing, counter proposing, agree and disagreement.

This is a prolonged process in which occasionally, will require the assistance of EI. EI propose the alleviation of an idea to an affirmation point. This assurance is crucial in generating effective decision making process within the preliminary CI model. Our findings in this study explain the manifestation of PI and EI and how both supports in the execution of a problem solving process.

In our future work, we will define the two important attributes of PI : knowledge and experience. We will succumb to a general algorithm that represents these two entities.

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