Enhancing Learning through Opening the Group Model in a Synchronous Computer-based Environment

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Abstract

This research seeks to apply the concepts of collaborative learning and open learner modelling in order to find out whether seeing their own group learner model helps learners improve their learning in a computer-based collaborative learning environment. There is previous work on giving back information about learning performance as a group but very little, if any, empirical work on the benefits of a group open learner model (GOLM).

A major benefit of collaborative learning is to encourage learners to learn further from what they cannot achieve when do it by themselves but they can manage with another. Combining this with viewing and judging the information about learning found in a learner model, it was expected that this would increase their learning awareness in order to improve their learning performance. Without such group learner models, learners might not improve their learning performance in the collaborative learning environment as much as they might.

To find out whether opening the group learner models helped learners to improve their learning performance we developed a system called 'GOLeM', and we focused on the learner's score on learning concepts and their degree of confidence in their answer. GOLeM was used as a learning environment to test for evidence in relation to two comparisons of individual performance. The first was a comparison of individual performance between participants in a non computer-based individual learning environment and a computer-based collaborative learning environment. The second respect was to compare the results of learning in two different computer-based collaborative learning environments which were only different in terms of whether or not the learners could see their group learner model.

The content of number-conversion is chosen for the domain knowledge. Dialogue games and sentence openers are used to implement a chat-tool to exchange beliefs between peers. Bar charts and textual explanations are used as external representations of learning performance as a group. The system was implemented and tested in two versions: paper-based, for the plausibility of the content and the user interface; and computer-based, for comparing the learning results among three different learning environments regarding the

two respects above. To make sure what we built was valid – in terms of suitable content applied to the right target group of learners, we did several tests. These tests consist of a questionnaire with multiple choice questions applied to a small group of participants some of whom have a background in computing, and some have no background in computing. The questionnaire was examined for the suitability of its content and for the target group. A modified questionnaire was used with 122 participants who have a background in computing to validate in relation to the difficulty level and item discrimination. Five questions were selected as representative of the domain knowledge for a paper-based design and applied to six pairs of learners for the suitability of the questions and the number to be used, time taken, user interface, etc before developing the computer-based version.

Regarding the comparison between participants in a non computer-based individual learning environment and a computer-based collaborative learning environment, the results show there is a significant difference at the 5% level in terms of learning concept-score and degree of confidence in favour of individual learning performance of learners in collaborative learning environment.

Considering the comparison of learning between the two computer-based collaborative learning environments, participants who are able to see their learning performance as a group learner models both before the group test and after each item of the group test, have a slightly higher concept-score and improved degree of confidence than those who cannot see these learner models. Moreover there evidence regarding the participant's self-assessment and peer-assessment, their opinion of the helpfulness of seeing the group learner model and their satisfaction in using this system confirms that further study in this area is justified.

It leads to the conclusion that in these specific circumstances, learners benefit more from learning and seeing their group learner model. However the evidence that we have here is not sufficient to answer whether it is likely to be true that other systems like this will always lead the better learning. As a result, we plan to continue our work in both similar and different directions to improve the strength of the conclusion that providing group learner model in a computer-based collaborative learning environment helps learners to benefit from learning.

The thesis mainly contributes to both CSCL and AIED communities for further study of GOLeM itself. Regarding the AIED community, GOLeM can be used for the further study on the benefits of seeing learning performance as a group learner model both before and after performing a group-test. Regarding the CSCL community, using this GOLeM with either a larger or a wider variety of groups of learners focusing on knowledge contribution during the group-test for the concrete evidence to support that social interaction has an impact on collaborative learning.

The evidence that we have found suggests that being able to see a GOLM improves learning. Though this evidence is not statistically significant, this thesis has provided the most thorough empirical examination of the benefits of a GOLM so far.

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Declaration of Author's Copyright

I hereby declare that this thesis was composed by my own that the all work described therein has been done by myself and this work has not been submitted for any other degree or professional qualification except as specified.

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Chapter 1

Introduction

1.1 Introduction

Open learner modelling is seen by a number of researchers as helping learners improve their knowledge by representing the state of their learning while collaborative learning is often seen as a good way to encourage peers to learn and teach each other. This research seeks to apply the concepts of collaborative learning and open learner modelling in a computer-based learning environment in order to see whether there is any impact of *seeing* their *group learner model* on their learning performance.

A learner model that can be inspected is known as an 'Open Learner Model' (OLM); this is considered to be an aid to reflection. In the past ten years there has been an increased amount of research focused on OLMs (Bull, Pain & Brna, 1995; Bull & Pain, 1995; Bull & Smith, 1997; Bull, Greer, McCalla, Kettel & Bowes, 2001; Bull & Nghiem, 2002; Bull, 2004; Kay, 1995 & 2000; Dimitrova, 2001 & 2003; Zapata-Rivera, 2001 & 2004) – all designed to help learners understand what they have learned more effectively. This kind of model allows the learner to inspect, and sometimes challenge, beliefs recorded in the user model in order to change them.

However, less has been done with 'Group Open Learner Models' (GOLMs) though there is some work with them. Zapata-Rivera and Greer (2001 & 2004) found that students could be very confused when seeking to understand their GOLM. However, this GOLM was developed by a group of students working together with a single instance of ViSMod. The issue of whether or not the GOLM can help learners is taken up as a major theme in this research.

Since it is often believed that the more the system knows about what is being exchanged between the group members, the more precise the pedagogic intervention can be for the learners. With respect to the benefits of collaborative learning, we decided to focus our work on information about the group rather than the individual. Hence we introduce our own notions of *group learner model* that uses *sentence openers* and a *dialogue games* to manage the interaction between learners and at the same time allows the system to estimate what is going on between the learners.

In this thesis, we introduce our *group learner model(s)*, explain the generation, and update mechanisms for the indicators that are used to measure learning performance in the chosen context. It is hoped that by using a *group learner model*, learners can either get a higher *concept-score* and/or improve their *degree of confidence* in this specific learning context.

Following Vygotsky (1978) who argued that learning had a strong social dimension, we believe that learners can often better improve their knowledge while learning with peers than learning individually. For collaborative learning in a computer-based learning environment, the aim is that learners and teachers get information that suits their needs.

The more precise knowledge that tutors have about learners, the more useful this information could be if it is reflected back to learners. To do that, information about each learner is considered and kept while they are learning in order to know how well they perform. We call this information a 'learner model'[1].

Many researchers work on building a *group learner model*[2]. Paiva (1997) introduced two scenarios which represent her notion of a group model. The first is to combine multiple individual models for the possible peer group (Hoppe, 1995; Bull & Smith, 1997). The second scenario is about learners who interact with the collaborative environment for which all of these properties should be considered: a shared-task space, a communication space, authorisation to see the communication, a domain model and an individual-task space (Soller, 1999 & 2001).

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[1] In this work, we call a learner model for a group a *group learner model*.
[2] Here, a *group learner model* is used to give information back to the learner to help improve learning.

In this research, we are considered *group learner model*s in three ways: generating, updating and representing the model. We define a *group learner model* as a *IdealLM* when it is obtained from the combining of information about individual learners[3], and we define an *GLM* when it is obtained from the interaction between members of the group[4]. In this work we try to understand what is going on between learners when they perform a group task in the specific learning environments In order to do that we provide a *chat-tool* which utilised the concept of a dialogue game for learners to convey a set of beliefs and goals. Analysis of each move can be used to update the *group learner model*. Information about the *IdealGLM* and *GLM* needs to be represented in a way that helps the learner understand the information presented.

Providing the right amount of information to suit the target group may encourage them to behave in more effective ways, for instance, providing learners with information about their group performance may help them to know how to react to their peer and tutor. To obtain such an advantage, learners can be presented with their performance in terms of their *group learner models*[5]. We expect that by giving information about the *group learner model*, learners can get either a higher *concept-score* or a higher *degree of confidence* in this specific learning context selected for this research – *number-conversion*.

1.2 Aim and Questions related to this Aim

The aim of this research is to find out whether *seeing* the *IdealGLM* and *GLM* in a computer-based collaborative learning environment which allows learners to communicate with their peer via a *chat-tool* helps them get either an improved *concept-score* or increased *degree of confidence* when they work on their own on a post-test. This leads to the following four questions, which are discussed in this thesis.

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[3] Taken from PairSM (Bull & Smith, 1997) that combines individual learner models to generate a *group learner model*.

[4] Soller (2001, 2004) focuses on the effective ratio of roles that group members play when they communicate via the chat session.

[5] At this moment, *group learner model* will be provide only to group members, not others, and no individual information is accessed or displayed to any learners.

1. In a computer-based collaborative learning environment, is there any impact of *seeing* and *not seeing* the OLM on participant's learning *concept-score* and their *degree of confidence*? (Comparing the results of pre-test vs. post-test, and pre-test vs. group-test)

2. Is there any difference in the learning *concept-score* or *degree of confidence* when a comparison is made between the results of learners who perform in a collaborative learning context and those who perform individually? In this work, the individual learning results of individual learning environment from the paper-based test is compared to the result of collaborative learning environment from the computer-based test.

3. Is there any impact of '*self-regulation*' on the improvement of learning performance focusing on the improvement of *concept-score* and *degree of confidence*?

4. Is there any impact of '*social interaction*' on the improvement of learning performance focusing on the improvement of *concept-score* and *degree of confidence*?

1.3 Methodology

To find answers for these four questions:

1. The content that was chosen to use in the research was selected to be *number-conversion* – specifically, for base 2, base-8 and base-16 conversion to base-10. The components of the chosen domain knowledge needed to be tested to confirm the validity of the tasks to be used in the experimental phase.

2. The context of the experimental work involved the design, implementation and testing of a system (called GOLeM). A 'low-tech' approach was taken, and the resulting paper-based version of GOLeM was checked for usability and for validity before implementing the version to be used with the participants.

3. The experimental work had to be designed. The core component of this design involved comparing learning with a computer supported collaborative learning (CSCL) environment with the GOLM visible with learning with an identical CSCL environment except with the GOLM hidden.

4. The experimental procedures had to be subjected to ethical approval from the Faculty of Education's Ethics Committee.

5. Participants had to be recruited who would find the work challenging.

The participants selected for the research were undergraduate students from the Department of Computer Science and Technology, Kanchanaburi Rajabhat University, Thailand. The choice of institution, where the author of this thesis has a position as a lecturer, made it easier to recruit participants, ensure that the experiment was conducted in a way that fitted into the local curriculum, and manage the experimental procedures. One hundred and twenty two participants were recruited for the work. All 122 participants were required to test the validity of the 30 questionnaire items selected. The results were used to validate the *difficulty level* and *item discrimination* (Explain further in Chapter 6).

A smaller set of items were selected for the work with GOLeM. We selected five questions, all of them in base-8, and these were used in the paper-based design of GOLeM. Base-8 was chosen is to avoid questions which were generally found to be too easy (base-2) or too difficult (base-16).

For the evaluation of the paper-based version of GOLeM, participants were divided into two groups (high and low scoring). Six pairs – (2 pairs of participants from the *low-score group*, 2 of participants from the *high-score group* and 2 pairs of participants from both *high-score group* and *low-score group*) – were selected. The result of the test suggested that the number of questions should be cut down to four to avoid the difficulties of participants getting tired during long period in which they would have to work. The domain was defined in terms of six basic concepts required for the four questions selected.

The suggestions from the participants were taken into account for the software version of GOLeM. In this work, Visual Basic 6 and MS Access are used for the simplicity of the implementation. The implementation of GOLeM is explained in Chapter 5.

The design of the experimental work involved a pre-test, group-test and post-test. To do these tests, participants were placed into three similar sized groups with respect to their score in the pre-test. Each group of participants was assigned to learn in one of three specific learning environments: *Envi1* – a collaborative learning environment in which learners were able to see their group model (*IdealGLM* and *GLM*), and have social interaction via a *chat-tool*; *Envi2* – a collaborative learning environment in which learners were able to have social interaction via the *chat-tool* but had no access to their group model; and *Envi3* – an individual learning environment. These three learning environments provided the same content – that of *number-conversion*. The experimental design and results are explained further in Chapter 6.

1.4 Outline of the Thesis

This chapter has introduced the idea of GOLeM and why it is worthwhile. In this work, four questions related to the main aim are asked to find out whether *seeing* the *IdealGLM* and *GLM* helps in a computer-based collaborative learning environment. This GOLeM enables learners to communicate with their peer via a *chat-tool* aimed at helping them get either an improved *concept-score* or increased *degree of confidence* when they work on their own on a post-test. The overview of what will be discussed in Chapter 2 to Chapter 7 is below.

The review of literature is mainly performed in relation to the learner model in terms of the general notion involved with the roles of *self-regulation*, *metacognition* and *external representation*. In Chapter 2, the focus is on individual learning while in Chapter 3 the concern moves towards learning in a group of two. The related topics of collaborative learning are divided into how to organise the communication, how the *group learner model* is generated, managed and represented, and a comparison of systems and works related to concepts associated with OLMs and Vygotsky's Zone of Proximal Development (ZPD).

After having the basic idea of opening the *group learner model* for collaborative learning, the specific requirement of GOLeM is described and motivated in Chapter 4. Later, this design was implemented as a paper-based version and tested for usability and plausibility of content before continuing to the computer-based version. These two versions of GOLeM are described in Chapter 5 in relation to the user interfaces and the way they were used.

There are 3 phases of testing described in Chapter 6. The first one is to test for the validity of the questionnaire items. The second phase focuses on the results of using the paper-based design of GOLeM with six pairs of learners for the plausibility of the design before continuing to implement the software version. The third phase is to find out whether using GOLeM can help learners get either a higher *concept-score* or an improved *degree of confidence* when compared to learners using the other two learning environments.

Chapter 2

'Solitary' Learning

The relevant research is considered in two parts – firstly, in terms of the solitary learner and secondly in terms of the collaborative learner. While no learner is truly solitary and no collaborative learner completely collaborative, this division provides for a clear progression of ideas that form the basis of the thesis.

In the past two decades, the concept of learner models has been widely used in intelligence tutoring systems (ITSs). The original uses of learner (or student) models were primarily intended to determine the learner's path through some curriculum. For example, *SCHOLAR* (Carbonell, 1970) for Geography subject, *BUGGY* (Brown & Burton, 1978) and *WEST* (Brown & Burton, 1979) for mathematics subject, and *IMPART* (Elsom-Cook, 1988) – the tutor for LISP.

In this thesis, we assume that the readers have some familiarity with the standard work on the nature of student models and the technical issues associated with them. VanLehn (1988) provided a well-known review of the kinds of student model then in existence, and the methods used for inferring these models. Dillenbourg and Self (1992) provided a detailed framework, which is explained in section 2.1.

The rest of the chapter provides a general view of learner modelling in ITSs, followed by the definition of learner model used in this thesis. Then the concept of OLM or 'Open Learner Model' is introduced both in terms of the notion and in terms of the definition of the OLM adopted in this thesis. The issue of 'opening' the learner model is then discussed. After that, the roles of metacognition that relate to the 'solitary' learner working with an OLM, which mainly focus on *self-assessment* and *self-regulation* are explained.

This leads to the development of a checklist to use as metacognitive control in the real system. Finally, issues connected with the manner in which the OLM is presented to the learner are raised by considering the literature on external representations (ERs). From a consideration of the possible way of representing the information in a learner model, we select a multiple ER exploiting both textual and graphical representations.

2.1 Overview of Learner Modelling in ITS

VanLehn's (1988) analysis of student modelling focused on two components of an ITS – the *student model* and the *diagnostic module*. He defined the *student model* as a component of ITS that represents the student's current state of knowledge, and the *diagnostic module* as the means by which the student model is manipulated.

In order to design a student model, there are three-dimensional spaces for the student model that VanLehn proposes: *bandwidth*, *knowledge type*, and *student-expert difference.* The first dimensional space, *bandwidth*, and focuses on how much of the student's activity is available to the diagnostic program. In this work there are three levels of bandwidth: *mental states* (all the activity, both physical and mental, is available), *intermediate states* (all observable, physical activity is available), and *final states* (only the answer is available).

The second dimensional space is *knowledge type* that focuses on what is the type of subject matter knowledge. The knowledge type is introduced by VanLehn in terms of three levels: *flat procedural* (procedural knowledge without subgoaling), *hierarchical procedural* (procedural knowledge with subgoaling), and *declarative*. The final dimensional space is *student-expert difference* that focuses on how the student model differs from the expert model. There are three types of difference between student and expert that are defined as *overlay* (some item in the expert model are missing), *bug library* (in addition to missing knowledge, the student model may have incorrect knowledge that the bugs come from the predefined library), and *bug part library* (bugs are assembled dynamically to fit the student behaviour).

The three-dimensional space introduced above which have three distinguishing values each can create (3 to the 3) kinds of student model. Under each dimension, the easiest of difficulty for each categories comes first. The easiest student model for the system to diagnose is *'mental state – flat procedural – overlay'* modelling and the hardest is *'final state – declarative – bug part library'* modelling. However during that time not many systems were built therefore there are twenty systems that are concerned and mapped in the simplicity two-dimensional space of *bandwidth* and *knowledge type*.

Being able to offer a representation of the 'solitary' learner's mental state might prove very useful, but the aim of this thesis is to focus on the group. In this case, the notion of mental state is not well defined for a group. Using *intermediate stages* or the final result is likely to be more useful.

By that time, after looking into detail of diagnostic techniques from the actual system, there are nine diagnostic techniques so far in the ITS literature. These techniques are *model tracing, issue tracing, plan recognition, expert system, path finding, condition induction, decision tree, generate and test interactive, and generate and test*. Among these techniques, *model tracing* seems to be an interesting technique that might suit the work in this thesis not only because it is probably the easiest techniques to implement but also because it assumes that all of student's significant mental states are available to the diagnostic program.

The next research of significance for the concept of learner modelling is that by Dillenbourg and Self (1992) who provided '*A Framework for Learner Modelling*'. They stated that this work presented a comprehensive conceptual framework and notion for learner modelling in ITS. The framework is based on the computational distinction between *behaviour, behavioural knowledge* and *conceptual knowledge*. Entities in this framework are defined in two dimension (vertical and horizontal dimensions). The vertical dimension consists of three entities that are behaviour, behavioural knowledge and conceptual knowledge while the horizontal dimension consists of three entities that are the system, the learner, and the system's representation of the learner. The concern of the vertical dimension is about *consistencies* between entities whereas horizontal dimension concern is about *discrepancies* between entities.

The difference between *discrepancies* and *consistencies* is that *discrepancies* indicate differences between two similar entities (e.g., two behaviours), whereas *consistencies* emphasize the logical link between very different things (e.g., learner's knowledge and his/her behaviour). In order to form the learner model, entities in these two dimensions are crossed with the nine possible models and might be extended to other two model. One of the extended models, which is interesting for applying in this thesis, is introduced as the model of *the learner's representation of his or her own representation of the conceptual knowledge* that relates to metacognition.

This framework clarified the terminology used in learner modelling, classified more detail about *discrepancies* and *consistencies*, explained more on diagnostic spaces and approaches. Moreover, the concept of misconception, bug and error are clearly defined.

While the framework is useful if the group is taken as a single 'unit', there is no support for trying to represent an individual's beliefs based on the beliefs inferred from the group's behaviour. Referring to more recent works, *STyLE-OLM* (Dimitrova, 2003), *Mr.Collins* (Bull et al., 1995), *PeerISM*, are all concerned with individual learner modelling but not group learner modelling. While *2SM* (Broady & Bull, 1998) introduced an idea close to that of group learner modelling in which system presents two individual learner models to a pair of students – but there is no direct use of any information from the group interaction.

In order to design student modelling and apply in our thesis, the model tracing technique is considered as the basic idea for investigated information during performing the task. The *overlay model* with *bug library* will be used for keeping information of the student model. The consistencies will be used to see the relationship between what learner does (behavioural) and the system thinks about what learner does. The *discrepancies* will be used to see the relationship between what the learner does and what the system thinks the learner does. After having the general idea of what learner modelling is, next the details of the learner model – introduced above as one of the crucial part in learner modelling, are illustrated.

2.2 Learner Model

A user model is similar to a learner model (or student model) but is intended to be used for a wider range of projects and for different purposes from tailoring information presentation, providing adaptive user interfaces, and maintaining co-operative dialogue (Dimitrova, 2003). Whereas learner model (s*tudent model*) are focused on building adaptive educational system for learners or students. Usually what will be kept in the learner model is information about learners' beliefs and other learning aspects. McCalla and Greer (1990) stated that one way of making tutoring system intelligent is to incorporate a model of the individual student that ideally contains at least the tutoring system's perception of (i) the beliefs of a student, (ii) a goal and motivation of the student and (iii) student's knowledge of the domain of instruction, including misconception.

The use of learner model is aimed at tracking a student's changing knowledge during the use of ITS. The learner model can be seen as either individual, known as UM (user model), SM (student model), or LM (learner model), or group model that is known as *group learner model*. During the last decades, there are many ITS that have used learner models – such as *WUSOR* (Carr & Goldstein, 1977) which introduced terms such as *overlay model* and represented the learner's knowledge by associating a value (known, intermediate, unknown) with each of 20 production rules to play game of *WUMPUS BUGGY* (Brown & Burton, 1978) was a system which represented domain knowledge by a network of production rules.

SCHOLAR (Carbonell, 1970) pointed out that a learner model might be built by annotating nodes and links in the network which means that it adopted a semantic network as a domain representation, *IMPART* (Elsom-Cook, 1988) proposed a 'bounded user model' which means that the learner model is represented by a set of upper and lower bounds on the possible states of the learners. *TAPS* (Hawkes & Derry, 1989) introduced a learner model that used fuzzy terms to indicate the value kept in the component of the model. *MACSYMA ADVISOR* (Genesereth, 1982) inferred misconceptions from the user's inputs and queries the user about these beliefs.

The ideal of *overlay model* was concerned at the very beginning with what learners know as a subset of an expert's knowledge. The value associated with conceptual knowledge either is that it can be only *known* or *not known* which does not support uncertainty as found in the real world e.g. learners have different learning results for similar questions. *WUSOR* (Carr & Goldstein, 1977) improved *overlay models* to represent learners' knowledge but added a stage of *intermediate* between *known* and *not known* to deal with uncertainty in the situation. However representing conceptual knowledge as *intermediate* leaves a wide range of possibilities.

In the real world, there are many factors that need to be taken into account for matters of uncertain situation – such as remembering and forgetting, data ageing, inconsistency of the beliefs, etc. With probabilistic models, the history of learning for each piece of conceptual knowledge are used together with the latest learning result to calculate the values associated with related conceptual knowledge at that time. Examples of probabilistic models are BBN – Bayesian Belief Network (Zapata-Rivera & Greer 2001; Read, Barros, & Barcena, 2006) and POK- Partial Order Knowledge Structures (Desmarais, Meshkinfam & Gagnon, 2006).

However, for the simplicity of the design of the learner model used in this thesis, we decided to be concerned only with what the learner did in the past and present without taking the age of the data into account. It means that whenever the data is performed is has the same significant value. Moreover, the information that is used to compare for learning performance among pre-test, group-test, and post-test comes from the present learning process. As a result of that, the used of an *overlay model* with a simple version of BBN, which not take the age of data, is considered to be adequate for the work done.

User model are widely used in many areas of interest. In this work, our focus is shaped into applying learner models to computer-based learning systems. At the very beginning, learner models were used to keep information about particular learners for individual (*DiyM*: Bull, 1998) and group learning (*PairSM*: Bull & Smith, 1997; Bull & Brna, 1997). After that, the concept of reflecting the information about learning was taken into account. Examples of such systems are: *See yourself write* (Bull, 1997), *2SM* (Broady & Bull, 1998) and *I-Help* (Bull et al., 2001). Later the idea of inspecting (PeerISM (Bull & Brna, 1999); Bull & Nghiem, 2002), negotiating (Brna et al, 1999; Bull & Pain, 1995) and challenging the beliefs in order to change the system's belief about learners are widely used (Mr.Collins (Bull et al, 1995); *STyLE-OLM* (Dimitrova, 2003); *Missing Peer* (Bull et. al, 1999)).

Kulhavy and Wager (1993) stated that giving some feedback is better than no feedback. The main purpose of giving feedback is to assist someone doing something so what should be reflected back should be precise, accurate, timely and necessary (Brown et al., 1997). The suitable time for providing information as feedback is right after they finished their task to avoid learners forgetting of what they did and have time to prepare for what to do next (Race, 2001).

In our system, the information of how well learners perform is externalised as *a bar-chart* with the option of textual explanation that is intended to help improve individual learning. Therefore the concept of providing information of what learners perform, which is known as an OLM, while using a particular ITS is concerned for a matter of learning improvement in aspects of *concept-score* and *degree of confidence*.

2.3 Open Learner Model (OLM)

When someone learns a topic, either on their own or with a friend, they may need to know how well they performed on that particular task at least to know their strength and weakness before continuing to do the next task (Gibb, 1992; Brown & Knight, 1994). In the classroom, the teacher may give some information such as a score or some suggestion about performance on the task[6]. An OLM is considered to be an aid to reflection insofar as it can convey – directly or indirectly[7]– such information, and provokes the learner to think about the truth or falsity of the information conveyed, and in doing this, reflects upon a number of issues including perhaps that of how their learning is progressing.

Bull and Nghium(2002) stated that "*the important reason for rendering the learner model accessible is to help student better understand their learning – 'opening' the learner model to the modellee offers a source of information about their relationship with a target domain which is otherwise unavailable, encourage them to reflect on their beliefs and on the learning process.*" In this section, firstly the general notion of 'opening' the learner model is illustrated, and followed by the roles of metacognition that may help learner from 'opening' learner model.

[6]This might be done in absolute or relative terms e.g. you got 7/10 or you did better than the average
[7]By indirect, we mean that the information may not be explicit but can be inferred from the information provided.

2.3.1 General notion of OLM

As defined by Bull & Nghiem (2002), an 'Open Learner Model' (OLM) is a student model that is designed to help learners for better understanding of their learning. This kind of model allows learners to inspect, negotiate or sometimes challenge for changing beliefs that are kept in the learner model (Kay, 2000). There are many learner models that obtain the concept of OLM such as *UM* (Kay, 1995), *TAGUS* (Paiva & Self, 1995), *Mr.Collins* (Bull, Pain & Brna, 1995), *See yourself write* (Bull, 1997), *2SM* (Broady & Bull, 1998), *PeerISM* (Brna & Bull, 1997), *ELM-ART* (Weber & Brusilovsky, 2001), *I-Help* (Bull et al., 2001) and *STyLE-OLM* (Dimitrova, 2003).

All of these systems support individual learning. Some systems – *UM, TAGUS, Mr.Collins, See yourself write, STyLE-OLM* – allow only the owner themselves to see the information of the learner model. Some systems – *PeerISM, 2SM,* and *I-Help* – allow other users (which can be the system, instructors or peers) to see the learner model.

Inspired by *UM* (Kay, 1995), what is kept or stored in the system as the user model is represented as components of learner's preference, knowledge, beliefs and attributes. Using these components and representing these in terms of an overlay model, what learners know as prior knowledge is considered to be a subset of what is in the expert model. However *UM*'s learner model did not explicitly refer to misconceptions. Therefore, our *overlay model* was extended to define misconceptions as learners' beliefs, which are not part of the expert's beliefs. In the system described in detail in Chapter 4, all of the expert's beliefs are represented as rules but misconceptions are not explicitly represented.

While *UM* does not allow any negotiation of the contents, *Mr.Collins* (Bull, Pain & Brna, 1995) seeks to provide this functionality. In *Mr.Collins*, learners can access the learner model to see what the system, which acts as a tutor, thinks about how well each particular learner performs. In the case that the result from the assessment of the system is lower than what the learner expects, they are able to negotiate for the system to record a higher level of how well they perform. However in order to change the beliefs of the system about that particular learner, they have to show evidence to prove whether or not they are at the level they require by doing another test provided by the system. That means the system has more control than learners do but in the way that allows learners to share beliefs and negotiate about what they do not agree about in their learning.

In other systems, the challenge of beliefs happens between the learners and the system. While in GOLeM, the learners can argue or negotiate only with their peers but not with the system. The system is used only as a mirror to reflect back what information it has about learners.

The way of *negotiating* is implicitly used in our system by adapting the idea of arguing, representing and managing the individual learner model to related issues for the *group learner model*. The idea of arguing is changed from human-computer negotiation between learners and the system that argue about what each other thinks about the learner model (the representation of what the system believes about learners' beliefs), to human-human negotiation where learners argue about what they think about each other's beliefs.

Even though the two peers negotiate to some extent, they do not negotiate with the learner model itself. In this thesis, learners who work together in groups of two have to negotiate for the group answer by providing evidence to each other which leads to an agreement about the group's answer.

The way learners exchange beliefs is borrowed from STyLE-OLM (Dimitrova, 2003), which introduced *dialogue games* as a technique that balances ease of use for both learners and the system for communication in a manageable way. Moreover *STyLE-OLM* represents the externalised of the user model as the combination of textual and graphical forms rather than text alone like *TAGUS, See yourself write, PeerISM* and *Mr.Collins*, which might help learners to get a better understanding of their learning performance.

However providing more than one source of information at a time, the matter of cognitive load should be considered to make sure that what we contribute to learners is helpful rather than preventing them from learning (Kalyuga et al, 1999; Mayer, 1997). To reduce the problem of cognitive load, the graphical representation is mandatory and displayed as a *bar-chart*, giving an option for the textual explanation to be displayed if the learner requires further information.

In terms of 'metacognition', *PeerISM* leads to the idea of using self and peer assessment as a reflection not only on how well they think they perform but also on how well your peer thinks you perform. This concept of *self-assessment* and *peer-assessment* applied together with regulatory check lists – used for self awareness which can be considered as a subset of metacognitive skills – might help learners to perform better in a group learning environment that enables group members to negotiate the answer and enables them to view the group learning performance as a *bar-chart* and optional textual explanation for further details.

In short, we borrow the idea of an overlay model and what is kept inherited from UM together with the awareness of misconception that might happen. In this case, we defined misconception as “what in learners' beliefs but not in the expert's beliefs” and keep all beliefs as rule-based for expert model. The graphical and textual representation can be displayed together if required to avoid the cognitive load but still contain what we expect to be helpful for learners. Combining concept of self and peer assessment with reflection back from the *group learner model* might help learners to be aware of how well they and their peers are performing – inferred individual performances by seeing *GLM* and *IdealGLM*.

The ways of scrutibilty (Kay, 2000) we consider here are either *viewable* or *negotiable* the beliefs that are kept in the learner model. The concept of *viewable* is used explicitly to externalise the learning performance as a group – for both *GLM* and *IdealGLM* (See more detail in Chapter 3 and Chapter 4) – which none of these systems work on. The concept of *negotiable* that we used is explicitly in the way that two learner’s exchange beliefs during the group-test in order to convey their peers with evidences for the agreement on the group answer. At the same time, this exchanged information is investigated and diagnosed by the system that means it is implicitly used as evidence for the group negotiation to manage the *group learner model*.

2.3.2 'Opening' the learner model

In the matter of 'opening' the learner model, there are many aspects that should be considered. The first question that has to be answered is *what is the definition of 'opening'?* – it has to make clear whether it means open to *only see but not change*, *can see and change in some conditions*, or *can see and change without any conditions*. In case that learner can change the learner model under some condition, what kind of condition might that be?

After discussing the scope of the accessibility for the model, the next question is *what will be opened?* This question focuses on the information that is given back to users. Are we going to show all of the information that is kept in the system or display only what is related to the representation of learning performance?

The question that will be considered next is *who can access the model?* Either the answer can be the learner model's owners themselves (Paiva & Self, 1995; Bull, Pain & Brna, 1995; Bull, 1997; Dimitrova, 2003), or their peers and their instructor as well (Brna & Bull, 1997; Broady & Bull, 1998; Bull et al., 2001). Moreover, learners could be allowed to set authority for others to access the learner model by either name or anonymously (Bull & Nghiem, 2002).

The next question that has to be cleared is *when is the learner model opened to users?* The answer can be any time or only at a specific time. In our system, the model of *IdealGLM* is reflected back to individual learners after finishing the pre-test, while *GLM* is provided when the group finishes each question of the group-test. In essence, the *IdealGLM* is how *GLM* is initialised.

After presenting the idea of what is meant by 'opening', we then moved on to what is opened to the user, who can access the model, how much information they can access and so on. This final question is about an external representation that is used to reflect back the learning information to users.

In this thesis, we try to investigate whether providing the learner model can help learners either improve their learning performance by getting a higher test score or increase their *degree of confidence* concerning each learning concept. Therefore, we have to make sure that the way of representing the learner model is suitable.

2.3.3 Roles of external representation in OLM

Providing the right amount of information to suit the target group may encourage them to behave in more effective ways, for instance, providing learners with information about their group performance may help them to know how to react to their peer and tutor. To obtain such an advantage, we then allow learners to see their performance as *group learner* *models*[8]. We expect that by giving information about both *group learner models* and representing them as *bar-charts* and in a textual format, learners can get either a higher score or a higher *degree of confidence* in this specific learning context.

As already stated, one of the useful features of the learner model is to keep the related information of particular learners which may help the inspector (which can be the system or human) to know how well learners perform. To access the information, there are many aspects of such an interaction within the system, interaction between human and system, interaction between human to human via the system, etc. During the interaction, there might be some exchange of beliefs between the learners. To exchange beliefs, we are concerned about which *information is made available* and *how to represent it to the others*? In order to answer these questions, the dual coding theory (Paivio, 1986) and cognitive theory of multimedia teaching (Mayer, 1997) are used.

Dual coding theory categorised the way that learners represent things in the world, which is as a series of complex association network, as visual and verbal representation. These non-verbal and verbal representations are attempts to explain what mental phenomenon or what happens within the mind. The non-verbal or depictive representation (such as picture, physical models) consists of iconic signs that are associated with the content that is represented through common features while the verbal or descriptive representation consists of symbols (sign and relation such as text), an arbitrary structure.

Multimedia allows multiple forms of external representations such as text, pictures, tables, and sound, to be combined in flexible ways (van Someren et al. 1998). The combinations of representations are used in a different way in the process of learning. Referring to Ainsworth (1999), multiple representation can be used to provide complementary information for each other and can support the construction of deeper understanding. Mayer (2001) states that "*Students learn better from words and picture than from words alone"*. Mayer found that students get a better understanding when they learn from text and picture rather than from text alone (Mayer, 1997).

[8] At this moment, *group learner model* will be provided only to group members, not others, and no individual information is accessed or displayed to any learners.

Kulyuga and others (1999) state that representing graphics with text is better than text alone or text with audio and graphics. It might be better to change the representation of text into audio format. However understanding audio is not easy to do at the same time as seeing the diagram when the dialogue is long and complicated. Therefore to avoid excessive cognitive load, the use of a diagram and textual representation is considered to be a good option for displaying the information to be learned.

There are many possible ways of combining the text and graphical forms to represent the learner model. *STyLE-OLM* (Dimitrova, 2003) uses a diagrammatic form of conceptual graph to represent the learner model and the text form for an interaction model. Moreover users can swap between learning mode and interaction mode to see what they have done in the past. *ViSMod* (Zapatra-Rivera, 2001) uses different colours and link sizes and nodes to indicate the level of knowledge for particular learners for each concept.

The colours that are used to represent each diagram should contain no more than five colours (Kulyuga et al., 1999). This should help learners quickly distinguish how well they perform for each concept. In our work, we will use a text form to represent the interaction model, while a graphical form will be used to indicate the level of knowledge for both group and individual learners. As a result, the representation of group learning in our system will use *bar-charts* to draw the attention of users to the information and then give the explanation on demand in a textual format.

2.3.4 Roles of metacognition in OLM

An OLM is seen as the model that reflects back to the learner information that lets them know how well they are performing particular tasks or how well they understand some concepts. From the information provided, learners then become aware of their knowledge and decide what should to do next. The generally held belief amongst researchers is that it is possible to improve learners' knowledge by showing them their learner model (Luckin & du Boulay, 1999; Zapatra-Rivera & Greer, 2004; Dimitrova, 2003). To investigate this belief, the concepts of 'theory of mind' and 'metacognition' are considered as crucial factors to understand how OLMs help improve knowledge (skills).

2.3.4.1 Theory of mind, metacognition and metacognitive skills

One definition of *theory of mind* is as "*a specific cognitive ability to understand others as intentional agents to interpret their mind in terms of theoretical concept of intentional states such as beliefs and desires"* (Davidson, 1984). In short, theory of mind is "*an awareness and understanding of mental processes"*. For example when a learner performs a specific task and the system reflects back the score or some other information, the way that learner tries to understand what the system reflects back is what the system believes about a learner's knowledge and skills.

What is presented by the system sometimes contains information that is not accurate in the judgement of the learner. How the learner reacts may be – consciously or unconsciously – influenced by the learner's attitude to the system. The learner may well assume that the system has some kind of intelligence – something that Reeves and Nass highlight in their work on the *media equation* (Reeves & Nass, 1996). Therefore we need to consider how seriously learners take into account what the system tells them and how they react to that information. Ideally, learners should be able to question what might be incorrect. However the learner may be influenced by cultural assumptions – if the system is intelligent and the systems is supposed to tell the truth then the learner may find it hard to challenge the system – especially in Thailand where the experiment is conducted. This is an additional factor to take into account in interpreting the results about their learning performance.

The main advantage of running this experiment in Thailand was that it was easier to obtain the participation of both members of staff and students. The main difficulty of working in this context seems to be that the culture does not help learners to make their opinions precise. In the Thai culture, people are taught to respect their teachers; therefore what the teacher says or does is not subject to doubt. As well as the result of this test, they try to get as high a score as they can to 'save face' and sometimes they copy each other's answers. Even though there were told that what they did during their participation had no affect on the assessment of their courses. We tried the best we could to avoid unexpected situation or factors that might affect the results of the test.

One form of metacognition is often simply defined as "*thinking about thinking"* (Livingston, 1997). However defining metacognition is not simple because there is still much debate over what metacognition means for a couple of decades. Defined by Wilson (1998, p.14), metacognition is the knowledge and awareness one has of their own thinking processes and strategies and the ability to evaluate and regulate one's own thinking processes.

According to Flavell (1979) metacognition consists of both metacognitive knowledge and metacognitive experience or regulation. Metacognitive knowledge is briefly stated to acquire knowledge about cognitive process and how to use knowledge to control the cognitive process. Flavell divided metacognitive knowledge into three categories: *knowledge of person variables, knowledge of task variables* and *knowledge of strategy variables*. Knowledge of person variables contains information about how well a particular person learned and processed information while knowledge about task variables considers the nature of the task to provide a suitable environment for the most productive results (e.g. reading a physics book is harder to understand than reading a novel so more time should be provided for this physics task). Knowledge strategy variables are concerned with when and where appropriate strategies are being applied.

Metacognitive experience involves the uses of metacognitive regulation to control cognitive activities to ensure that the cognitive goal has been met (Brown, 1987). For example, after reading a lesson asking oneself what one has learned from the lesson. If the question cannot be answered, then go back to the lesson again and at the same time determine what else can be done to ensure that that lesson has been understood.

2.3.4.2 Regulatory Checklists

Schraw (1998, p.121) has developed a regulatory checklist that students can use to monitor their own metacognitive control. His checklist is classified into three sections corresponding to processes of *planning, monitoring* and *evaluating*. Details of the lists for each process are displayed in Figure 2.1.

1. Planning

- What is the nature of the task?
- What is my goal?
- What kind of information and strategies do I need?
- How much time and resources will I need?

2. Monitoring

- Do I have a clear understanding of what I am doing?
- Does the task make sense?
- Am I reaching my goal?
- Do I need to make changes?

3. Evaluating

- Have I reached my goal?
- What worked?
- What didn't work?
- Would I do things differently next time?

Figure 2.1. A regulatory checklist of Schraw (1998)

Relatively few attempts have been made to evaluate metacognitive activity with OLMs. Dimitrova (2003) evaluated the use of her *STyLE-OLM* system in terms of reflective activities with seven postgraduate students. Applying this checklist to her work on learners' reflection, it is possible to see some connections. The concern of this thesis is also to encourage *self-regulation*. Implicitly, the same holds for the learners using *STyLE-OLM* since this system allows learners to make claims and later review these claims, possibly changing their beliefs after interacting with the system. This revision process is similar to '*Do I need to make change?'* under the monitoring process in Schraw's checklist.

In Dimitrova's work, if either the system or learners have doubts about each other, they can make a challenge for a justification from the other. While in our thesis, the challenge of beliefs can be done only by members of the group without interference from the system.

As seen in Figure 2.2, an initial adaptation of Schraw's checklist to combine thinking about both oneself and the group[9].There are three groups of checklists: *developing a plan of action, monitoring the plan* (being aware of everything that has been done by oneself), and *evaluating the plan*.

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[9]These check lists suggest a way of evaluating metacognitive activity

1. Check lists for developing a plan of action (Before performing a task)

- How much prior knowledge do I have?
- What should I do first?
- How much time is needed to complete this task?

2. Check lists for Monitoring a plan of action (During performing a task)

- How am I doing?
- How should I proceed?
- What do I need to do if I don't understand?

3. Check lists for evaluating a plan of action (After performing a task)

- How well did I do?
- Did I do more or less well than what I had expected?
- What could I have done differently?
- Did I learn more?
- How well have I helped myself to learn better?

Figure 2.2. A self-regulatory checklists applied from Schraw's

If learners have such a metacognitive experience, we assume that they will have self-awareness of what they know and what they not know, and what they should do to complete the given task. However for individual learning, it might hard to make *self-regulation* explicit because it might not work naturally if a learner keeps expressing what they already know to themselves that might cause boredom using the system. To avoid such a problem and still maintain this self-regulation, the questions of *how much prior knowledge do I have?, how am I doing?* are considered for this section on solitary learning and then add more checklists for collaborative learning that are explained in Chapter 3 for the full detail.

2.4 Summary

In this thesis we assume that the readers have some familiarity with standard works on the nature of student models and the technical issues associated with them. Referring to VanLehn (1988) and Dillenbourg and Self (1992), learner modelling in both frameworks was reviewed to make the notion of 'learner modelling' clear, and how the learner model is used in ITSs. The 'student model' is defined as a component of an ITS that represents the student's current state of knowledge (VanLehn, 1988). The information that is kept in the student model can be either hidden from or reflected back to users.

In this research we focus on 'opening' the information in the learner model to users. Therefore the systems and projects that were already introduced in the section 2.3 all contain the concept of 'opening' to others. There are many researchers working on learner modelling. For example, Kay – *UM*, Bull (both by herself and with colleagues) – *Mr.Collins, 2SM, PeerSM, I-Help, See yourself write*, Dimitrova – *STyLE-OLM*, etc. Moreover in section 2.3.2, questions of 'opening', are introduced. These questions were *what is the definition of 'opening', what will be opened? who can access the model?, when is the learner model opened to users? Which external representation is used to reflect back the learning information to users*? More details of these questions for applying in our system are explained in Chapter 4.

In order to investigate whether providing the learner model can help learners improve their learning performance either by getting higher testing score or degree of confidence of each learning concept. There are two respects with which we are concerned. The first one is an ability of learners to understand the provided information – related to the concept of *self-regulation, metacognition,* and *metacognitive skills.* The second respect is about choosing the *external representation* that is suitable and might help a learner to improve either concept score and/or learning degree of confidence – examined in terms of *external representation, dual coding theory,* and *multimedia theory*. The way selected for representing the information in the learner model is to combine graph – *bar-chart*, with textual explanation (See more detail in Chapter 5)

In the next chapter, the concept of 'opening' the learner model will be shifted from 'solitary' to 'collaborative' learning to represent *GOLM* which is introduced as the representation of the group that generate and manipulate the information from the interaction of learners during performing the group task. *Dialogue games* and *sentence openers* are used in the communication session that allows learners to exchange beliefs and at the same time enable the system to investigate this exchanged information.

Chapter 3

'Collaborative' Learning

The definition of 'collaborative learning' is broadly expressed as “a situation in which *two or more* people learn or attempt to *learn something together*” (Dillenbourg, 1999). This definition introduces three elements of collaborative learning which are *two or more, learn something,* and *together.* Each element is interpreted in difference ways. The element of *two or more* refers to the number of the group members which can be a peer (group of two people), small group (group of under 10 people), and group of more than ten people.

The definition of *learn something* is interpreted as *follow the course*, *problem solving,* or *course material*. The final element is how this group of learners interact with each other in order to learn something. The word *together* is considered here as either face-to-face or computer-mediated interaction. The interaction can be either asynchronous or synchronous, relying on the time of the interaction. For division of labour, it can be either truly joint effort (Panitz, 1998) or divided labour (Beck, 1997).

In this chapter, firstly the broad idea of 'collaborative learning′ (Dillenbourg, 1996) is introduced and shaped into what will be used in our research. Secondly, the application of collaborative learning and CSCW: Computer Support Cooperative Work (Kumar, 1996) is introduced as CSCL or Computer Support Collaborative Learning. The main concern CSCL is to facilitate group activities and support the work that face-to-face cannot do but such an approach is not meant to replace face-to-face interaction (Stahl, 2002 & 2003).

The focus of CSCL is on an educational setting that aims at supporting and promoting learning together effectively (Baker & Lund, 1996 & 1997). In section 3.1, the correlation between CSCL and metacognition, and how and why communication works with CSCL are explained.

In section 3.2, the review of *group learner model* is illustrated for matters of generation, management and representation. In section 3.3, the review of group open learner model (GOLM) which focuses on 'opening' the *group learner model* is concerned about what to feed back to learners and using which external representation. The chapter ends up with example systems that explicitly apply the ZPD concept for open learner modelling in collaborative learning environments.

We hope that the work we describe allows learners to obtain an improved conceptual understanding and a greater level of confidence in their understanding. This is achieved through the use of a group open learner model which allows learners to exchange their beliefs during a group test and which reflects back the information about the group's learning performance The pre/post test design enables us to examine the learning gains to evaluate the effectiveness of the approach.

3.1 CSCL: Computer Supported Collaborative Learning

Computer Supported Collaborative Learning or CSCL emerged from the research interests of 'collaborative learning′ and ′CSCW'. Cited by Hsiao, Ellist et al (1991) defined CSCW or Computer Supported Cooperative Work as a computer-based network for a group to work. CSCL is different from CSCW for the aspect both of the focus and the intended purpose.

CSCL focuses on what is being communicated rather than the communication techniques themselves (Barros & Verdejo, 2001). It has been used in educational environments to scaffold or help learner to learn together more effectively. Moreover, CSCL is used to facilitate group activities (Greer et al., 1997 & 1998) and support the work that cannot be done through face-to-face interaction – but it is not meant to replace face-to-face interaction. CSCL is concerned with various aspects such as social, psychological, and learning effects.

3.1.1 General notion of CSCL

As defined by Dillenbourg and others (1994), there are three theories of learning which have been taken into account. These are *socio-constructivist theory, socio-cultural theory* and *share cognition theory.* What we are concerned about here is the socio-constructivist approach that is used as an approach to *cognitive development* – focusing further on the interaction among peers that would increase their mastery of the concepts to be learned.

Socio-constructivist theory, which is a theory that was strongly influenced by the theories of Piaget (1928, 1932), that is concerned with the cognitive development of the individual from *social interaction*. Piaget's work was extended through the empirical study of Doise and colleagues (Doise, Mugny & Perret-Clermont, 1975). Doise et al. provided empirical evidence that *'social interaction'* helps learners in a group achieve more than they do individually – this neo Piagetian work is related to that on Vygotsky's Zone of Proximal Development which focuses on what learners cannot do by themselves but can do it with others, – and later these learners still acquired that particular knowledge/skills individually when performing similar task as those they performed in a group.

The similarity of socio-constructivist (Piaget, 1932) and ZPD (Vygotsky, 1978) is that they both acknowledge the intertwined social and individual aspects of development, but Piaget attributes the primacy to the individual while Vygotsky's work on the ZPD attributes learning to the social environment. Because our work is concerned not only with how learners use the information provided through *social interaction* to improve individual's cognitive learning but also they use it to improve their group learning performance. In order to do that, issues relating to metacognition – which is simply defined as '*thinking about thinking*' – and focusing on *self-regulation* and *self-assessment* are expressed in section 3.1.2.

As defined by Wikipedia (2007), *social interaction* is a dynamic, changing sequence of social actions between individuals (or groups) who modify their actions and reactions according to the actions by their interaction partner(s). *Social interaction*, for such an experimental approach, would be treated as if it were a black box, which cannot be opened to see what is inside. However what we are concerned with here in this thesis is not only to examine whether or not learners benefit – in this case is to get a higher post-test score – from learning in a particular collaborative learning environment. We also need to know more about the causality of these particular results. Consequently, the relation between the changes in cognitive development and *social interaction* is considered.

In order to understand what is going on when learners perform the group task together, information about *social interaction* should be revealed in some way. One way of doing so is to develop a computational model (Dillenbourg and Self, 1992b). Allowing learners to communicate to their peers while doing the group task, and then manage to represent this information as a learner model might help us to extract what is going on within the learning process. More details about applying such a computational model with the mapping of the changed cognitive improvement during the *social interaction* are expressed in section 3.1.3.

We could, like with many other studies examine learning gains using a pre/post test design with the treatment being a collaborative activity. The result from the difference between pre-test and post-test performance could be used to tell whether learners benefit from collaborative learning or not.

3.1.2 How s*elf-regulation* and metacognition works with CSCL

In order to understand how collaborative learning works we need to be concerned with *theory of mind* and *metacognition*. *Theory of mind* is a cognitive ability to understand others in order to interpret their mind in terms of theoretical concepts of intentional states such as 'beliefs' and 'desires'. Because we cannot directly connect to others' minds, what we can do is to guess other intention from both implicit and explicit information they perform.

The beliefs of self or others that we have in the matter of collaborative learning can be both precise and not precise. It depends on the ability of particular learners on *self-assessment* and other metacognitive skills. In order to give the effective reaction or response to specific participants, what learners should be aware of are considered into three periods that are before doing the task, during doing the task and after doing the task. *Self-regulation* is introduced as a method of controlling what we try to do in the effective way

(Zimmerman, 1998; Randy, Isaacson & Fujita, 2006). Applying Schraw's *self-regulation*, the group regulation is displayed in Figure 3.1.

1. Check lists for developing a plan of action (Before performing a task)

- ***How much does my peer know?***
- ***How much prior knowledge do I have?***
- How can I get my peer to help me?
- What should we do first?
- How much time is needed to complete this task?

2. Check lists for Monitoring a plan of action (During performing a task)

- ***How are we doing?***
- Can I make a group contribution?
- How should I proceed?
- What do we need to do if either you or I don't understand?

3. Check lists for developing a plan of action (After performing a task)

- How well did I do?
- Did we do more or less well than what we had expected?
- What could I have done differently?
- Did we learn more?
- How well have I helped my peer to learn better?

Figure 3.1. A group regulatory checklist applied from Schraw's

According to the 'checklist' that we applied from Schraw's regulatory checklist, there are three lists are explicitly used in our work. These lists are *how much does my peer know?, how much prior knowledge do I have, and how are we doing*. The list of *how can I get my peer to help me?* In addition *what should we do first?* Are not explicitly used but can imply further from the conversation that the pairs make during the group-test. At the end of the post-test, we do not plan to ask learner to assess themselves or their peers so there is none of these lists is applied and used in our system.

In collaborative learning, there is a need not only to understand themselves but also to understand others that motivates our concern to include notions of *theory of mind*. Thus knowing how the group is doing and reflecting upon this, the learner also needs to understand themselves so that they can determine their strength and weakness. At the same time, they may need to take into account the knowledge of their peers and the potential for their peers to help them. There are experimental results about the benefit of *self-regulation* that are used as method for metacognition on learning (Soller, 2001; Dimitrova, 2003; Gama, 2004).

We believe that *self-assessment* is one of the process used for *self-regulation* to compare what learners have done to the correctness. In this work, we scope *self-assessment* onto the expression of their thoughts and their beliefs about their peers according to the provided group learning performance. We have an assumption that from the provide information of group learning performance, learners who have precise *self-assessment* might have precise *peer-assessment*.

According to the benefit of metacognition on learning performance (Gama, 2004; Zimmerman, 1998), this work tries to show that learners who are accurate on both *self-assessment* and *peer-assessment* can be expected to have better learning performance in collaborative learning.

3.1.3 How 'communication' works with CSCL

Collaborative learning is interpreted here in two distinct ways - the way that learners help each other in a group and the way that a teacher or a learning system helps the student to gain a better understanding (Dillenbourg, 1996). Teaching collaboratively helps learners to learn skills and ideas initially in their ZPD (Vygotsky, 1978) which is why 'collaborative teaching' is important.

As defined by Vygotsky, The Zone of Proximal Development is the distance between the actual development level – as determined by independent problem solving, and the level of potential development – as determined through problem solving under adult guidance or in collaboration with more capable peers (1978, p. 86). Murray and Arroyo (2002) implemented a learner model to support the concept of ZPD – their work illustrated that the student who masters material collaboratively today can master it individually tomorrow. Moreover the concept of ZPD has been utilised in other research – such as that of Ecolab (Luckin & du Boulay, 1999), HOMEWORK (Luckin et al, 2006) and CKC (Hansen et al., 1999). Both

Luckin and Hansen defined the framework for measuring ZPD and using computer technology to extend the use of the ZPD concept.

In this work we are concerned not only with how well learners did individually after they worked with others but we are also concerned with what learners cannot do on their own but can do with others. Therefore we drew on both the theory of socio-constructivism and the concept of ZPD to examine the cause of *social interaction* that impacts on group performance and might be the cause of individual cognitive development.

According to socio-constructivist theory, talk with others as a *social interaction* helps learners improve individual cognition. For the *social interaction*, we are concerned with using a text for exchanging beliefs. The ways of using a text to exchange beliefs are introduced as *free-text, semi-structured* and *fixed-text*. The *free-text* is the most flexible technique to send texts to others such as email, web-board, etc. This technique is suitable for human-human combination with using computer as a medium to pass on texts.

However, the aim of applying a computer as a tool to mediate learning is to focus on how to use what the investigates from the learning process to encourage learning in some ways. *Fixed-text* and *semi-structured* are both possible techniques that can be used to encourage computer-based learning. With the *fixed-text* approach, learners can send only sentences provided by the system while the *semi-structured* approach lets learners combine with utterances that sometimes they can type-in freely together with what a system provides. Rather than the flexibility of communication that humans need, the understanding of what learners believe via the exchanged texts is what we do not want to miss. As a result, a *semi-structured* approach is taken that applies the concepts of *dialogue games* and *sentence openers* are introduced in this thesis as a technique for using in the *chat-tool*.

Related to the idea of ZPD is that the idea that everyone may be in a different state of learning in a group. Hence with a user model, either a personal or a group model, it is possible to individualise the level of knowledge to provide a suitable degree of reflection (Luckin & du Boulay, 1999; Goos, Galbraith & Renshaw, 2002). However for developing more efficient collaborative learning, empirical studies have changed the focus from 'establishing parameters' to trying to understand the role such variables play in mediating interaction.

3.2 Group Learner Model

There are not many researchers who work on building a *group learner model*[9]. Paiva (1997) introduced two scenarios that represent her notion of a group model. The first is to combine multiple individual models for the possible peer group (Hoppe (1995); Bull and Smith (1997)). The second scenario is about learners who interact with the collaborative environment for which all of these properties should be considered: a shared-task space, a communication space, authorisation to see the communication, a domain model and an individual-task space (Soller, 1999 & 2001 & 2005). In this research we will consider *group learner models* in three ways: *generating, updating* and *representing*. Next, the explanation of generating and updating are introduced in this section. The detail of representing the model will be explained later under the topic of 'Opening the *group learner model*'.

3.2.1 Representation of *group learner model*

The *group learner model* is introduced here in two scenarios: combining from multiples individual models, and generating from the interaction within the collaborative environment. To combine the group models from individual models, the information of individual model are manipulated using specific merging formulas (Bull & Smith, 1997).

The way of representing this group model for the first scenario can be done the same way as representing an individual model which can be represented as graph, text, the combination of both graphic and text (Bull et al., 2005), skill meters, conceptual graphs (Dimitrova, 2001; Zapata-Rivera & Greer, 2001; Van Labeke, Brna & Morales, 2007), etc. The factors that should be considered for this matter of representation are *accessibility* – who can access the model?, which information can be seen and which cannot?*, role of time* – when learners can see the model?, when it shows, it shows for a specific period or forever?*, access method* – Is it viewable, inspectable, editable, negotiable?*, presentation* – textual, graphics, *etc* (Cumming & Self, 1991; Bull & Kay, 2005).

9 Here, a *group learner model* is used to give information back to the learner to help improve learning.

The second scenario is different from the previous one by focusing on using the information during the group learning to manage the group model. There are various types of information that can be used to represent the group model depending on the aim of the research. Soller and others (1999, 2004, 2005) investigated the combination of eight roles of sentence openers: *argue, mediate, inform, request, motivate, acknowledge, maintenance*, and *task to communicate*. The combination of percentage for using these roles is used to tell whether the particular conversation is either balance or supporting or not.

Using *sentence openers* to elicit what learners believe is applied in our thesis but we do not include the eight roles that are introduced in Soller's work. That is because the purpose of these roles is to check for the combinations of effective communication in the group learning situation that we are not concerned with at this point. Moreover, we decided to apply both scenarios of representing group model by defining *IdealGLM* for the group model of the first scenario, and *GLM* for the group model of the second scenario.

3.2.2 Generating the *group learner model*

Most people see the group model as some kind of addition of individual models. Hoppe (1995) combined multiple individual learner models with the aim of forming more effective peer groups though Paiva (1997) looked for something better by combining the concept of a group model with an individual learner model to construct a basic framework for models in collaborative situations.

However PairSM (Bull & Smith, 1997), a model that applied a simple picture and a set theory equation to illustrate the *group learner model*, seems to be interesting because it considers a *group learner model* together with the notion of the ZPD even though the group model comes from a simple combination of the individual learner models.

$$S1S2 = SM1 \cup SM2 \cup SM\ S1\&S2$$

Figure 3.2. An equation for generating group model from Bull & Smith (1997)

The explanation above can express a group model as an equation in Figure 3.2, which SM represents the knowledge of an individual learner, and SM S1&S2 represents knowledge that the two can display only when working together. Referring scenarios of group model above, our work borrows ideas from Paiva's and PairSM to generate the group model for Collaborative Learning with consideration to ZPD concept.

The *IdealGLM* is generated from the combining of two individual models using the *'union'* and the *'intersection'* of the set as formulas for the group model. The *GLM* is generated from the transformation values of the exchanged beliefs of the group members during the group-test. In order to elicit what learners exchange during the learning process, *dialogue game* and *sentence openers* are applied.

The *dialogue game* (Burton, 1998; Dimitrova, 2003) is used for assigning the roles for learners. For the simplicity, this work occupied only two roles that are 'Questioning' and 'Informing'. These roles are represented by fourteen *sentence openers* one of which is used to compose a sentence for communication. The detail of how *GLM* and *IdealGLM* are generated is explained later in Chapter 4.

3.2.3 Managing the Interaction of *group learner model*

The intention of this work is to try to understand what is going on between learners when they perform a group task in the learning environment developed for this research (Dimitrova, 2003; Brna & Burton, 1997). In order to do that we provide a *chat-tool* that allows them to express what they believe in a sensible way. Learners are not allowed to type freely but to use the provided *utterances* instead. A *dialogue game* defined by Levin and Moore (1980), and used in Dimitrova (2003), Burton and Brna (1996), is a knowledge structure that represents multiple turn dialogue patterns organised around specific dialogue goals.

Natural language is excessively complicated to deal with while fixed text lacks flexibility for learners to state for what they want. Fortunately there is a *semi-structured* approach that obtains the benefits of both flexibility of typing together with enabling a computer to investigate processes while they performed a group-test (Jermann & Schneider, 1997; Baker & Lund, 1996). As a result of that, a *semi-structured* approach that applies concepts of *dialogue games* and *sentence openers* is used in our *chat-tool*.

A *dialogue game* is used to convey a set of beliefs and goals. Burton (1998), McManus and Aiken (1995) used *sentence openers* as a mechanism to identify which *speech act* is being used. However, allowing learners to fill in anything they like to complete the provided *sentence openers* may not be sufficient to identify a *speech act*. Based on the above researches (Dimitrova, 2003; Brna & Burton, 1997; Levin & Moore, 1980; Burton & Brna, 1996; Burton, 1998; McManus & Aiken, 1995), we develop a set of *sentence openers* together with additional structure (termed complements) as *dialogue utterances*. The rules of the *dialogue game* will restrict the use of *dialogue utterances* to ones permitted by the state of the game. Analysis of each move will be used to update the score indicator in the *group learner model*.

STyLE-OLM (Dimitrova, 2003), and *ICLS* (Soller, 1999 & 2001) use different means of tagging individual moves in the interaction. *STyLE-OLM* uses the notion of a *dialogue game* for *communicative interaction* between a learner and the system, while the OLM concept allows student to inspect and negotiate their own model. *Mr.Collins* (Bull et al., 1995) aims at improving learning through promoting reflection by giving a chance to both students and a system to defend their beliefs using the difference of confidence in beliefs between the learner and the system. Whether learners can challenge and negotiate models through menu, changing models ultimately depends on the rules programmed into the system.

ICLS (Soller, 1999 & 2001) is an 'Intelligent Collaborative Learning System' that provides a good example of the use of *sentence openers.* This emphasises the role of *communicative interaction*. The *ICLS* system classifies groups of sentence openers, helping the group know how well they perform. In our work, we borrow the idea of dialogue game and sentence opener for the communication interaction and the level of confidence for their beliefs to generate the learner model.

The *group learner model* is introduced in our work as both *GLM* and *IdealGLM* in respect to different representations of the learning performance – *GLM* and *IdealGLM*. The *IdealGLM* is generated from the combining of two individual models for the group model that the system expects if these two learner perform group-test together. However during the real situation of the group-test, the information of the group model is unpredictable. Therefore dialogue game and sentence openers are introduced for communication method that used to elicit the exchanged beliefs of learners. These exchanged beliefs are transformed into the values that can be used for managing and updating the *GLM*. More detail of how *GLM* and *IdealGLM* are generated, updated and represented is explained in Chapter 4.

3.3 Group Open Learner Model

Brna(1998) investigates collaborative relationships with a specific interest in collaborative student modelling. Collaborative learning is good in the way of encouraging peers to learn and teach each other whereas open learner modelling gives the learner an opportunity to inspect or sometimes challenge their user model to make it more accurate (Brna, 1999). Is it possible to merge these two effective concepts together? *Mr.Collins (Bull, Pain & Brna, 1997)* contains the idea of collaborative learner modelling which student and instructor (computer) help each other to build the model by inspecting and challenging. In this point, the instructor can decide what the student's answer is right or wrong (In this case, the system has more power than student does). *PeerISM* (Bull & Nghiem, 2002; Gan, 2001) – a human-human peer system, is an environment where students use feedback from each other as an inspector of their model but in case that both cannot accept the same thing they have to report to teacher.

3.3.1 'Opening' the *group learner model*

The notion of a GOLM emerges from the combination of a 'group model′ and an 'OLM'. An 'OLM' is simply thought of as an aid to reflection while a 'group model' is a more complex concept. While there are many examples of research that use a group model, there are few that can define the OLM in a way that differentiates clearly between the emerging properties of the group and the properties of the individuals involved OLM.

For our work, we especially need to define what exactly the group model is, how it works, and precisely what the model includes. We take as a starting point Paiva (1997) who considers a group model as '*a way of capturing the aspects that identify a group as a whole*' and it may include group beliefs, group actions, group goals, group misconceptions, differences between individuals and group conflicts.

Less has been done with GOLMs though Zapata-Rivera and Greer (2001 & 2004) found that students could be very confused when seeking to understand their GOLM. However, this GOLM was developed by a group of students working together with a single instance of Zapata-Rivera's ViSMod system. Referring to the external representation of the previous chapter, our *group learner model* will be displayed as a *bar-chart* and textual explanation (Mayer, 1997; van Someren et al., 1998; Ainsworth, 1999; Kulyuga et al., 1999). The further detail of external representation of GOLM *as IdealGLM* and *GLM* is explained in Chapter 4.

3.3.2 Example of systems that explicitly applied ZPD concept for OLM in collaborative learning environment.

There are many systems that are used for collaborative learning, some of which refer to the concept of ZPD, some reflect back the learner model to an individual student and a very few use a GOLM but how many of them contain both concepts of reflecting back group knowledge and explicit use of the notion of the ZPD? Six systems have been selected as representative of the state of the art; these are compared. More details of these six systems are explained later in the chapters.

Table 3.1. The comparison of systems
to represent concept of ZPD, individual and group leaner model

System's name	References	Did they use the ZPD concept explicitly[10]?	Did they reflect back to individual learner?	Did they reflect back the *group learner model* ?
Mr.Collins	(Bull et al., 1995)	No	Yes	No
PairSM	(Bull & Smith, 1997)	Yes	Yes	Yes
ECOLAB	(Luckin & du Boulay, 1999; Luckin, 1998)	Yes	Yes	No
ICLS	(Soller et al., 1999)	No	Yes	Yes
ViSMod[11]	(Zapata-Rivera & Greer, 2001 & 2004)	No	Yes	No
STyLE-OLM	(Dimitrova, 2003)	No	Yes	No

[10] We mean that internally there is a model of the learner that represents ZPD in some direct ways.

[11] Another version of ViSMod describes some works with a group model but not the kind that we are interested.

According to Table 1, *ViSMod, STyLE-OLM* and *Mr.Collins* are systems that reflect back only to individual learners whereas *Ecolab* use both the concept of ZPD and reflecting back the model to each learner. *ICLS* reflects back both individual and *group learner models*. Even though PairSM reflect back meet all three requirements but the learner model that reflect back to learners are merged from the information of individual learner models. The first question is why a group model is utilised and the second is how are we going to generate, manage and represent the *group learner model*?

In our research we focus on a GOLM for collaborative learning. The *group learner model* will borrow ideas from Paiva and Bull's PairSM to generate the *group learner model* while taking the notion of the ZPD into account. *Dialogue game* and *sentence openers* will be used for *communicative interaction* whereas it is planned to use a *bar-chart* and textual explanations as mirroring tools to represent the learner's beliefs and knowledge.

3.4 Summary

This chapter firstly gave the general idea of 'collaborative learning' and then shaped this to the specific definition as a group of two learners performing a group-test. The theory of 'socio-constructivist' is used with the addition of further looking into the *social interaction*. From the perspective of socio-constructivist, *self-regulation* and *self-assessment* are applied in order to understand how an individual's cognition improves. Only some questions in Figure 3.1 are explicitly used to express *self-assessment* and *peer-assessment*. During the group-test, learners are able to exchange their beliefs via the provided *chat-tool*. Respectively to *social interaction*, we utilised *button interface* rather than using *free-text* because we aimed to investigate what is going on while learners talk to each other. Even though a *free-text* approach seems to be the natural way for learners to exchange beliefs and easier to use than a *button interface*. The related useful information of learners during the group task are managed and kept in the learner model.

Applying the concept of GOLM to manage and represent information about learners as a group might help them to improve individual *self-awareness* that are considered as a subset of *self-regulation* from seeing the external representation of

IdealGlM and *GLM*. Moreover with the benefit of collaborative learning which is introduced by Vygotsky as ZPD concept, learner can get over their actual performance when do it with peers.

As that result, if learners get either higher learning concept scores or degree of confidence (compare results of post-test to pre-test) when learning in the computer-based collaborative learning environment, this would imply that learners can benefit from interacting with this *group learner model – IdealGLM* and *GLM*. Nevertheless there are many undesirable, uncontrollable factors that might occur when assigning humans to work together. Therefore what happened in one situation can only be used as an implication as plausible situation for the other. As well as what happened as a result in this thesis cannot guarantee the result when applied in other circumstances.

Chapter 4

The Domain of 'GOLeM'

Within this chapter, the advantages of the *group learner model* coupled with collaborative learning will be illustrated via the following: an illustration of learning in a group of two, a detailed explanation of testing methodologies, and a detailed explanation of the *IdealGLM* and *GLM* results. Firstly, the concept of collaborative learning as it applies to this study is introduced in order to give the view of whom this system will be effective. Later the scenario view of how this system work is explained. The aim of this detail is to provide an idea of how we applied the concept of *group learner model, collaborative learning* and *communicative interaction* to build the system called 'GOLeM' to work in a specific context of GOLM. After having a view of how this system works, we then continue to work on the concept of GOLM.

The three domains, which are considered as core parts of GOLM are *domain knowledge*, *group learner model*, and *communicative interaction*. These domains are responsible for generating, updating, and representing the *group learner model*. The domain knowledge provides the idea of what we are concerned about and how to manage the learning content. Without this domain, we do not have a clue of what should be measured, of what is right, and of what is wrong.

The next domain is the domain of *group learner model*, which focuses on generating, updating, and representing the information of the group learning performance. Applying this domain together with the domain knowledge, *IdealGLM* is generated from the learning performance of individual learners. The generating and updating of the *GLM* corresponds to the information from communicative interaction during the group-test. The *IdealGLM* and *GLM* are represented as *bar-chart* and *textual explanation* and are provided to learners if required.

4.1 Participants in GOLeM

The participants in GOLeM obtain the benefits of perceiving learning performance as *IdealGLM* and *GLM*. In order to show the benefits of perceiving learning performance, we first explain the reasons for choosing group learning rather than individual learning. Then we continue with an explanation of participation that includes the number of group members and types of participation that makes a group that works more effectively.

4.1.1 Individual learning vs. collaborative learning (ZPD)

Nowadays many researchers give more credit to learning in a group than as an individual because of effectiveness. The statistical analysis on the test scores in Gokhale's research illustrated that students who participated in collaborative learning performed slightly better in drill-and-practice tests and significantly better in critical-thinking tests than individual learning (Gokhale, 1995). The classifications for Bloom's Taxonomy: *knowledge, comprehension* and *application* were categorised as a *drill-and-practice*, while *synthesis, analysis* and *evaluation* were categorised as a *critical thinking* (Bloom, 1956).

The content of *number-conversion* that is applied in GOLeM aims at improving at least the knowledge and comprehension referred to within Bloom's Taxonomy. Therefore, the testing scores should not be much different from the results already stated within Gokhale's research. However, in practice there are many factors that influence the test results, especially time and the familiarity of the student with the test. Sometimes learners cannot share how they think or calculate step-by-step because the answer is automatically generated in their brains but ideally, the test should show what the participants think they know.

In our point of view, collaborative learning should focus on the way that mutual participants (Burton, 1998) engage to solve the problem and accept the result of the group together. The result of the group will be pass or fail depending on all of the participants. All participant decisions have the same priority of significance. The decisions of the group will be *all (participants) for one (group result) and one for all*.

4.1.2 How to group participants more effectively

From the group learning perspective, many variables affect learning performance. For example, *number of the group members, prior knowledge of the group members, the method of grouping, gender, age, nationality, social background*, can all affect learning performance. In this work, we are concerned with two factors – *number of the group members and prior knowledge of the group members.*

4.1.2.1 Number of the group members

Collaborative learning, by the definition of Dillenbourg (1999), is "*the situation in which two or more people learn or attempt to learn something together*". Within my learning context, we choose a learning group of two members rather than three members for the following reasons.

First, one member's performance can be implied from the other group member. However if the members are more than two, it is more complicated to imply the performance of other group members. For example if the group of A and B has belief about X but A does not know about X, it implies that B has a belief about X.

Second, in the group of two, the members have a better chance to share ideas with a peer than in a group of three, sometimes when two members discuss with no channel for the other member the other member can become bored. Even if the channel is opened for the other member to join, if he/she doesn't want to talk, no one knows that he/she has learned or not.

Diversity of ideas is one reason for learning collaboratively (Soller, 1999 & 2001). It is suitable for the task that needs more diversity of ideas, more members increases the amount of diversity, from different backgrounds of members and requires a lot of time. However, in some learning domains a group size of two or three gives almost the same result of diversity but a group size of two members can be easier to control and provides a result in a shorter amount of time. Therefore, we focus our collaborative learning on mutual peers in a group of two.

4.1.2.2 The way of grouping rely on 'prior knowledge'

The group participants are focused on the learners who already know about *number-conversion*, especially on the conversion of base-2, base-8 and base-16 into base-10. The participants that will be used here are undergraduate students in the 1st to 4th year of study.

These students are classified by the use of the 30-item questionnaire test and then split into two groups, *high-score* group and *low-score* group, according to the test scores. Within this work, learning groups are considered in three different cases, which are to pair students who have *high-score* together, pair student who have *high-score* with *low-score*, and pair students who have *low-score* together. Paring is done by researchers corresponding to the 30-item test scores. More information of grouping and test results is explained further in Chapter 6.

4.1.3 Conclusion of the participation in GOLeM

In this work, the focus of participants in collaborative learning falls within peer learning under the investigation of an expert peer. The method of grouping is concerned with two member groups and grouping under the condition of prior knowledge in three member groups. The result from each group type is analysed separately and as a whole to see the difference between group types and later is applied to the difference in learning environments. More information of grouping and testing results is explained in Chapter 6.

4.2 Scenario View of GOLeM

Within this section, we aim at focusing our idea of GOLM into a specific context, which allows learners to communicate with peers during the group test and provides the learning performance as *IdealGLM* and *GLM*. After developing this focus, learners can get a higher testing score or *degree of confidence* in group-test than pre-test. In order to build such a system, we are concerned with how to get accurate information to update the *group learner model*, which will be given back to learners as *IdealGLM* and *GLM* for a particular time.

To elicit the information within the group-test, allowing learners to express what they believe is simple and straightforward. However doing that does not help if the system cannot interpret useful information from what learners expressed. Therefore, the *chat-tool* that we have in mind allows learners to exchange their beliefs and at the same time allows conversation investigation by the system. The detail of the conversation is interpreted into *concept-score*, which is used to generate, update, and represent group learning performance as *GLM*. Further detail of what components this system consists of and how each component works, will be explained later in the chapter.

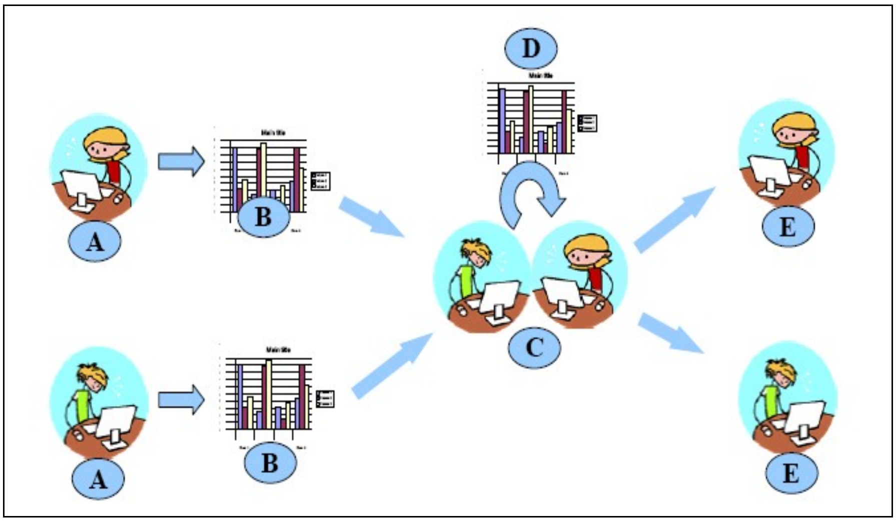


Figure 4.1. The scenario view of GOLeM

Referring to Figure 4.1, it can be seen that the system is made up of five steps designated alphabetically from A to E. Starting with step A; the learners do the test individually as a pre-test. Then the system provides the learning performance as *IdealGLM* if required (Step B). After that, learners continue to do the group-test (Step C) in which they can communicate with peers via the *chat-tool*. After finishing each question of the group-test, group members are able to see the learning performance as *GLM* if required (Step D). Later when finished with the group-test, these learners do the individual test again as a post-test.

Step A: Two learners login to the system and decide to learn together. After that, they do individual pre-tests and submit the results to the system after they finish. The results consist of their answers and their *degree of confidence* for each question item. Once their task is submitted to the system, their score (*concept-score*), the measurement indicator of their performance, will be calculated.

Step B: Learners request to see how well they perform as an *IdealGLM*, which is provided through *bar-chart* first, and later with *textual explanations* if learners require seeing further detail. During this step, learners are requested to finish the questionnaire before asking for *IdealGLM*.

Step C: Learners do a group task and exchange their beliefs about the content via the provided *chat-tool*. For each step, every sentence that a learner composes and sends to their peer will be interpreted in order to update the *GLM*.

Step D: After finishing each question of the group-test, learners can require seeing how well they perform as a *GLM*, which is provided through a *bar-chart* first, and later with *textual explanations* if learners require seeing further detail. During this step, learners are requested to finish the questionnaire before asking for *GLM*.

Step E: After finishing the group-test, learners continue doing an individual post-test, and submit the results to the system. The results consist of their answers and their *degree of confidence* for each question item. Once their task is submitted to the system, their *concept-score*, the measurement indicator of their performance, will be calculated and the system is terminated.

All direct and indirect information of the pre-test, the group-test, and the post-test will be considered to see whether there is any benefit from learning in this computer-based collaborative learning environment. Further explanation of the system testing results is presented later in Chapter 6. The next three sections are about the core domains applied in GOLeM. Within section 4.3 an explanation of the following will be provided, the domain knowledge, what will be contained in this domain, how to confirm the validity of the content, and how to measure participant knowledge. Next, in section 4.4 the application of the *dialogue game* and *sentence openers* within the *chat-tool* to elicit what learners communicate during a group-test is illustrated. Later in section 4.5, the generating, updating, and representing of the *IdealGLM* and *GLM* are explained.

4.3 The Learning Concept Applied in GOLeM

As mentioned above, the first core domain, which is needed in GOLeM, is domain knowledge. Firstly, in section 4.3.1, the reason for choosing *number-conversion* as learning content is explained. Secondly, in section 4.3.2, the concepts that need to be learned are defined for the conversion of base-2, base-8 and base-16 numbers to base-10. Thirdly, in section 4.3.3, the 30 item multiple-choice test is produced to test for the suitability of the content and the validity of the test. Fourthly, in section 4.3.4, there are explanations of six learning concepts, which are revised from four learning concepts that were applied in the paper-based test. Then later in section 4.3.5, the application of these six learning concepts into four questions of the test and ending with the summary in section 4.3.6.

4.3.1 Why we choose *number-conversion*

For the research, there was a need to find a topic that is reasonably easy to generate questions suitable for undergraduates, as these students were judged able to cope with open learner models more easily than schoolchildren. It was also important to find an area for which it was easy to recruit participants. For pragmatic reasons, a domain was chosen that was within my area of expertise – i.e. Computer Science. The curriculum of the Department of Computer Science and Technology, Kanchanaburi Rajabhat University, Thailand suggested that *number-conversion* was appropriate.

The knowledge of *number-conversion* is used as background for improved understanding in many subject areas within Computer Science such as Computer Architecture (Peterson, 1978), Microprocessor, Assembly Language (Leventhal, 1979) etc. In computing, because computers and humans do not understand the same language, we have to learn to understand how computers work in order to use them more efficiently. Actually, commands being executed by the computer rely upon a base-2 representation whereas humans are taught to understand base-10. To understand more deeply how computers work, learners have to know about base-2, base-8, and base-16 for the relation between themselves and base-10.

However, from the experience of teaching these subjects, misconceptions about *number-conversion* caused many problems and led to delays in learning of the higher-level subjects, boredom, frustration, etc. In order to prevent such a problem, the idea of providing a system that learners can use to test them and improve their understanding in *number-conversion* emerged. This idea was extended to the introduction of a computer-based collaborative learning system called GOLeM. Next, the plausibility of utilising the content of *number-conversion* is examined to verify its suitability for the target group.

4.3.2 How do we know this content is suitable for the target group?

During my four years of teaching experience in subjects of Assembly Language, Computer Architecture, problems in *number-conversion* always occurred with learners who had already learned this topic. According to the curriculum of the Department of Computer Science and Technology, Assembly Language is taught in the 2nd semester of the 2nd year while Computer Architecture is taught in the 1st semester of the 4th year. Based on this, my first assumption was that the content of *number-conversion* might be suitable for 2nd year and 4th year students.

In order to confirm the plausibility of this content, a 30-item multiple-choice test was produced in English and approved by my supervisor who had experience in *number-conversion*. Later this test was translated into Thai, tested with a couple of participants who had already graduated in computing before using this test with 122 students in the Department of Computer Science and Technology selected from each year between the 1st and the 4th year. The test results showed that normally the ones who got the higher scores had already learned about this concept. However, some of them still got a low score almost certainly owing to forgetfulness and misconceptions.

Because of the way in which the curriculum is taught, students normally graduate within three and a half years. Therefore, it was decided that the target group for further research would be students in the 2nd and 3rd year if the test was to take place in the 2nd semester or 3rd and 4th year if the available time for the test were the 1st semester. Next, the validation of the test in terms of *difficulty level* and *item discrimination* is introduced.

4.3.3 How to confirm the validity of the test?

The validity of the items used was tested using the following steps. Firstly, the 30-item multiple choice test was produced and then approved by my supervisor who had experience in the content of *number-conversion*. After that, this test was translated into Thai and approved by English, Thai and Content experts for the reliability of the test in the Thai language. Next, the test was distributed to two participants experienced in *number-conversion*. The test results and comments were used to revise the test to produce a more reliable version.

The final version of the 30-item test was used with 122 participants. The results showed that, for the *difficulty level*, there were 6 items classified as '*Quite easy*', 14 items classified as '*Moderate*' and 10 items classified as '*Quite difficult*' (See details in Chapter 6). For *item discrimination* there were 2 items classified as '*Very good*', 17 items classified as '*Good*', 10 items classified as '*Fair*' and only 1 item classified as '*Should be improved*'.

It can be concluded that this test is reliable in relation to the aspects of *difficulty level* and *item discrimination* (Kubiszyn & Borich, 1984; Miller, 1972; Townsend & Burke, 1975; Gay, 1980). Next, the six learning concepts, which were used to represent the content of *number-conversion*, are introduced before applying in specific question types.

4.3.4 The revised version of the six learning concepts

The content of *number-conversion* was initially represented in terms of four learning concepts. Each concept has subsidies for each specific question number of five questions that are applied in the paper-based test. After investigating the results of the tests, we found out that the four concepts that we have do not clearly specify what we want to measure from the test. Moreover, there is too long of a time (between 1 to 2 hours) for finishing these five questions as a group-test so we decided to reduce the number of questions to four.

In the paper-based test, each learning concept is used to represent each question number, except Question2 and Question3 that were used to represent learning concept2. However having the result and comments from testing with the paper-based design, we realised that each question contains more than one learning concept. Therefore, we modified our learning concepts into six concepts, which still contained the same overall idea that the previous one contained. A specific combination of these six concepts is used for each type of question, which will be explained later. The details for each learning concept are explained below:

Concept1: Learners can use the value of each bit position on the left of the decimal point to calculate for a specific number. (See more detail in 4.4.2.1)

Example of Concept1: The number on the **1st left** of decimal point of base**-2** number is equal **2^0**.

Concept2: Learners can use the value of each bit position on the right of the decimal point to calculate for a specific number. (See more detail in 4.4.2.1)

Example of Concept2: The number on the **1st** **right** of decimal point of base**-2** number is equal **2^{-1}**.

Concept3: Learners can use the arithmetic operator to calculate for the value within each specific bit. (See more detail in 4.4.2.2)

Example of Concept3: The value of a number in each bit can be calculated by **x** that particular number to the value of that bit.

Concept4: Learners can use the arithmetic operator to calculate for the value between each bit. (See more detail in 4.4.2.4)

Example of Concept4: The result of *number-conversion* can be calculated by +(plus symbol) the value of each bit.

Concept5: Learners can transform the given number, which is on the left of the decimal point into other forms. (See more detail in 4.4.2.3)

Example of Concept5: For base**-2**, the value of **2^7** is equal **2x2x2x2x2x2x2** .

Concept6: Learners can transform the given number, which is on the right of the decimal point into other forms.(See more detail in 4.4.2.3)

Example of Concept6: For **base-2** , the value of **2^{-2}** is equal **(1/2)x(1/2)**.

4.3.5 How each question type relates to the six learning concepts

Table 4.1. The specific concept combination for each question type

Base	Question Type	Concept combination
Can be either base-2, base-8 or base-16	QuestionType1	1,3,5
	QuestionType2	1,3,4,5
	QuestionType3	2,3,6
	QuestionType4	2,3,4,6

Table 4.1 shows that there are four types of question, which are used in the system in the form of a multiple-choice test. Each question type contains a specific combination of concepts. *QuestionType1* consists of concept 1, 3, and 5. *QuestionType2* consists of concept 1, 3, 5 and 6. *QuestionType3* consists of concept 2, 3, and 6. *QuestionType4* consists of concept 2, 3, 4, and 6.

For the simplicity of the system, only base-8 numbers are used**.** Example of question types 1-4 are displayed below.

QuestionType1: What has the same value as the underlined position of $\underline{1}01_8$ after being converted into Base10?

a.$1 \text{ x } 10^3$

b.1+(8x8)

c.8 x 3

d.$1 \text{ x } 8^2$

QuestionType2: What is the value of the underlined positions of $7\underline{156}_8$ in terms of an equation after being converted into Base10?

a.$(1 \text{ x } 8^2) + (5 \text{ x } 8^1) + (6 \text{ x } 8^0)$

b.$(1 + 8^2) \text{ x}(5 + 8^1) \text{ x}(6 + 8^0)$

c.$(1 \text{ x } 8^3) + (5 \text{ x } 8^2) + (6 \text{ x } 8^1)$

d.$(1 + 8^3) \text{ x}(5 + 8^2) \text{ x}(6 + 8^1)$

QuestionType3: What has the same value as the underlined position of $0.0\underline{1}_8$ after being converted into Base10?

a. 1×8^{-1}
b. 1/(8x8)
c. 0.64
d. 0.01

QuestionType4: What is the value of the underlined positions of $0.\underline{42}1_8$ in terms of an equation after being converted into Base10?

a. $(4 \times 8^{0}) + (2 \times 8^{-1})$
b. $(4 + 8^{0}) \times (2 + 8^{-1})$
c. $(4 \times 8^{-1}) + (2 \times 8^{-2})$
d. $(4 + 8^{-2}) \times (2 + 8^{-1})$

4.3.6 Summary of the learning concepts used in GOLeM

The content of *number-conversion* is chosen from the teaching experience of the researcher and the validity confirmed through the testing with experienced participants. Firstly, two experienced participants did the test before continuing to use the test with 122 participants selected from each year between the first and the 4th year from the Department of Computer Science and Technology.

The result from testing with these 122 participants showed that not only was the content of *number-conversion* suitable for the target group but also the *difficulty level* and *item discrimination* are in the range of standard level (See section 6.1 for more detail of *difficulty level* and *item discrimination*).

Moreover, six learning concepts for *number-conversion* were used to construct the four types of questions. It can be inferred from each question how well learners performed for each particular learning concept. In regards to this information, it might help the system to reflect back exactly which learning concept is their strength and weakness for learning on *number-conversion*. Next, the use of a *dialogue game* and *sentence openers* is introduced as a method for composing the sentence within the designed *chat-tool*.

4.4 Applying *Dialogue Game* and *Sentence Openers* in a *Chat-tool.*

In this system, we aimed at giving learners the ability to express their beliefs to their peers. At the same time, the system can investigate to see what each learner achieved during a group-test. *Sentence openers* are used to compose expressions. Respective to the concept of the *dialogue game*, the rules of each move are set and applied to each *sentences opener* in order to control the flow of conversation in the group-test.

We adopted a simple version of the *dialogue game*. In this game, there are two types of moves that learners can apply: 'Questioning' and 'Informing' (Burton, 1998). Since we wish to extract more information from the move than whether it is a questioning or informing move, we have devised fourteen *sentence openers*. The different intentions captured are classified as one of the basic moves ('Questioning' and 'Informing').

The *chat-tool* is designed around the concepts of *dialogue game* and *dialogue moves* (Dimitrova, 2003; Soller, 1999 & 2001) (with associated *dialogue utterances*) to allow learners to exchange beliefs. This will give some reasonable idea as to what the learners are discussing, where they are facing difficulty, and how they resolve any disagreements. *Dialogue utterances* are associated with each of these fourteen *sentence openers*. Some *sentence openers* provide sufficient structure to allow the learners to complete them with a simple piece of information. Others need additional structure to be provided (called complements here). The game is terminated when both learners agree with the answer and the *degree of confidence* that both have in the answer.

4.4.1 *Sentence openers*

In the designed *chat-tool*, *sentence openers* are used as a control of the flow in the conversation. Respective to the rules for each move, *sentence openers* allow the system to investigate the participants' knowledge during the group-test. At the very beginning of the design, there are fifteen *sentence openers*. After testing this design as a paper-based test, the number and minor detail of *sentence openers* was revised. Therefore, applying the revisions here in GOLeM, there are 14 *sentence openers* as displayed in Table 4.2.

Table 4.2. The details of 14 *sentence openers*

No.	Type of sentence	Sentence Detail
1	Informing	I agree with you
2	Informing	Yes (This answer is used for the Yes/No question)
3	Informing	I don't agree with you
4	Informing	No (This answer is used for the Yes/No question)
5	Informing	I believe that …
6	Informing	I am not sure but I believe that …
7	Informing	I do not know about this and guess that…
8	Informing	I believe that because …...
9	Questioning	Please give me further explanation; I would like to know more.
10	Questioning	Please go on, I do not want to talk about this any more.
11	Questioning	Please you could explain more about …
12	Questioning	Why do you think that...?
13	Questioning	Do you mean that …?
14	Questioning	Shall we change the topic?

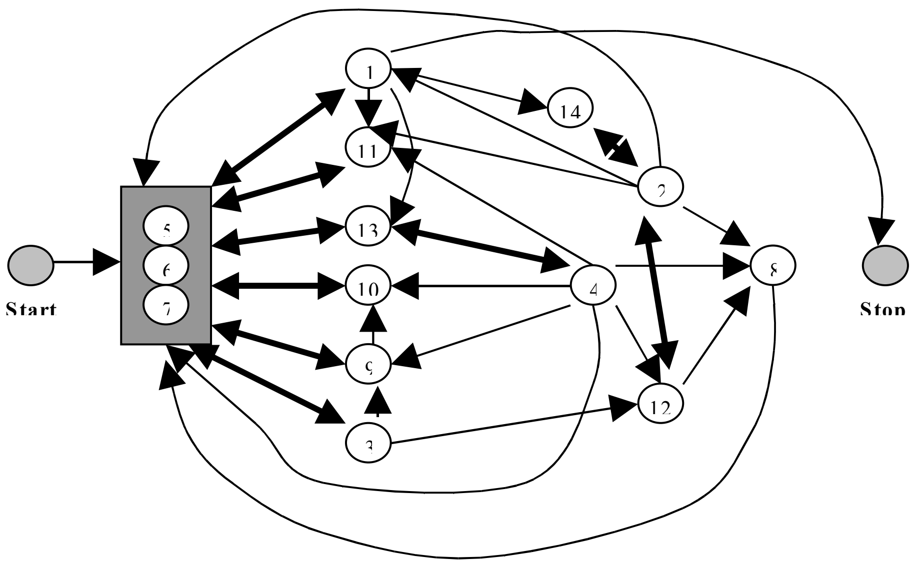


Figure 4.2: Using *sentence openers* with regard to state of the *dialogue game.*

Table 4.3. The explanation of symbols represent in Figure 4.2.

→	Represent one of the moves that can be made from the present state. The head of the arrow is a possible move for the next state
◆	Represent two arrow sides. → showing it is possible to move in each direction
○	Represent the state of the move after apply a particular *sentence opener*

Figure 4.2, regarding the rules of the game, the number in the circle stands for each *sentence opener* described above. The *dialogue game* is allowed to start using one of sentences 5, 6, or 7. If one of these sentences is selected as a move, the next possible move is the sentence that has arrows pointing from the present stage. The game is stopped only when the present stage involves selecting sentence number 1 and the previous stage involved one of sentence number 5, 6, or 7 with *utterance5*. In other words, the game will be terminated when both learners agree to the answer and the *degree of confidence* that the other proposed.

4.4.2 *Utterances* to complete the sentences

The system provides utterances for all the *sentence openers* that contain '…' symbols for the six domain concepts above. The utterances are grouped into five options. Each utterance is associated with its own rule to calculate specific values used to update the *GLM*. *Utterance1* to *utterance4* contain expressions related to *number-conversion* while *utterances5* is used when a learner wants only to state the result and their *degree of confidence*.

4.4.2.1 Utterance1

The number on the **A** **B** of decimal point of **C** number is equal **D**.

Example of utterance1

The number on the **1^{st} right** of decimal point of **base-2** number is equal **2^0**.

In a position **A**, the order of *1^{st}, 2^{nd} , 3^{rd}, 4^{th}, 5^{th}, 6^{th}, 7^{th}* and *8^{th}* can be applied. The value of *right* and *left* are applied in position B. For the simplicity of the system, position A and B are combined and used as one filling gap. In a position **C**, the values that can be applied here are *base-2, base-8,* and *base*-16. The values that can be applied in position **D** are under three bases: base-2, base-8, and base-16. . The values of base-2 are in the lists of *2^{-8}, 2^{-7},..., 2^7,2^8*. The values of base-8 are in the lists of *8^{-8}, 8^{-7},..., 8^7,8^8*. The values of base-16 are in the lists of *16^{-8}, 16^{-7},..., 16^7,16^8*.

4.4.2.2 Utterance2

In order to calculate for the value of each bit, the operator **A** is used for doing a calculation.

> ***Example of utterance2***
>
> The value of a number in each bit can be calculated by **x** (multiplication symbol) that particular number to the value of that bit.

The values that can be applied in position **A** are arithmetic operators: + (plus), - (minus), x (multiply), and / (division).

4.4.2.3 Utterance3

For **A** , the value of **B** is equal **C** .

> ***Example of utterance3***
>
> For **base-2** , the value of **2^7** is equal **2x2x2x2x2x2x2** .

In a position **A**, the values that can be applied here are *base-2, base-8,* and *base-16.* The values of *right* and *left* are applied in position B. The values that can be applied in position **B** are under three bases: base-2, base-8, and base-16. The values of base-2 are in the lists of 2^{-8} , 2^{-7} ,..., 2^{7} ,2^{8}. The values of base-8 are in the lists of 8^{-8} , 8^{-7} ,..., 8^{7} ,8^{8}. The values of base-16 are in the lists of 16^{-8} , 16^{-7} ,..., 16^{7} ,16^{8}. The values that are applied in position **C** are displayed in terms of the other representations that are equivalent to the value in position **B**.

4.4.2.4 Utterance4:

The result of *number-conversion* can be calculated by **A** the value of each bit.

> ***Example of utterance4***
>
> The result of *number-conversion* can be calculated by ± (plus symbol)the value of each bit.

The values that can be applied in position **A** are arithmetic operators: + (plus), - (minus), x (multiply), and / (division).

4.4.2.5 Utterance5:

Choice **A** is the correct answer with *degree of confidence* **B**. (level 1 is lowest and 10 is highest)

> ***Example of utterance5***
> Choice **A** is the correct answer with *degree of confidence* **9**. (level 1 is lowest and 10 is highest)

The values that can be applied in position **A** can be a choice of A, B, C, or D. While the value that will be filled in the position B is a number from 1 to 10.

4.4.3 The use of *sentence openers* and *utterances*

This topic illustrates how *sentence openers* and *utterances* are used. Referring to the rules of the game applied to each *sentence opener*, a learner can make a move when the turn is provided. The examples below are an actual conversation that learners perform during the group-test.

For each question item of the group-test, the system provides the information of what members have done individually and state as *belief of the answer* and *degree of confidence*. In an example below, Learner15 and Learner16 are paired to do the task together. They have the same answer but a different *degree of confidence*. At this time, the turn is given to Learner16.

Example1:

The detail of the answer and *degree of confidence* in this question for Learner15 and Learner16 are *Learner15* choose to answer choice *C* with *degree of confidence 10* while *Learner16* choose choice *C* with *degree of confidence 8*. Please give reasons of your answer by composing sentences with the provided *utterances* (start with Learner16)

Learner16 said: (5) I believe that... (1) The number on the 2^{nd} left of decimal point of base8 number is equal 2^{-2}.

Learner15 said: (1) I agree with you.

Learner16 said: (5) I believe that … (2) the value of number on each bit can be calculated by multiplying that particular number to the value of that bit.

Learner15 said: (1) I agree with you.

Learner16 said: (5) I believe that … (3) for base8, the value of 8^1 is equal 8x1.

Learner15 said: (5) I believe that... (5)Choice C is the correct answer with degree of confidence 4.

Learner16 said: (1) I agree with you.

In example1, the conversation starts with Learner16 choosing sentence number 5, which contains the symbol '...', so an utterance is required as a complement. According to the rules of move, the sentence that can be used after applying sentence number 5 are the sentences in the list of 1, 3, 5, 6, 7, 9, 10, 11, and 13. In this case, Learner15 selected sentence number 1. The next move, the sentences that can be applied are in the list of 5, 6, 7, 13 and 14. Learner16 chose to move on with sentence number 5.

The conversation continued respectively to the turns and the rules of game. In order to terminate the conversation and move on to the next question, learners should confirm their agreement on the final answer. To do that one member should choose sentence number 5 with *utterance5* for the answer and the *degree of confidence*, and the other one should accept with sentence number 1. This example is referred to again in 4.5.2 to illustrate how the *GLM* is generated and updated during the group-test.

4.4.4 Summary of *dialogue game* with *sentence openers* in *chat-tool*

In regards to the simple version of the *dialogue game*, which defined the move as *'Questioning'* and '*Informing'*, there are 14 *sentence openers* applied in GOLeM – the first eight sentences are defined as *Informing* and the last six sentences are defined as *Questioning*. Each sentence contains it own rules of moving and applying with utterance as complement. The turn of the conversation is controlled by the system in order to give both learners equally chance to exchange their beliefs. The rules of using these *sentence openers* whether or not applying with *utterances* are illustrated 4.4.2. Then continuing with examples of applying these *sentence openers* in the conversation, which is explained in 4.4.3.

Next, the use of six learning concepts and the conversation during the use of *chat-tool* are illustrated for the matter of generating and updating the *IdealGLM* and *GLM*. Later the representing of group learning performance will be illustrated by the used of *bar-chart* and *textual explanation.*

4.5 Managing the use of *IdealGLM* and *GLM*

During the learning process, it is necessary to keep and update information that may help to improve the learning performance. The more precise the information we have the more effective the feedback we can give to learners. The focus of this work is into the domain of computer-based collaborative learning environment. The *group learner model* is represented into two aspects – *IdealGLM* and *GLM*.

We focus here on the details associated with generating, updating, and representing the *group learner model*. The specific context of the research is *number-conversion*. There are two types of *group learner model* introduced in GOLeM, which are *IdealGLM* and *GLM*. We define a *group learner model* as a *IdealGLM* when it is obtained from the combining of information about individual learners[12], and we define an *GLM* when it is obtained from the interaction between members of the group[13]. In order to represent learning performance as *IdealGLM* and *GLM*, the *concept-score* will be displayed in terms of *bar-chart* and textual explanation of the chart when learners require further detail.

[12] Taken from PairSM (Bull & Smith, 1997), which combines individual learner models to generate a *group learner model*.

[13] Soller (2001, 2004) focuses on the effective ratio of roles that group members play when they communicate via the chat session.

4.5.1 Generating the *IdealGLM*

An analysis of the domain of *number-conversion* allowed us to define six learning concepts (See section 4.3.3). The measurement of the learning performance involves several indicators relating to these concepts. We selected four types of questions related to '*number-conversion*', which contained specific sets of concepts (See Table 4.1).

To calculate the *concept-score* for each concept, we first checked the validity of the answer, and then used the *degree of confidence* to calculate the *result* for each question item. After that, we used the equations (See Table 4.6) to generate the *concept-score* for each domain concept for an individual learner.

4.5.1.1 Example of generating *result* for each question

The results of individual learning of Learner A and Learner B, who were assigned to do the group-test together, are shown in Table 4.4. After that the *correctness* and *degree of confidence* for each question is calculated and used as *result*. The details of *result* for each question are displayed in Table 4.5.

Table 4.4. The detail of *correctness* and *degree of confidence* for individual pre-test

	Question 1		Question 2		Question 3		Question 4	
	correct ness	*Degree of confidence*	*correct ness*	*Degree of confidence*	*correct ness*	*Degree of confidence*	*correct ness*	*Degree of confidence*
Learner A	1	7	1	4	1	7	0	3
Learner B	1	5	0	5	0	5	0	4

Table 4.5. The detail of *result* for individual pre-test.
The values in the brackets ( ) display how the *result* is calculated.

	Result of Question1	*Result* of Question2	*Result* of Question3	*Result* of Question4
Learner A	7 (7x1)	4 (4x1)	7 (7x1)	0 (3x0)
Learner B	5 (5x1)	0 (5x0)	0 (5x1)	0 (4x0)

4.5.1.2 Example of generating *concept-score* for six learning concepts

Applying the *result* of each question in Table 4.5 with the formula in Table 4.6, the *concept-score* of six learning concepts for Learner A and Learner B are displayed in Table 4.7.

Table 4.6. The detail of *result* for individual pre-test.
The values in the brackets ( ) display how the *result* is calculated

***concept-score* of six learning concepts**	**Formulas to calculate for *concept-score* of each learning concept**
concept-score of Concept1	(*result*_Q1[14] + *result*_Q2) / 2 * 10
concept-score of Concept2	(*result*_Q3 + *result*_Q4) / 2 * 10
concept-score of Concept3	(*result*_Q1 + *result*_Q2 + *result*_Q3 + *result*_Q4) / 4 * 10
concept-score of Concept4	(*result*_Q2 + *result*_Q4) / 2 * 10
concept-score of Concept5	*result*_Q1 * 10
concept-score of Concept6	*result*_Q3 * 10

Table 4.7. The detail of *concept-score* for the six learning concepts for Learner A and B

	concept-score of Concept1	*concept-score* of Concept2	*concept-score* of Concept3	*concept-score* of Concept4	*concept-score* of Concept5	*concept-score* of Concept6
LearnerA	55	35	45	70	70	70
LearnerB	25	0	12.5	25	50	0

4.5.1.3 Example of generating *expect-group-potential-performance* in three aspects.

The generating of *IdealGLM* – the estimation of group learning performance before applying the group-test – the *concept-score*s of each learning concept according to aspects of *intersection*, *union* and *average* are applied. In the aspect of *intersection*, the *concept-score* of two members are compared. The lower *concept-score* of each concept after comparing is used as a lower bound for the *expect-group-potential-performance:* the range of performance that is expected the group will achieve. In the aspect of *union*, the *concept-score* of two members are compared. The higher *concept-score* of each concept after comparing is used as upper bound for the *expect-group-potential-performance*.

[14] Note that *result*_Qn is the *result* for QuestionType *n* which n = 1, 2, 3 and 4

The information from both aspects of *intersection*, *union* cannot be represented to learners at the same time because it can be inferred who is right and who is wrong which may affect the way of learning in group-test. Nevertheless the use of only *intersection* or *union* cannot represent learning performance as a group. As that result the aspect of *average* is introduced to *concept-score* for solving this problem.

The *expect-group-potential-performance* – known as *IdealGLM* for aspect of *average* – is calculated from the average *concept-score* of two members. Referring to the *concept-score* for each member in Table 4.7, the *expect-group-potential-performance* for all aspects of *intersection*, *union* and *average* are summarised and displayed in Table 4.8.

Table 4.8. The detail of *concept-score* for the six learning concepts in 3 aspects of the *expect-group-potential-performance*

	concept-score of Concept1	*concept-score* of Concept2	*concept-score* of Concept3	*concept-score* of Concept4	*concept-score* of Concept5	*concept-score* of Concept6
Aspect of *'union'*	55	35	45	70	70	70
Aspect of *'intersection'*	25	0	12.5	25	50	0
Aspect of *'average'*	40	17.5	28.75	47.5	60	35

Next, the generating and updating of the *GLM* is introduced in order to clarify what is being kept in the group model during the group-test that allows learners to communicate to exchange their beliefs.

4.5.2 Generating and Updating the *GLM*

The objectives of the group-test are to encourage learners to exchange their beliefs with peers. Every move, which is made during the test, is investigated and justified by rules, which will be explained later in the topic. Only the move that is relevant to the specific question is taken into account for the *correctness* of the beliefs. For each learning concept, the following are recorded: *concept-score*, *the number of beliefs that are 'correct'*, *the number of beliefs that are 'incorrect'.* The *concept-score* of learning concepts that are used to represent *GLM*, are calculated from the total *concept-score* of each learning concept divided by the number of beliefs that group members contributed during the group-test.

The relationship between the five options of utterance and the six learning concepts are defined as 21 rules, which are explained in 4.5.2.1-4.5.2.4. The sentence numbers 5, 6, and 7 are used to imply the *degree of confidence* for each move. If the sentence number 5 is chosen, the *concept-score* of that sentence is set to the same value. However if the sentence number 6 or 7 is chosen, the original *concept-score* will be reduced or the matter of confidence– by half of applied with sentence 6, and as 1/10 of the original *concept-score* if applied with sentence 7. The matter of confidence in each sentence that learners contributed always applies in updating the six learning concepts.

4.5.2.1 Updating six learning concepts from the correction of *utterance1*

Rule 1: If the question number is 1 or 3 **and** *utterance1* is used **and** the sentence is defined as *correct* **then**

{

Check for the use of sentence number 5, 6, or 7 for the matter of confidence

add the *concept-score* of that particular time to the total *concept-score* of Concept1,

add 1 to the number of *correct beliefs* for Concept1

}

Rule 2: If the question number is 1 or 3 **and** *utterance1* is used **and** the sentence is defined as *Incorrect* **then**

{

add the *concept-score* of that particular time to the total *concept-score* of Concept1,

add 1 to the number of *incorrect beliefs* for Concept1

}

Rule 3: If the question number is 2 or 4 **and** *utterance1* is used **and** the sentence is defined as *correct* **then**

{

Check for the use of sentence number 5, 6, or 7 for the matter of confidence

add the *concept-score* of that particular time to the total *concept-score* of Concept2,

add 1 to the number of *correct beliefs* for Concept2

}

Rule4: If the question number is 2 or 4 **and** *utterance1* is used **and** the sentence is defined as *incorrect* **then**

{

add the *concept-score* of that particular time to the total *concept-score* of Concept2,

add 1 to the number of *incorrect beliefs* for Concept2

}

4.5.2.2 Updating six learning concepts from the correction of *utterance2*

Rule 5: If *utterance2* is used **and** the sentence is defined as *correct* **then**

{

Check for the use of sentence number 5, 6, or 7 for the matter of confidence

add the *concept-score* of that particular time to the total *concept-score* of Concept3,

add 1 to the number of *correct beliefs* for Concept3

}

Rule 6: If *utterance2* is used **and** the sentence is defined as *incorrect* **then**

{

add the *concept-score* of that particular time to the total *concept-score* of Concept3,

add 1 to the number of *incorrect beliefs* for Concept3

}

4.5.2.3 Updating six learning concepts from the correction of *utterance3*

Rule 7: If the question number is 1 or 3 **and** *utterance3* is used **and** the sentence is defined as *correct* **then**

{

Check for the use of sentence number 5, 6, or 7 for the matter of confidence

add the *concept-score* of that particular time to the total *concept-score* of Concept5,

add 1 to the number of *correct beliefs* for Concept5

}

Rule 8: If the question number is 1 or 3 **and** *utterance3* is used **and** the sentence is defined as *incorrect* **then**

{

add the *concept-score* of that particular time to the total *concept-score* of Concept5,

add 1 to the number of *incorrect beliefs* for Concept5

}

Rule 9: If the question number is 2 or 4 **and** *utterance3* is used **and** the sentence is defined as *correct* **then**

{

Check for the use of sentence number 5, 6, or 7 for the matter of confidence

add the *concept-score* of that particular time to the total *concept-score* of Concept6,

add 1 to the number of *correct beliefs* for Concept6

}

Rule10: If the question number is 2 or 4 **and** utterance 3 is used **and** the sentence is defined as *incorrect* **then**

{

add the *concept-score* of that particular time to the total *concept-score* of Concept6,

add 1 to the number of *incorrect beliefs* for Concept6

}

4.5.2.4 Updating six learning concepts from the correction of *utterance4*

Rule 11: If *utterance4* is used **and** the sentence is defined as *correct* **then**

{

Check for the use of sentence number 5, 6, or 7 for the matter of confidence

add the *concept-score* of that particular time to the total *concept-score* of Concept4,

add 1 to the number of *correct beliefs* for Concept4

}

Rule 12: If *utterance4* is used **and** the sentence is defined as *incorrect* **then**

{

add the *concept-score* of that particular time to the total *concept-score* of Concept4,

add 1 to the number of *incorrect beliefs* for Concept4

}

4.5.2.5 Updating six learning concepts from the correction of *utterance5*

Rule 13: If *utterance5* is used **and** the number of question is 1 **and** the sentence is defined as *correct* **then**

{

Check for the use of sentence number 5, 6, or 7 for the matter of confidence

add the *concept-score* of that particular time to the total *concept-score* of Concept number 1, 3, and 5

add 1 to the number of *correct beliefs* for Concept number 1, 3, and 5

}

Rule 14: If *utterance5* is used **and** the number of question is 1 **and** the sentence is defined as *incorrect* **then**

{

add 0 to the total *concept-score* of Concept number 1, 3, and 5

add 1 to the number of *incorrect beliefs* for Concept number 1, 3, and 5

}

Rule 15: If *utterance5* is used **and** the number of question is 2 **and** the sentence is defined as *correct* **then**

{

Check for the use of sentence number 5, 6, or 7 for the matter of confidence

add the *concept-score* of that particular time to the total *concept-score* of Concept number 1, 3, 4, and 5

add 1 to the number of *correct beliefs* for Concept number 1, 3, 4, and 5

}

Rule 16: If *utterance5* is used **and** the number of question is 2 **and** the sentence is defined as *incorrect* **then**

{

add 0 to the total *concept-score* of Concept number 1, 3, 4, and 5

add 1 to the number of *incorrect beliefs* for Concept number 1, 3, 4, and 5

}

Rule 17: If *utterance5* is used **and** the number of question is 3 **and** the sentence is defined as *correct* **then**

{

Check for the use of sentence number 5, 6, or 7 for the matter of confidence

add the *concept-score* of that particular time to the total *concept-score* of Concept number 2, 3, and 6

add 1 to the number of *correct beliefs* for Concept number 2, 3, and 6

}

Rule 18: If *utterance5* is used **and** the number of question is 3 **and** the sentence is defined as *incorrect* **then**

{

add 0 to the total *concept-score* of Concept number 2, 3, and 6

add 1 to the number of *incorrect beliefs* for Concept number 2, 3, and 6

}

Rule 19: If *utterance5* is used **and** the number of question is 4 **and** the sentence is defined as *correct* **then**

{

Check for the use of sentence number 5, 6, or 7 for the matter of confidence

add the *concept-score* of that particular time to the total *concept-score* of Concept number 2, 3, 4, and 6

add 1 to the number of *correct beliefs* for Concept number 2, 3, 4, and 6

}

Rule 20: If *utterance5* is used **and** the number of question is 4 **and** the sentence is defined as *incorrect* **then**

{

add 0 to the total *concept-score* of Concept number 2, 3, 4, and 6

add 1 to the number of *incorrect beliefs* for Concept number 2, 3, 4, and 6

}

Rule 21: **If** the sentence number is 1, 2, 3, or 4 **then** use the information of *concept-score* **and** others from the previous sentence.

Rule 22: **If** the sentence is defined as '*Questioning*' (sentence number 8-14) **then** no *concept-score* is updated

4.5.2.6 Example of generating and updating the *GLM*

Referring to the conversation that the group made during the group-test as shown in 4.4.3. The number of *correct beliefs* and *incorrect beliefs* is used as a role part for generating and updating the *GLM*. This conversation is for the first question of the group-test so the value of *concept-score*, number of *correct beliefs* and number of *incorrect beliefs* for 6 learning concepts are begun with zero. The justification of each sentence is displayed in Table 4.9.

Table 4.9. The detail of applying and justifying sentence which are contributed during the 1st question of the group-test.

Order of sentences	What each learner contribute	Justification for the *correctness*	Rule(s) to applied with
1	(5) I believe that... (1) The number on the 2^{nd} left of decimal point of base8 number is equal 2^{-2}.	incorrect	Rule 1
2	(1) I agree with you.	incorrect	Rule 21
3	(5) I believe that … (2) the value of number on each bit can be calculated by multiplied that particular number to the value of that bit.	correct	Rule 5
4	(1) I agree with you.	correct	Rule 21
5	(5) I believe that … (3) for base8, the value of 8^1 is equal 8x1.	correct	Rule 7
6	(5) I believe that... (5)Choice C is the correct answer with *degree of confidence* 4.	correct	Rule 13
7	(1) I agree with you.	correct	Rule 21

There are 18 variables of *GLM* that might be changed according to the justification of the *correctness*. The first six variables contain information about the number of *correct beliefs* for each learning concept of Concept1 to Concept6. The second six variables contain information about the number of *incorrect beliefs* for each learning concept of Concept1 to Concept6. The last six variables contain information about '*Total concept-score*' for each learning concept of Concept 1 to Concept 6. For more understanding of how to update the

18 variables of *GLM*, the information form the justification of the *correctness* of Table 4.9 is displayed step-by-step in Table 4.10. Because in this example, there is only the information of Concept1, Concept3, and Concept5 (displayed in the table as C1, C3 and C5) which are changed during the test of Question1. Therefore, information of Concept2, Concept4, and Concept6 are not considered for this matter.

By the end of the conversation, the *concept-score* of Concept1, Concept3, and Concept5 are calculated. The *concept-score* of Concept1 is equal to 20 (calculated from 80/(2+2)), *concept-score* of Concept3 is equal to 70 (calculated from 280/(4+0)) and *concept-score* of Concept5 is equal to 60 (calculated from 180/(3+0)). While the *concept-score* of Concept2, Concept4, and Concept6 remain with the same values from the start, which is zero. Next, the representing of *IdealGLM* and *GLM* is illustrated as *bar-chart* to draw attention from learners and provide further explanation if required.

Table 4.10. The detail of applying and justifying sentence which are contributed during the 1st question of the group-test.

Order of sentences	Number of the *correct beliefs*			Number of the *incorrect beliefs*			Total *concept-score* for concept 1-6		
	C1	C3	C5	C1	C3	C5	C1	C3	C5
Before the start	0	0	0	0	0	0	0	0	0
1	0	0	0	**1**	0	0	0	0	0
2	0	0	0	**2**	0	0	0	0	0
3	0	**1**	0	**2**	0	0	0	**100**	0
4	0	**2**	0	**2**	0	0	0	**200**	0
5	0	**2**	**1**	**2**	0	0	0	**200**	**100**
6	**1**	**3**	**2**	**2**	0	0	**40**	**240**	**140**
7	**2**	**4**	**3**	**2**	0	0	**80**	**280**	**180**

4.5.3 Summary for the use of *IdealGLM* and *GLM*

Graphical representation will draw attention from learners at the very first time. However, without the clarification of what has already been displayed, the usefulness of applying such a graphical representation may not help effectively. Therefore the use of graphical and textual explanation are applied here as the method of representation for the learning performance – represented here as *IdealGLM* and *GLM*. The learning performance is measured by the use of *concept-score*. For *IdealGLM*, each bar of the *bar-chart* represents the *concept-score* of each learning concept in respect to the aspect of *average* (See 4.5.1.2). The way of representing *IdealGLM* and *GLM* are not different, therefore only the *IdealGLM* is illustrated here.

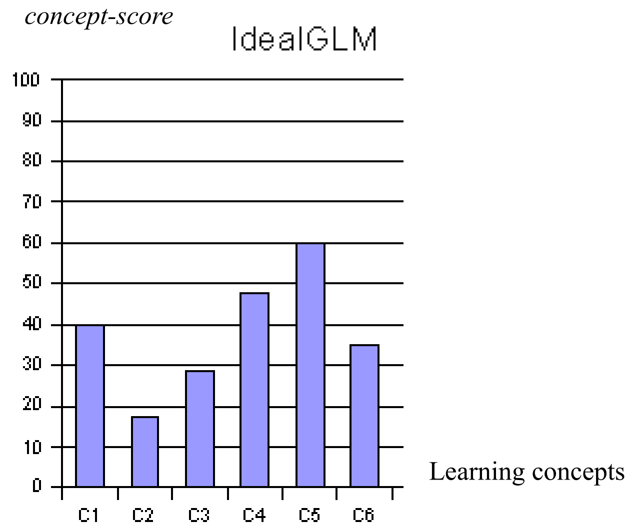


Figure 4.3. The *bar-chart* representing the *concept-score* of each learning concept as *IdealGLM*

As seen in Figure 4.3, the graphical representation of *IdealGLM* is displayed as *bar-chart*. Each bar of the *bar-chart* on the x-axis represents each of the six learning concepts. The y-axis represents the range of *concept-score*, which ranges from 0 to 100.

C1: Learners can use the value of each bit position on the left of the decimal point to calculate for a specific number in the ***'Fairly good'*** level. (The level of *concept-score* = 40)

C2: Learners can use the value of each bit position on the right of the decimal point to calculate for a specific number in the ***'Should be improved'*** level. (The level of *concept-score* = 17.5).

C3: Learners can use the arithmetic operator to calculate for the value within each specific bit in the ***'Fairly good'*** level. (The level of *concept-score* = 28.75).

C4: Learners can use the arithmetic operator to calculate for the value between each bit in the ***'Good'*** level. (The level of *concept-score* = 47.5).

C5: Learners can transform the given number, which is on the left of the decimal point into other forms in the ***'Good'*** level. (The level of *concept-score* = 60).

C6: Learners can transform the given number, which is on the right of the decimal point into other forms in the ***'Fairly good'*** level. (The level of *concept-score* = 35).

Figure 4.4. The textual explanation of six learning concepts.

Perceiving of only the *bar-chart* may not give sufficient detail of how well the group might perform in the group-test. Therefore, the addition of textual explanation is provided later for further detail of what each bar of the particular *bar-chart* represents can be seen within Figure 4.4.

4.6 Summary

In this chapter, the domains of interest are focused on the computer-based collaborative learning. In order to design for the system to suit the criteria of collaborative or group learning, the number of participants in the group started from two. In this GOLeM, a group of two participants, with respect to the prior knowledge, is applied. (See section 4.1 for more detail). After having the solution for the number of participants, the scenario view of GOLeM is introduced for more understanding of how it works (See section 4.2 for more detail).

After the big picture of how GOLeM is defined, the next step is to work on detail of *domain knowledge*, *group learner model*, and *communicative interaction*. These three domains works are crucial parts for building GOLeM. The content of *number-conversion* is defined as six learning concepts and applied in four types of questions. These questions and learning concepts are used as domain knowledge. The reason for using *number-conversion*, defining to six learning concepts, and further detail are explained in section 4.3 of the chapter.

After knowing about domain knowledge, what is explained next is the domain of communicative interaction. This domain focuses on the defining of what can be exchanged and rules of exchanging using *dialogue moves* and *sentence openers*. The example of using *sentence openers* either alone or with optional *utterances* is illustrated in section 4.4.3. This chapter ends with the managing of the domain of *group learner model*, which includes generating, updating, and representing the learning performance in terms of *IdealGLM* and *GLM* (See section 4.5 for more detail).

The next chapter will explain the process of implementing software for GOLeM in respective to the domains that have already been introduced in this chapter. The design and implementation is first done as a paper-based design to test for the plausibility. Later the design is implemented as software.

Chapter 5

'GOLeM': Design and Implementation

In previous chapters, the aim, hypotheses, and approach to evaluation have been explained. In this chapter, the design of 'GOLeM' is described and its implementation outlined. The design of the software draws on concepts from three distinct domains: the representation of *domain knowledge,* research on *group learner models* and *communicative interaction.* The system has to be designed to firstly allow learners to do the pre-test, then work as a group to take the group-test (which needs to include a *chat-tool* for communication), and end up with the learners taking the post-test. During each test, each learner can access either the *IdealGLM* or the *GLM* – they are provided in the relevant experimental group.

This software is used as a tool to prove whether learning as a group of two in a computer-based environment, learners can improve either *concept-score* or *degree of confidence* by perceiving *IdealGLM* and *GLM*. In this chapter, we first describe the aspects of the three domains – *domain knowledge, group learner model,* and *communicative interaction* – that need to be taken into account for the design of GOLeM. As part of the design process, a low-tech paper-based version was implemented and trialled to test for the plausibility of the knowledge content and user interface. The paper-based version was utilised with pairs of participants and the comments were used to finalise the design of GOLeM.

The implementation of GOLeM is described firstly through the presentation of a flowchart. This shows how the system is intended to work. Next, the database design is sketched. Then, an explanation is given about the software that was used to build GOLeM. In the end, Visual Basic 6.0 and Microsoft Access 2002 are chosen.

After GOLeM was implemented, it was used with participants as a learning environment to compare their performance with two other two learning environments for assessing the benefits of students having access to their *IdealGLM* and *GLM*. The design of the study and the results of the comparisons between these three learning environments are explained in Chapter 6.

5.1 Summaries of the Domains

As explained in Chapter 4, three domains have to be taken into account for the design of GOLeM. These domains are *domain knowledge, group learner model,* and *communicative interaction*. The issues connected with each domain are explained below.

5.1.1 Domain knowledge

The *number-conversion* tasks were selected for the learners to work on. This content is a basic and important concept in the Thai University/College computer science curriculum. Based on my own experience as a lecturer, we have found that learners do not know how to perform *number-conversion*. Even though the concept is not hard to learn. In order to keep the design simple, the tasks given to the student involved the conversion of base-2, base-8 and base-16 into base-10.

After deciding on the content, we then designed a 30 item multiple-choice test that was intended for use to assess the learner's skills at *number-conversion*. The test is firstly approved by someone very experienced in such skills and then translated into the Thai Language. For this process, two experts were chosen to assess the reliability of the content after translating into the Thai Language: one is an expert in both the Thai and English Languages, and the other one is the expert in these two languages and the content of *number-conversion*.

The Thai version was revised based on the comments from both experts. Two experts and non-experts in *number-conversion* then checked the revised version. The result showed that none of them meets the ceiling of the score even though they already learned this content. This test was revised based on the comments from the participants and then applied to 122 Thai students in the Department of Computer Science and Technology, Kanchanaburi Rajabhat University, Thailand. The result shows that the validity of the test is quite high for both *difficulty level* and *item discrimination*. The result of this test is explained in Chapter6.

5.1.2 Group learner model

In GOLeM, the notion of *group learner model* is instantiated as both an *IdealGLM* and a *GLM*. These *group learner models* are used in different contexts: the *IdealGLM* is usable after the completion of each individual test, while the *GLM* is usable during and at the end of the group test. The *IdealGLM* is used to represent the estimated potential group learning performance. It combines the information of each individual's performance, which, in this thesis, is represented in terms of the score associated with each of six key concepts, and is shown to members of the group if requested.

The *GLM* is used to represent the group's learning performance which is generated and updated from what group members do during the group-test. In the group-test, updates to the *GLM* are based both on task performance and on communications between learners using the provided *chat-tool*. The information exchanged using the *chat-tool* is used to update the *GLM* (See more detail on section 5.2.3.2) (**<u>Note</u> that the definition of *IdealGLM* and *GLM* are given in Chapter 1)**

Both the *IdealGLM* and the *GLM* represent the *group learner model* as *bar-charts* as well as textual explanations. Each bar in the chart represents one of the concepts that have to be learned. Note that, at the very beginning of system design, four learning concepts had been selected to represent the necessary domain knowledge. Later, after the paper-based design sessions, the number of learning concepts was changed to six concepts but the same basic idea is retained. The detail of how the *IdealGLM* and *GLM* are generated, updated, and represented was explained in Chapter 4.

5.1.3 Communicative interaction (*Chat-tool*)

The *chat-tool* provided here is used for learners to exchange information with their peers. In order to allow the system to examine what information the group exchanged during the group-test in a simple manner without entering into the issue of *free-text* comprehension, the concepts of *sentence openers* and *dialogue game* is adopted in GOLeM. A *dialogue game* is used to control the moves within each conversation. There are two types of moves for simplicity that are 'Questioning' and 'Informing' (Burton, 1998). The reason that we choose only just these two types of moves is because we are concerned with what is inside the move rather than grouping the use of moves for the diversity of answer (Soller, 1999).

To make the dialogue more flexible, *sentence openers* are used. During the early stages of the design process, fifteen *sentence openers* were defined; later, after the paper-based test, the number was reduced to fourteen that mainly contained the same concept as the previous one. These fourteen *sentence openers* contain rules of move with regard to the state of the *dialogue game*. The detail of how to communicate with peers using the *sentence openers* was explained in more detail in Chapter 4.

Not only in regards to 'Questioning' and 'Informing' state of the game, the requirement of *utterances* to complete the sentences are used to categorise these *sentence openers* into two groups: *complete sentence* and *incomplete sentence*. The *complete sentence* needs no further information but the particular *sentence opener*. While *incomplete sentence* contains the symbol '...' that needs an utterance to complete the sentence. There are five main options for *utterances.* Each utterance with specific details is explained later in the chapter.

After providing a rough idea of what is contained within the three domains, *domain knowledge, group learner model,* and *communicative interaction* that makes up GOLeM, the next topic to be discussed is the implementation of the system that is introduced as the paper-based design for simplicity. This design tests for the plausibility of the user interface, number of questions, *sentence openers*, *utterances* and other related concepts.

5.2 The Paper-Based Design

In order to confirm the plausibility of the system for both the user interface and the knowledge content, a paper-based version of the system is designed and utilised as a prototype to avoid unnecessary implementation costs and to confirm feasibility of the approach. Even though this prototype is called 'simple', every major requirement of GOLeM is included in the design. This prototype was tested with two participants for comments on the user interface and other aspects of the learning content before using the system in the main experiment with six pairs of participants from the Department of Computer Science and Technology, Kanchanaburi Rajabhat University, Thailand.

The results of the paper-based test show the positive learning results and comments from both user interface and knowledge content, which motivate us to take action on implementing the system. The further detail of the paper-based test is explained in Chapter6. In section 5.2, firstly, we give information of what we provide to learners in the paper-based test and then we explain how these tools are used

5.2.1 The contents of the paper-based design

There are cards, charts, and sheets provided to learners as tools for the use of the paper-based design. These tools are defined as alphabets A-I (See Figure 5.1) which rely on the three domains. The tools in A and B are applied within the *domain knowledge*. The tools in C, D, E, F, and G are used in the *communicative interaction* domain. The tools in H and I are used to represent *group learner model*. The result from applying each tool of A-I will be used to generate, update, and display for the domain of *GLM*.

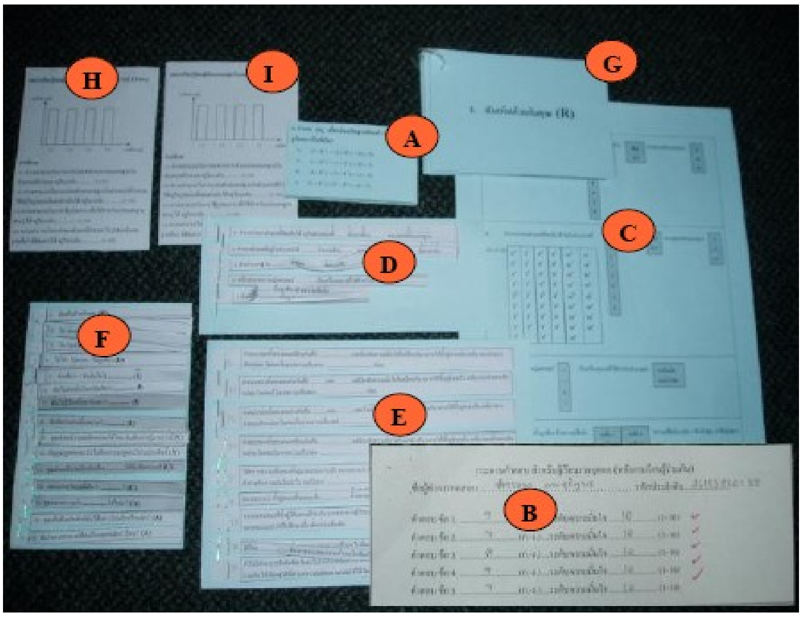


Figure 5.1. The paper-based prototype of GOLeM

A: Question Cards: each card contains details of each question

B: The answer sheet: this form is used for pre-test, group-test, and post-test

C: Utterance Options: there are five options of *utterances* and further details

D: The chart of scratched papers contain 5 options of *utterances*

E: The chart of scratched papers contain options of sentences used by the system

F: The chart of scratched papers contain options of 15 *sentences openers*

G: The cards that contain rules and details of 15 *sentence openers*

H: The sheet for giving the learning performance as *IdealGLM*

I: The sheet for giving the learning performance as *GLM*

After knowing what tools are used in the paper-based design, the next step is an explanation of how the provided tools are used.

5.2.2 The instructions of using the paper-based design

Firstly, the instructor who works as the system gives participants a set of paper-based tools as in Figure 5.1. Then the instructor asks each participant to finish five question items individually (see **A**). The answer to each question and *degree of confidence* will be stated in the form **B**. After that, participants are asked whether they want to see the learning performance as a group of two or not. If they request to see, the information of the group that is calculated from the individual performance will be represented in form **H**.

For the group test, members of the group will help each other to come up with the final group result. They are allowed to use the provided paper-based tools **C, D, F,** and **G** to communicate within their pair. Firstly, the participant who has the turn to start the conversation will begin the sentence with one of five sentences from **D**. Then complete the sentence with the *one of fifteen* complements which some of them need information from C to finish the sentence. After one completes and submits the sentence, the turn then changes to the other member. The communication will be terminated if both members agree on the final answers. However, if they keep talking but do not come up with the final agreement, the instructor, who acts as a system, will intervene in the conversation by using a sentence from **E** that relates to the particular conversation.

After each question of the group test, participants will be asked whether they want to see the group performance as a graph and explanation. If they request to see, the information of the group will be represented in form **I**. After finishing five questions, participants are then asked to do the test individually as a post-test. The answers and *degree of confidence* will be filled in the form similar to form **B**

5.2.3 Example of using paper-based design.

In this section, we represent how to use the paper-based design into four steps with examples for each step for more understanding. The first step is about providing the pre-test for individual learners, scoring, and representing the *IdealGLM* to individual learners. The second step is about providing the group-test, scoring, and representing the conversation and *GLM*. The third step is about providing an option for learners to see the comparison between *IdealGLM* and *GLM* or not. Then the final step is about providing the post-test for individual learners.

5.2.3.1 Step 1: During the pre-test

In this step, firstly, the system provides both learners with an individual test (the scores are kept secret in the system). After finishing the individual test, the system then scores the pre-test for learning performance.

P_A's pre-test score = 5 and summation of confidence = 31 (7+5+5+7+7)
P_B's pre-test score = 3 and summation of confidence = 24 (0+9+8+7+0)

Later this performance is represented as a graph of *IdealGLM*, which the system provides as an estimate of what these particular pairs could have achieved when learning together (See Figure 5.2). The textual explanation of the graph is displayed in Figure 5.3.

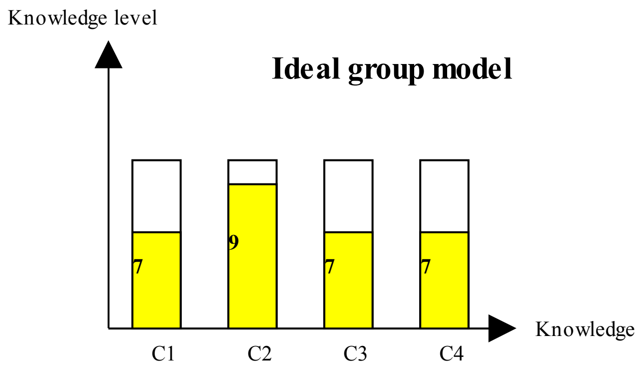


Figure 5.2. The *IdealGLM* that the system provides to group members

Concept 1 (C1):	Ability of knowing the value in the specific position of base-8 number is in level **7** apart from 10.
Concept 2 (C2):	Ability of transforming the number in the specific position of base-8 number into various forms is in level **9** apart from 10.
Concept 3 (C3):	Ability of using suitable equation to convert base-8 number into base-10 is in level **7** apart from 10.
Concept 4 (C4):	Ability of converting the number of base-8 number into base-10 is in level **7** apart from 10.

Figure 5.3. The explanation of *IdealGLM* for pre-test

5.2.3.2 Step 2: During the group-test

In this step, the system asks learners to complete the task in pairs using the individual result to start the conversation and provide the group performance as *GLM*. To do this, firstly, the system provides both learners to do the group-test. During the test through each conversation they make, the performance is scored and then represented if required as *GLM*. These processes are repeated until five questions are finished. Each example of this step contains question detail, conversations performed during the question, the representation of the *GLM* and, the explanation of each *GLM*.

5.2.3.2.(a) Question1

What is value of the underlined position of $\underline{1}11_8$ after being converted to base10?

1. 32
2. 64
3. 100
4. 512

System: You both choose the different answer which is **A** and **B** with the same degree of confidence. I would you like to give some explanation for this answer so lets start with you, **P_A**.

P_A: I believe that … The value of number in the **3rd** position from **the left side** of the **base8** decimal point is equal $\mathbf{8^2}$.

P_B: I don't agree with you.

P_A: Shall we change the topic?

System: After listening to you for a while, can you both come up with a final solution for this question? Let's start from you, **P_B**.

P_B: I believe that…The answer **D** is correct with degree of confidence **9** from 10.

P_A: I believe that…The answer **B** is correct with degree of confidence **6** from 10.

System: After listening to you for a while, can you both come up with a final solution for this question? Let's start from you, **P_B**.

P_B: I am not sure but I think… **(5)** The answer **D** is correct with degree of confidence **9** from 10.

P_A: I agree with you.

System: Do you mean that you both agree to choose the answer **D** with the degree of confidence equal **9**?

P_B: Yes

P_A: Yes

System: If there is no question about this item shall we move to the next one?

P_B: Yes

P_A: Yes

System: Before continuing to the next question if you would like to see the performance of the group, please select the provided 'student model'.

Both P_B and P_A choose to see the *GLM*, so the system gives them information of how well the group performs as a *bar-chart* (See Figure 5.4) and further detail as a textual explanation (See Figure 5.5)

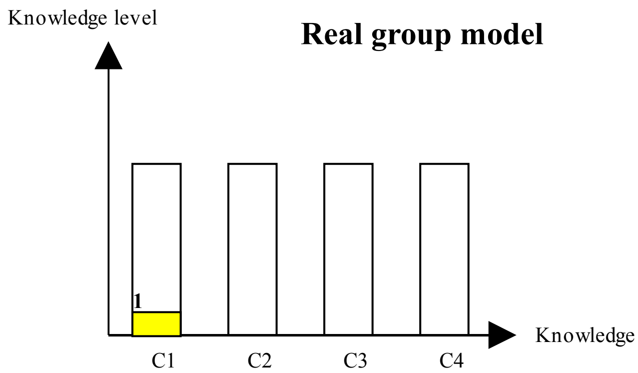


Figure 5.4. The *GLM* of Question1

Concept 1 (C1):	Ability of knowing the value in the specific position of base-8 number is in level **1** apart from 10.
Concept 2 (C2):	Ability of transforming the number in the specific position of base-8 number into various forms is in level **0** apart from 10.
Concept 3 (C3):	Ability of using suitable equation to convert base-8 number into base-10 is in level **0** apart from 10.
Concept 4 (C4):	Ability of converting the number of base-8 number into base-10 is in level **0** apart from 10.

Figure 5.5. The explanation of *GLM* for Question1

From the conversation you made for this item, the system believes that the group has a misconception about knowing the value in the specific position of base-8 number.

5.2.3.2(b) Question2

What is the other form of the underlined position of $\underline{1}11_8$ after being converted to base10?

A. 1×10^2
B. 1×8^2
C. 1×10^3
D. 1×10^3

System: You both choose the same answer that is **B** with the different degree of confidence. I would you like to explain this answer so let us start with you, **P_B**.

P_B: I believe that … The value of number in the **3rd** position from **the left side** of the **base8** decimal point is equal **8^2**?

P_A: I agree with you.

System: After listening to you for a while, can you both come up with a final solution for this question? Let's start from you, **P_A**.

P_A: I believe that. The answer **B** is correct with degree of confidence **9 from 10.**

P_B: I agree with you.

System: Do you mean that you both agree to choose the answer **B** with the degree of confidence equal **9**?

P_B: Yes

P_A: Yes

System: If there is no question about this item shall we move to the next one?

P_A: Yes

P_B: Yes

System: Before continuing to the next question if you would like to see the performance of the group, please select the provided 'student model'.

Both P_B and P_A choose to see the *GLM* so the system gives them information of how well the group performs as a *bar-chart* (See Figure 5.6) and further detail as a textual explanation (See Figure 5.7)

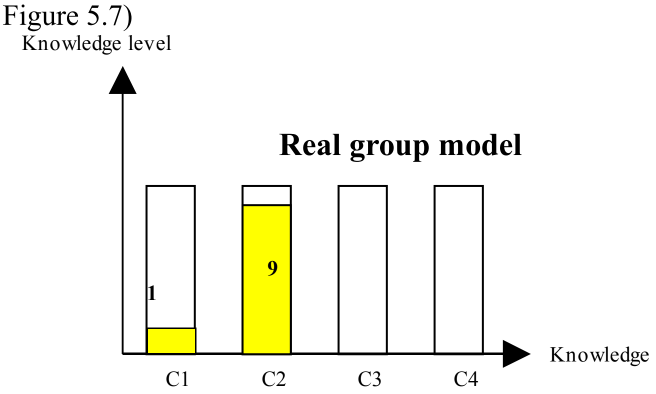


Figure 5.6. The *GLM* of Question2

Concept 1 (C1):	Ability of knowing the value in the specific position of base-8 number is in level **7** apart from 10.
Concept 2 (C2):	Ability of transforming the number in the specific position of base-8 number into various forms is in level **9** apart from 10.
Concept 3 (C3):	Ability of using suitable equation to convert base-8 number into base-10 is in level **0** apart from 10.
Concept 4 (C4):	Ability of converting the number of base-8 number into base-10 is in level **0** apart from 10.

Figure 5.7. The explanation of *GLM* for Question2

5.2.3.2(c) Question3

What is the value of the underlined position of $\underline{7}02_8$ after being converted to base10?

A. 7 x 10 x 10
B. 7 + (8 x 8)
C. 7 x (8 x 8)
D. 7 x 8

System: You both choose the same answer that is **C** with the different degree of confidence. I would you like to give some explanation for this answer so lets start with you, **P_A**.

P_A: I think that because …The number at the underlined position is in the **3rd** position from **the left side** of the **base8** decimal point.

P_B: I would like to know more, could you please tell me about this?

P_A: Shall we change the topic?

P_B: Yes.

System: After listening to you for a while, can you both come up with a final solution for this question? Let's start from you, **P_A**.

P_A: I belief that…The answer **C** is correct with degree of confidence **9** from 10.

P_B: I agree with you.

System: If there is no question about this item shall we move to the next one?

P_A: Yes

P_B: Yes

System: Before continuing to the next question if you would like to see the performance of the group, please select on the provided ‘student model’.

Both P_B and P_A choose to see the *GLM* so the system gives them information of how well the group performs as a *bar-chart* (See Figure 5.8) and further detail as a textual explanation (See Figure 5.9)

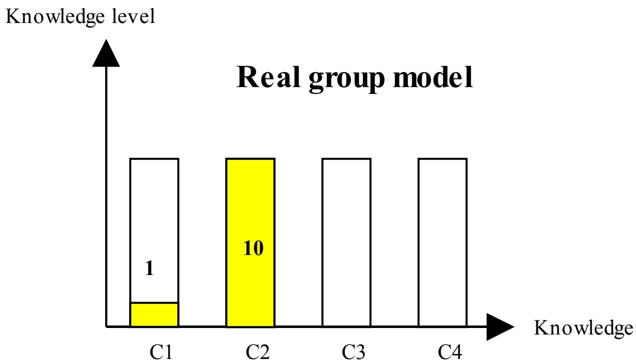


Figure 5.8. The *GLM* of Question3

Concept 1 (C1):	Ability of knowing the value in the specific position of base-8 number is in level **1** apart from 10.
Concept 2 (C2):	Ability of transforming the number in the specific position of base-8 number into various forms is in level **10** apart from 10.
Concept 3 (C3):	Ability of using suitable equation to convert base-8 number into base-10 is in level **0** apart from 10.
Concept 4 (C4):	Ability of converting the number of base-8 number into base-10 is in level **0** apart from 10.

Figure 5.9. The explanation of *GLM* for Question3

5.2.3.2(d) Question4

What is the value of the underlined positions of $\underline{156}_8$ in terms of equation after being converted to base10?

A. $(1 \times 8^2) + (5 \times 8^1) + (6 \times 0)$
B. $(1 \times 8^2) + (5 \times 8^1) + (6 \times 1)$
C. $(1 \times 8^3) + (5 \times 8^2) + (6 \times 8)$
D. $(1 + 8^2) \times (5 + 8^1) \times (6 + 1)$

System: You both choose the same answer that is **B** with the same degree of confidence. I would like you to give some explanation for this answer so lets start with you, **P_B**.

P_B: I believe that ...For **base8** number, the value of **8^0** is equal **1**.

P_A: I agree with you.

P_B: I believe that...The answer **B** is correct with degree of confidence **10** from 10.

P_A: I agree with you.

System: Do you mean that you both agree to choose the answer **B** with the degree of confidence equal **10**?

P_B: Yes

P_A: Yes

System: If there is no question about this item shall we move to the next one?

P_A: Yes

P_B: Yes

System: Before continuing to the next question if you would like to see the performance of the group, please select the provided 'student model'.

Both P_B and P_A choose to see the *GLM* so the system gives them information of how well the group performs as a *bar-chart* (See Figure 5.10) and further detail as a textual explanation (See Figure 5.11)

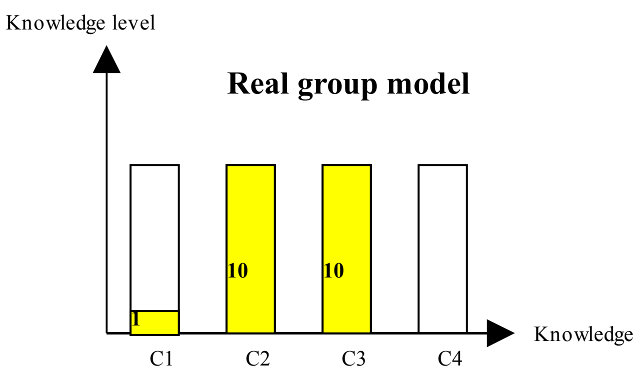


Figure 5.10. The *GLM* of Question4

Concept 1 (C1):	Ability of knowing the value in the specific position of base-8 number is in level **1** apart from 10.
Concept 2 (C2):	Ability of transforming the number in the specific position of base-8 number into various forms is in level **10** apart from 10.
Concept 3 (C3):	Ability of using suitable equation to convert base-8 number into base-10 is in level **10** apart from 10.
Concept 4 (C4):	Ability of converting the number of base-8 number into base-10 is in level **0** apart from 10.

Figure 5.11. The explanation of *GLM* for Question4

5.2.3.2(e) Question5

What is the value of 75_8 after being converted to base10?

A. 56
B. 61
C. 75
D. 96

System: You both choose the different answer that is **B** and **D** with the different degree of confidence. I would you like to give some explanation for this answer so lets start with you **P_B**.

P_B: I don't know about this but I guess … (5) The answer D is correct with degree of confidence **2** from 10.

P_A: I don't agree with you.

P_B: I would like to know more, could you please tell me about this?

P_A: I am not sure but I think ...The answer **B** is correct with degree of confidence **5** from 10.

System: **P_B,** Do you want to say anything else?

P_B: No.

System: **P_A,** Do you want to say anything else?

P_A: No.

System: After listening to you for a while, can you both come up with a final solution for this question? Let's start from you, **P_A**.

P_A: I belief that the answer **B** is correct with a degree of confidence **10** from 10.

P_B: I agree with you.

System: Do you mean that you both agree to choose the answer **B** with the degree of confidence equal **10**?

P_B: Yes.

P_A: Yes.

System: If there is no question about this item shall we move to the next one?

P_A: Yes.

P_B: Yes.

System: Before continuing to the next question if you would like to see the performance of the group, please select the provided 'student model'.

Both P_B and P_A choose to see the *GLM* so the system gives them information of how well the group performs as a *bar-chart* (See Figure 5.12) and further detail as a textual explanation (See Figure 5.13)

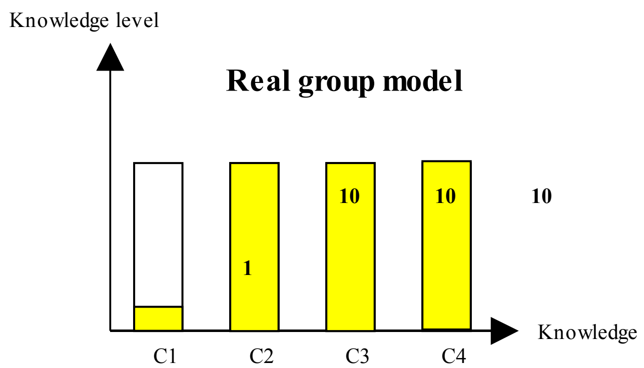


Figure 5.12. The *GLM* of Question5

Concept 1 (C1):	Ability of knowing the value in the specific position of base-8 number is in level **1** apart from 10.
Concept 2 (C2):	Ability of transforming the number in the specific position of base-8 number into various forms is in level **10** apart from 10.
Concept 3 (C3):	Ability of using suitable equation to convert base-8 number into base-10 is in level **10** apart from 10.
Concept 4 (C4):	Ability of converting the number of base-8 number into base-10 is in level **10** apart from 10.

Figure 5.13. The explanation of *GLM* for Question5

5.2.3.3 Step3: Compare *IdealGLM* to *GLM*

At this step, the system provides the option for learners to see the comparison between *GLM* (See Figure 5.15)and *IdealGLM* or not. The performance that the system represents to the group as *IdealGLM* is considered into two respects – the union (See Figure 5.14) and the intersection (See Figure 5.16) of individual performance.

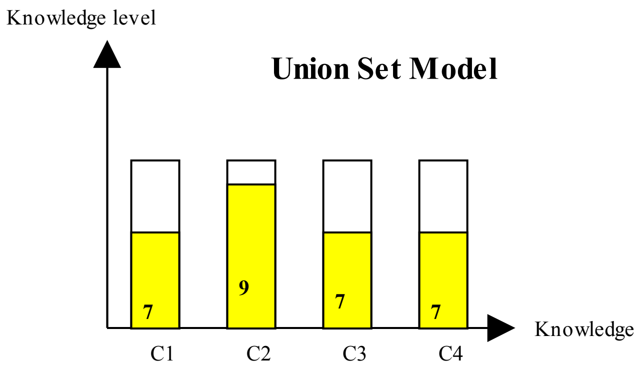


Figure 5.14. The *union set* of individual performance

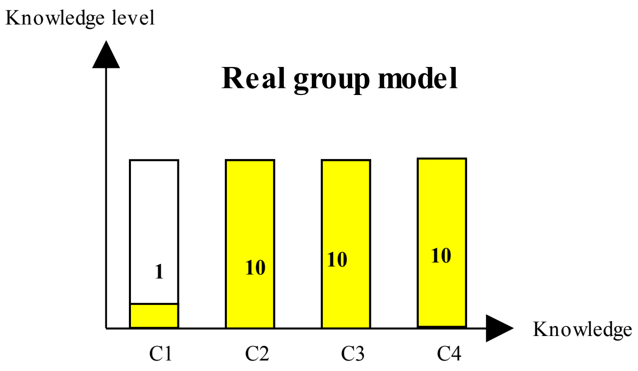


Figure 5.15. The *GLM* after performing five questions

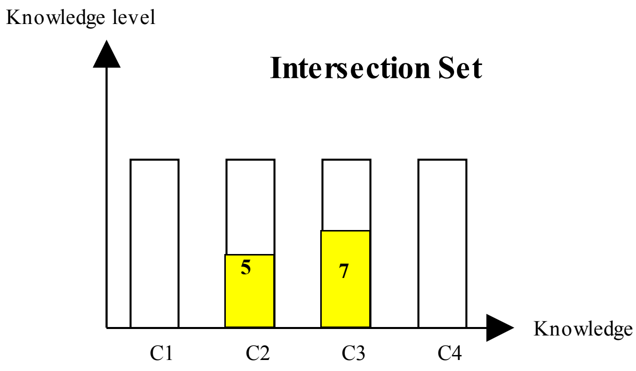


Figure 5.16. The intersect set of individual performance

5.2.3.4 Step 4: During the post-test

This step is similar to step 1 but only runs after the group-test as a post-test. Firstly, the system provides both learners with a post-test and an individual test (the scores are kept secret in the system). After finishing the individual test, the system then scores the post-test for a learning performance. After running from step1 through step 4, the summary of the results are displayed in Table 5.4.

P_A's post-test score = 5 and summation of confidence = 45 (9+9+9+9+9)

P_B's post-test score = 5 and summation of confidence = 50 (10+10+10+10+10)

Table 5.1. This is the summary result after running step1-4

Participants	Group*	pre-test score		group-test Score		post-test score	
		Correct item	Overall confidence	Correct item	Overall confidence	Correct item	Overall confidence
P_A	High	5	31	4	37 (9+9+10+9)	5	45
P_B	High	3	24			5	50

* A group of participants are categorised as *high-score group* and *low-score group* from the score that they have from doing the test (30 multiple choices items) before doing this group test. The subjects in the *high-score group* have scores from 13 to 30 and subjects in the *low-score group* have scores from 0 to 12.

5.2.3.5 Summary and comments

This is the result of the group that has scores in the high group after doing the multiple-choice test for 30 items. The result from the model shows that for Concept1 (Question1), P_A contributed her belief that is correct, but her friend did not agree with her. However, she did not want to talk about his any more and tried to change the topic to continue the next test but the system did not allow them to do so until both of them gave the final solution. Finally, P_A decided to agree to the answer that P_B provided, which is incorrect, so at this time the knowledge level of this group is between 0 and 1 because one of them expressed the correct concept that was relevant to this topic.

For concept 2 (Question 2 and 3), P_B and P_A agreed to what each other contributed and answered both questions correctly. In this case, the system has some evidence to believe that both learners know about this topic at the level 10.

For concept 3 (Question 4), both learners chose the same answer and *degree of confidence* so they did not contribute any knowledge, but confirmed that their own answer ,which is correct, so the level of knowledge for this group stays at the same level that it should be which is level 10.

For concept 4 (Question 5), both of them chose a different answer and *degree of confidence*. They confirm only just their belief in the answer, but do not contribute any knowledge therefore; the system cannot update any score until they give a final solution with the highest *degree of confidence* that is correct. This time the level of knowledge is updated in level 10.

In order to see the benefit of learning as a group, the results from the *union set* and *intersection set* of individual learner model should be considered. The result from the *union set* is used to present to the group as an '*ideal group learener model*' in order to encourage learners to see the range of the potential knowledge that the system expects learners to achieve when learning together. While the result from the *intersection set* is being used to see the actual knowledge that at least both of them can achieve together as a group.

After learning together as a group, the '*ideal group learner model*' from the *intersection set* (See Figure 5.16) is being compared *high-score* to the *'real group learner model'* (See Figure 5.15) to see the improvement of the group. For this pair, knowledge level of C1 is increased from 0 to 1, C2 increased from 5 to 10, C3 increased from 7 to 10 and C4 increased from 0 to 10.

To confirm that collaborative learning in the computer-based learning environment helped them to improve either their knowledge or *degree of confidence* in that particular topic, the result of an individual learner before and after learning as a group is being compared. From the information in Table 5.1, even though the number of correct items of P_A's pre-test and post-test is still the same but the *degree of confidence* is increased from 31 to 45 and for P_B, both correct items and overall *degree of confidence* is increased from 3 to 5 items and 24 to 50.

In this case, learners from the *high-score group* are paired together so they can achieve more than the potential level that the system expects and after learning individually by themselves again, both of them can achieve more than the pre-test result for either number of the correct item or the overall confidence. Comments from P_B and P_A about this design are explained below.

1. The system should provide an example of number based conversion of each concept to help learners to express their belief easily and sensibly.
2. The user manual should be contributed to learners before doing this test to make sure that they are familiar with the system. (A different version of question is applied for this matter)
3. System is well designed but too much information has to be learned before doing this test may delay finishing time and obstruct their interest of learning so user manual is one of their suggestions.
4. The system should provide explanation in either description or example for some vocabulary such as left bit of the decimal point (give learners the picture of what is the left and what is the right)
5. Learners agree that student model provided as a bar chart with the explanation below the *bar-chart* for each concept quite useful for doing this test as a group of two.

Combining both comments from six groups of participants together with the results of the paper-based design, we then come up with the revised version of the system that will be used as the computer-based learning environment called GOLeM.

5.2.4 The results of testing the paper-based design

The paper-based design version of GOLeM is applied to 12 participants that are paired into six groups. Before having these 12 participants, we applied the 30-item multiple choice test for prior knowledge to 122 participants. The score from this test was used to classify participants into a *high-score group* and a *low-score group*. The participants who have the higher testing score than at the percentile 50 are in the *high-score group*. While participants who have the testing score lower than at the percentile, 50 are in the *low-score group.*

After classifying participants into a *high-score group* and a *low-score group*, twelve participants are randomly selected. The first six participants are from the *high-score group* and the other six are from the *low-score group*. These participants are then paired into three-group types that are *high-high*, *high-low*, and *low-low*. The *high-high* group type is the group that both participants are from the *high-score group*. The *high-low* group type is the group that one participant is from the *high-score group* and the other one is from the *low-score group*. The *low-low* group type is the group that both participants are from the *low-score group*. There are two groups of participants for each group type.

After applying these twelve participants to the paper-based design, the result shows that participants can improve their potential performance when they learn with each other and maintain that level of performance when they do it alone by themselves. Moreover, the opinion of participants as a group confirms that what we have done is sensible and worth doing to help participants to improve their learning in the computer-based collaborative learning environment.

The information after testing the paper-based design is taken into account for the revision of GOLeM. The number of questions that are applied in the system is reduced from five to four to avoid boredom. The learning concepts are increased from four to six concepts for more clarification of the relationship between each question and the learning concepts. The number of *sentence openers* is reduced from fifteen to fourteen. The user manual will be prepared and provided before and during use of the system. This revised version of GOLeM is applied within a computer-based learning that is explained in the next topic. Hopefully, the result of the computer-based learning will be the same or better than the paper-based even though no one can guarantee the similarity of the result.

5.3 Software Implementation

After we are satisfied with the paper-based testing result, we continue to work on the software implementation. The comments on the previous testing are considered in order to build the system that works as close as possible to both requirements of GOLeM and users. For this step, the flowchart is used to simplify and illustrate how GOLeM works.

Now that we have the blue print of what to build and how to build, it is time to decide which software tools to use to build this GOLeM. At first, we have many combinations of software that worked as web-based and non web-based. In the end, with the constraint of time, knowledge, and other factors, we come up with the solution of using Visual Basic 6.0 and Microsoft Access 2002 as the software to implement GOLEM.

5.3.1 Software: Visual Basic 6.0, Microsoft Access

The minimum requirement for GOLeM is that there are two computer machines connected together. The system should have a login process to check the permissions for each user. These machines exchange information via the *chat-tool* synchronously; the system can investigate and use the communication dialogues to update the *group learner model*. The information that is kept in the *GLM* is updated in real-time in respect to the rules of updating that are stated in more detail in Chapter 4. The system should keep and retrieve information of learning performance for both individual and group learning. To represent the information of the *group learner model* in terms of *IdealGLM* and *GLM*, the bar chart and textual information are displayed.

For the requirement above, MS Access 2002 is used as the database to keep information of learning performance for each learner as both individual and group. Visual Basic 6.0 is used as a user interface to represent the look of the system design and represent the bar chart and textual explanation for the *IdealGLM* and *GLM*. Moreover, Visual Basic is used as an interface to retrieve and update data in the database. The *chat-tool* utilises the 'Winsocks' component of Visual Basic to communicate between two machines. The flowchart that gives an idea of what will happen in the system is introduced in the next step.

If the results of this system go well, the future work is to expand this concept to long distance learning using web-based and other software programming technologies such as Java to implement a more complex design. Moreover, the system should allow learners to choose their own pair and provide the test based on group performance.

5.3.2 The flowchart for further detail of how GOLeM works.

The design of GOLeM aimed at helping learners to improve either learning score or *degree of confidence* when learning as a group of two in a computer-based learning environment that allowed them to communicate and perceive the information of the learning performance as *IdealGLM* and *GLM*. What should be considered in this system is, firstly, each learner logs into the system for permission to use this system. In this process, the system will check and decide whether to allow or not allow a particular learner to access the system.

If login is successful, the system provides four multiple-choice questions, one at a time. After that, learners have a chance to require seeing the *IdealGLM*. If learners ask to see the *IdealGLM*, they should fill in the questionnaire before perceiving. However, if learners do not want to see the *IdealGLM*, they can continue further to doing the group-test. During the group-test, learners can exchange information with their peers using the provided *chat-tool*. At the same time, the system investigates and checks each conversation with the updating rules and then transforms the results into a *concept-score* to update the *GLM*. After finishing each question in the group-test, learners can request information regarding the *GLM*. Later, after the learner has finished all four questions as a group, the system then provides the post-test. The process of doing the post-test is similar to pre-test. The flowchart of how this system work is displayed in Figure C.1 – C.5 of Appendix C.

5.3.3 The user interface of GOLeM

The user interface display is made up of four zone areas that rely on the steps that are explained later in the chapter. All zone areas are displayed in Figure5.9. The first zone is *Login Area* that is used to check for the permission before using the system. The second zone is *Question Area* that is used to perform the individual tests for both pre-test and post-test. The third zone is the *Display Group Learner Model Area* that is used to represent the *IdealGLM* and *GLM* as a *bar-chart* and textual explanation. The last zone is the *Chat Area*. This area is used only in the group-test. Learners connect two machines, exchange information, and come up with the group result within this area.

The four steps are used to explain the process within the four zone areas of *Login Area*, *Question Area*, *Display Group Learner Model Area* and *Chat Area*. Step1 explains the process of *Login Area*. Step2 explains the process of *Question Area.* Step3 explains the process of *Display Group Learner Model Area and S*tep4 explains the process of *Chat Area.* After running the program, TutorPeer*GLM* will be displayed as in Figure 5.17.

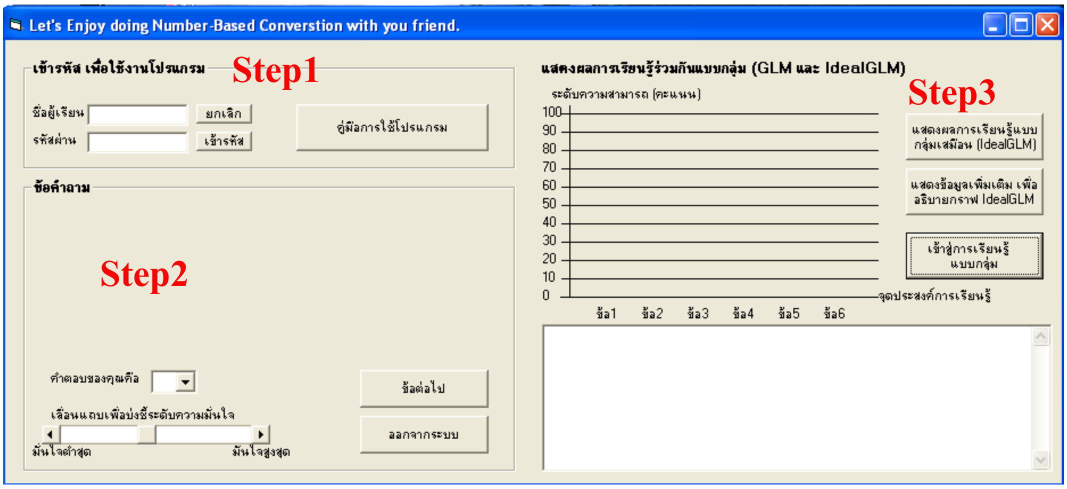


Figure 5.17. The display of the program as it is first called

5.3.3.1 Step1: Login to the system

In the *Login Area* as seen in Figure 5.18, learners can login to the system by typing in their *user name* and *password* that are assigned by the instructor. Later press the button เข้ารหัส to login to the system or press button ยกเลิก to clear all typed in data. In this area, a learner can request to see the user manual by pressing the button *'คู่มือการใช้โปรแกรม'*.

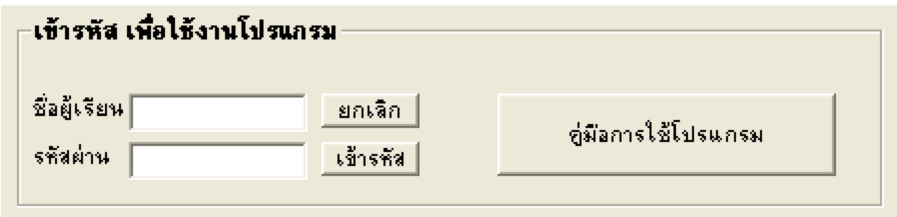


Figure 5.18. The *Login Area*

5.3.3.2 Step2: Doing an individual pre-test

After learners login to the system, the set of questions will be sent to that particular learner and their peers according to the group's previous knowledge. A set of questions consists of four question types that relate to the six learning concepts that have already explained in the previous chapter. The questions will be provided automatically after learners have logged in as seen in 'The *Question Area*' (See Figure 5.19).

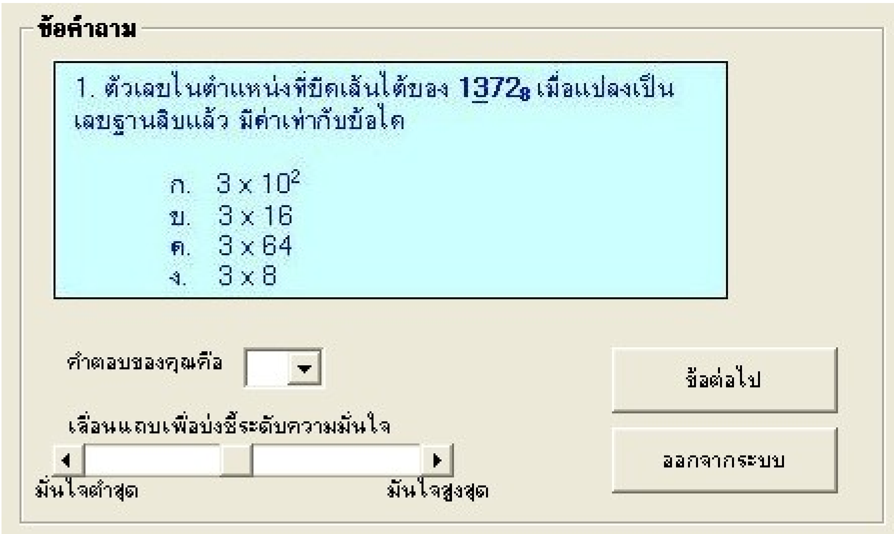
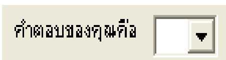
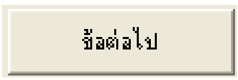


Figure 5.19. The *Question Area*

In order to answer these four questions, firstly, learners state the answer in the combo box 

and later scale on the confidence scale 

for how confident they are in each particular question (the *degree of confidence* ranges from level 1(most left) to level 10 (most right)).

After giving the answer and *degree of confidence* for each question, learners then press the button 

for the next question. At the end of question four, the system will check the ready status of peers before giving an opportunity to see an *IdealGLM*.

5.3.3.3 Step3: Display the group performance

As seen in Figure 5.20, there are three buttons. The first two buttons from the top are the button to show *IdealGLM* as a '*Bar-chart'* and 'Display in textual explanation'. The lowest button is the button for continuing to the group-test.

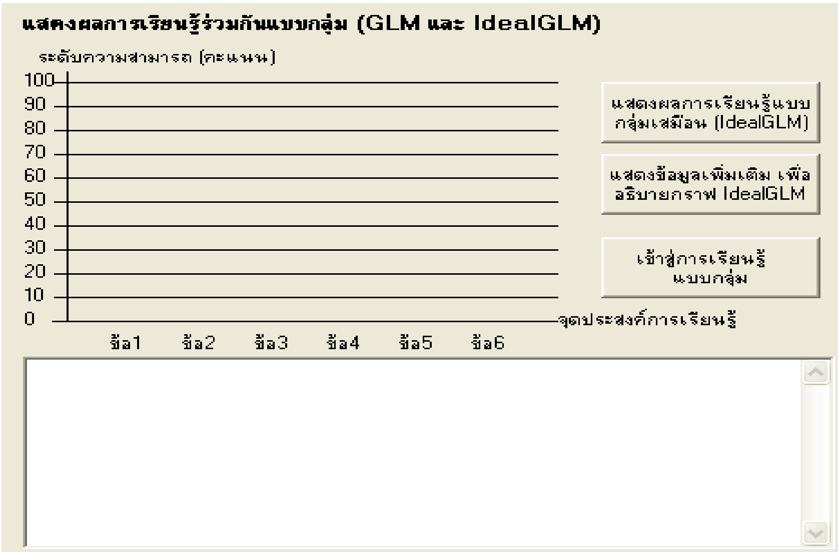


Figure 5.20. Display Group Performance Area

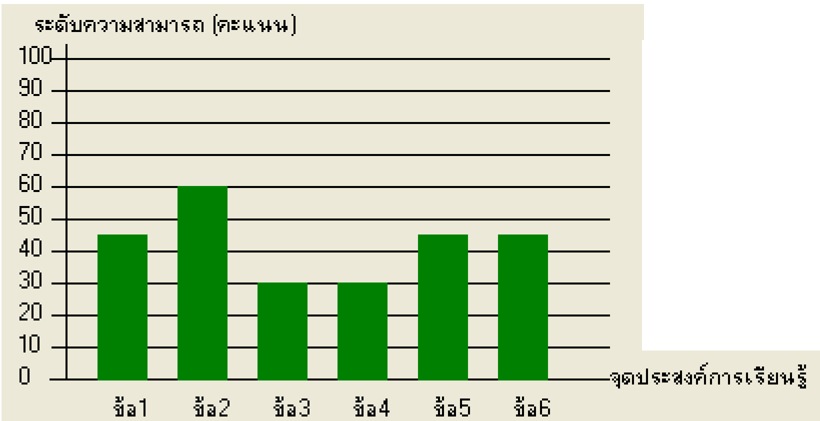
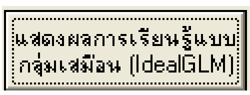


Figure 5.21. The display of *IdealGLM* as Bar charts

If the button 

is pressed, the system will provide information regarding *IdealGLM* that is defined as an expectation of the group performance from individual performances. As seen in Figure 5.21, information of the *IdealGLM* will be displayed as bar chart. Each bar stands for performance of each learning concept. The x-axis stands for the six learning concepts and the y-axis stands for the learning *concept-score.*

Moreover, if learners would like to have more explanation, they can press button "แสดงข้อมูลเพิ่มเติม เพื่ออธิบายกราฟ ***IdealGLM*"**. The explanation of each bar chart will be displayed as seen in Figure 5.22. The scroll bar is used to see more detail.

After learners press the button for doing the group-test, the questionnaire window (See Figure 5.22) is displayed. This questionnaire asks for the option of 'Seeing the *IdealGLM*'.

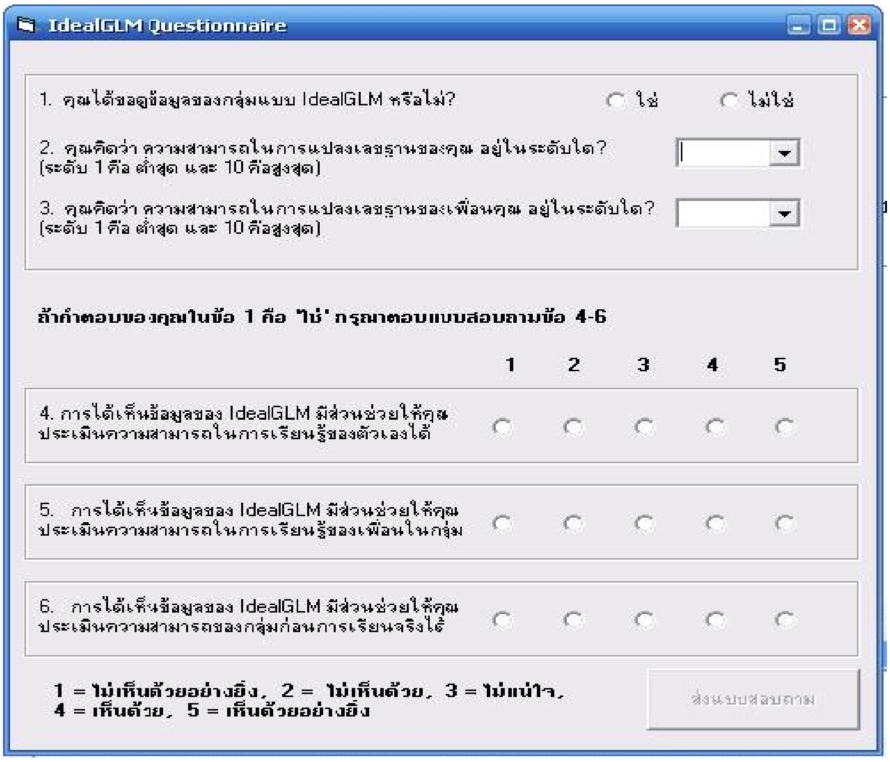


Figure 5.22. The display for *IdealGLM* questionnaire

After the learner has finished filling this questionnaire, they press the submit button to close this window and continue to the group-test. The window of the group-test that contains the chat program (See Figure 5.23) is displayed. At the same time, the relevant question will be provided in the *Question Area* (See Figure 5.19).

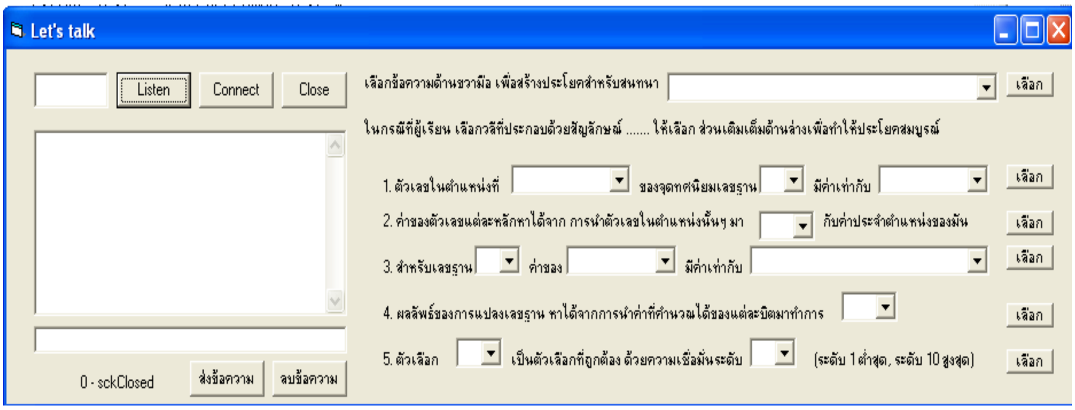


Figure 5.23. The display of the provided chat program with *sentence openers*

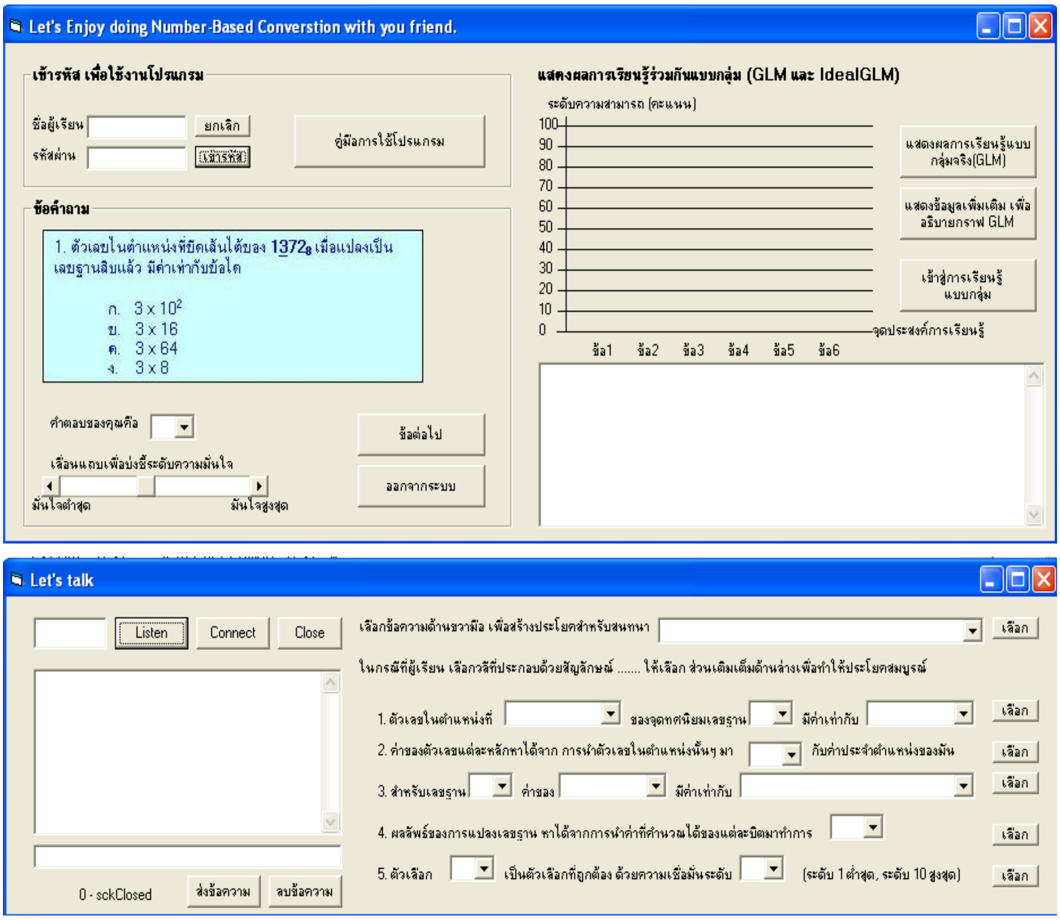


Figure 5.24. The display of learning with peer for group-test

5.3.3.4 Step4: A group-test and chat with friends

In Step4, only *Chat Area* will be enabled for learners to interact. The system will start the conversation from what each member answers through the individual task of the pre-test. The system then assigns the turn to one of the group members to start the conversation. During each turn, only one group member can compose a sentence to communicate with the other member. To start using the *Chat Area*, firstly, learners make the connection for two specific computers by managing IP address with the buttons displayed in Figure5.25.

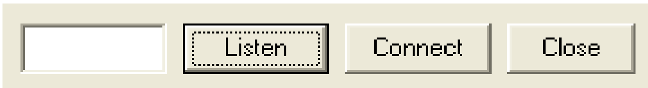


Figure 5.25. Chat Connection Buttons

After the connection is established, anyone whose 'turn' is assigned as enabled selects the sentence from the provided 14 *sentence openers* (See the bottom right area of the Figure 5.24) to communicate with peers. Learners select the sentence opener in the combo box and press the button  to continue.

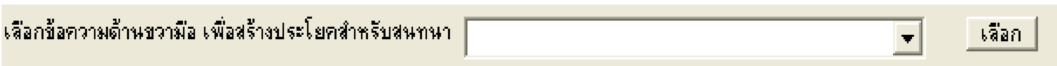
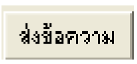
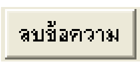


Figure 5.26. The 14 Sentence Openers

As explained in the previous chapter, some of *sentence openers* need the utterance to complete the sentence. Therefore, in cases that *sentence openers* contain '…', learners are asked to complete these sentences with five options of utterances (See Figure 5.26). After completing each sentence, press  to continue. Then the sentence is sent to the compose text area (see the bottom left area of Figure 5.24). To send the message, press the button  or to delete the message and compose the new press the button .

The dialogue will be terminated for each question only when group members agree with the answer and *degree of confidence* that the other one has proposed. In other words, when one member has proposed a sentence that contains option5 and another one chooses to agree on that sentence then the system will provide the *GLM* and prepare to provide a next question. At The end of each question, learners can see the *GLM* if required. Before continuing to the next question, the system provides the questionnaire asking for the option of perceiving *GLM* (See Figure 5.27). After finishing the group-test, the post-test is provided for the measurement of learning improvement then the system is terminated.

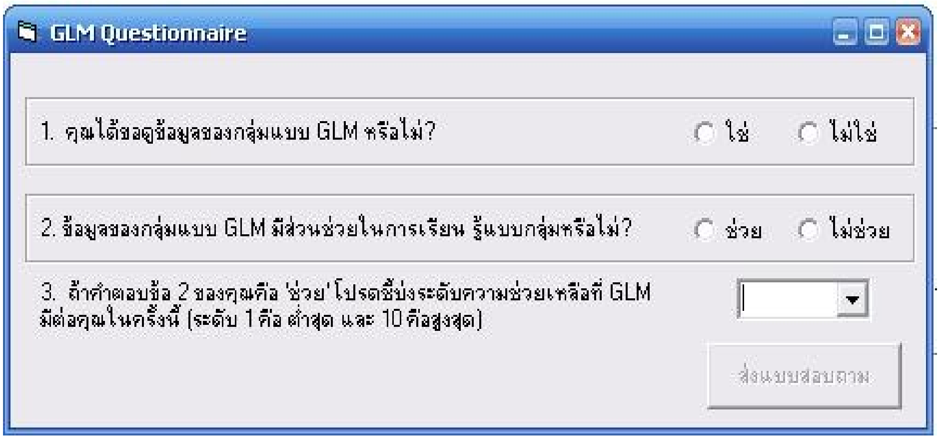


Figure 5.27. The questionnaire for asking to perceive *GLM*

5.3.4 The results of testing the computer-based design

After finishing the software implementation of the computer-based design, we brought this software to test with a couple of pairs who had expertise in user interface design. This design was revised and tested several times before it was used by the 36 participants from the Departments of Computer Science and Technology, Kanchanaburi Rajabhat University, Thailand.

During the first use of the system, participants complained about the large amount of information that they had to learn to use the system. Later, after doing one question and learning how to deal with this system, they felt more relaxed about using the system. The majority of the participants required seeing the information of the *group learner model* as *IdealGLM* and *GLM*. They agreed that seeing *IdealGLM* and *GLM* helped them to improve their learning performance for both learning *concept-score* and *degree of confidence*.

However, in the *Chat Area*, learners had to type in the appropriate IP addresses in order to connect specific computers together. They sometimes forgot to type in crucial information that caused connection errors at startup time (this did not affect data collection). Therefore, what we decided to do to reduce this kind of problem was to ask them to stop and let me check before making a connection. However, in future work, the task of making connections between computers will be improved making the overall system more flexible and reliable.

5.4 Summary

Three domains will be considered for the design of GOLeM. These domains are *domain knowledge, group learner model,* and *communicative interaction.* These domains have been introduced and applied as the paper-based design. The content of *number-conversion* that has already been validated is selected to apply in the paper-based design for five questions. The result after applying this design to six pairs of participants shows that participants can improve their potential performance when they learn with each other and maintain that level of performance when they do it alone by themselves.

The suggestions from the test are used to improve the computer-based design. The software that is used to design the system is Visual Basic 6.0 and MS Access 2002 that meet minimum requirements of the system. The detail of flowchart for how the GOLeM works can be seen further in Appendix C. Then the system is implemented and then illustrated concerning use. The system is tested with a couple of pairs for a couple of times before testing with 36 participants.

In Chapter 6, the computer-based design is applied as one of the three learning environments which are used to compare the aspect of s*eeing* and *not seeing* the *IdealGLM* and *GLM*. The other aspect is to see whether there is any difference between the Individual learning and the group learning, especially in computer-based group learning in the context of *number-conversion*.

Chapter 6

Testing Results and Analysis of Data

The aim of this research is to show the results of learning with others in a group of two in a computer-based learning environment. Allowing participants to see learning performance as a group communicates via the provided *chat-tool*, may help them to improve their learning performance (*concept-score*, *self-assessment*) compared to other learning environments. The explanation below will give ideas of what we will do within this thesis. The testing stages are separated into 3 phases.

Phase1: Validate questionnaire items, which includes composing questionnaire items, translating into Thai language, testing with a small group of participants both experts and non-experts for the specific content, revising the questionnaire and using with the 122 participants.

Phase2: Test for the plausibility of the system design, which includes selecting 5 items from the questionnaire in Phase1, applying this test to the paper-based design, and applying this design to the 6 pairs of participants who are selected from 122 participants in Phase1. The first six participants are randomly selected from *high-score group* and the other six are selected from *low-score group*. These 12 participants are paired as *high-high*, *high-low* and *low-low*. *High-high* is the pair that both participants are in the *high-score group*. *High-low* is the pair that one participant is in the *high-score group* and another one is in the *low-score group*. *Low-low* is the pair that both participants are in the *low-score group*.

Phase3: Use the design system to answer the question of the thesis. In this phase, there are three learning environments applied for the test, which are *Envi1, Envi2* and *Envi3*. *Envi1* is the learning environment that allows participants to learn in pair so they can communicate via the provided *chat-tool* and request to see the learning performance which will be represented as a group model. *Envi2* is similar to *Envi1* but does not allow participants to see information of learning performance. *Envi3* allows participants to do the test individually, and during the pre-test and post-test they are provided with a 10 pages handout .

What will be done in this phase is firstly apply the 30 items questionnaire to 120 participants and split into *high-score group* and *low-score group*, according to their test score. Secondly, separate these participants into three groups which will be assigned in *Envi1*, *Envi2* and *Envi3* ensuring that participants in each learning environment are representative of the group as a whole. Thirdly, compare the pre-test and post-test result to see whether there is any significant difference between these three learning environment. Referred to Dillenbourg and Baker (1996), and Soller and others (1999) who suggested that participants perform better in a group than as individuals, this step is to confirm that collaborative learning is more effective in this computer-based learning environment.

Whatever the results, our focus will remain on the computer-based collaborative learning environments which are introduced here as *Envi1* and *Envi2*. At this stage, we are interested in *seeing* if there is any significant difference between *seeing* and *not seeing* the information of learning performance when both group participants are allowed to communicate via the provided *chat-tool*. The information that will be used to compare the difference between *Envi1* and *Envi2* are *Test Score, self-assessment, peer-assessment, Information during the communication,* and *Opinion after applied particular learning systems*.

6.1 Validate Questionnaire Items

Ensuring that the learning content is suitable to the participants, the 30 item multiple choice test is completed by 122 participants who all have a major of study in computer science at Kanchanaburi Rajabhat University, Thailand. Table 6.1 shows the average time required for the test is 32.12 minutes with S.D. 19.138, and the average score is 14.18 with S.D. 7.25. Furthermore, as seen in Figure 6.1, the minimum score, maximum score and the frequency of the test results show that there are a variety of group scores that participants made which implies that these 30 questions are not too easy or too difficult for this group of participants.

Table 6.1. The general information of '*Test Score*' and '*Time to finish the test*' for five group of participants

Year of Study	Test Score			Time to finish the test (mins)		
	Mean	N	S.D	Mean	N	S.D
1st Year	20.06	32	6.16	60.00	32	0.00
2nd Year	8.60	30	5.01	25.00	30	12.44
3rd Year	17.76	17	8.11	31.82	17	10.87
4th Year room1	12.90	21	5.45	17.71	21	4.08
4th Year room2	11.68	22	4.24	15.27	22	5.37
Total	14.18	122	7.25	32.12	122	19.14

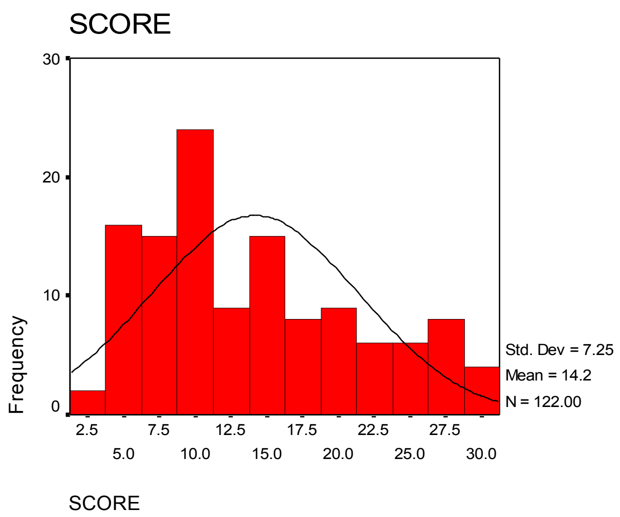


Figure 6.1. Mean and S.D of 122 participants in the 30 item test

6.1.1 Difficulty level (D_f)

After *seeing* that this questionnaire is neither too easy or too difficult for this group participants, the next step is to find out the *difficulty level* of the test and item discrimination for the validity of the test. *Difficulty level* (D_f) can be calculated by using a number of subjects that answer each item correctly and then divide this number by the number of all subjects (122 participants in this case). *Difficulty level* (D_f), as seen in Table 6.2, is classified here in five ranges and given definitions of each range as '*Very Difficult', 'Quite Difficult', 'Moderate', 'Quite Easy',* and *'Very Easy'.*

Table 6.2. The ranges and definitions of *difficulty level*

Range definition	Range of D_f
Very Difficult	$0 \leq D_f \leq 0.14$
Quite Difficult	$0.14 < D_f \leq 0.40$
Moderate	$0.40 < D_f \leq 0.60$
Quite Easy	$0.60 < D_f \leq 0.84$
Very Easy	$0.84 < D_f \leq 1.00$

Table 6.3. The *difficulty level* of 30 items questionnaire

Item No.	No. of correct	D_f	Explanation
1	95	0.78	Quite Easy
2	69	0.57	Moderate
3	72	0.59	Moderate
4	96	0.79	Quite Easy
5	35	0.29	Quite Difficult
6	42	0.34	Quite Difficult
7	80	0.66	Quite Easy
8	86	0.70	Quite Easy
9	80	0.66	Quite Easy
10	55	0.45	Moderate
11	61	0.50	Moderate
12	67	0.55	Moderate
13	58	0.48	Moderate
14	61	0.50	Moderate
15	51	0.42	Moderate
16	54	0.44	Moderate
17	57	0.47	Moderate
18	65	0.53	Moderate
19	46	0.38	Quite Difficult
20	34	0.28	Quite Difficult
21	56	0.46	Moderate
22	46	0.38	Quite Difficult
23	49	0.40	Quite Difficult
24	26	0.21	Quite Difficult
25	19	0.16	Quite Difficult
26	55	0.45	Moderate
27	52	0.43	Moderate
28	75	0.61	Quite Easy
29	45	0.37	Quite Difficult
30	28	0.23	Quite Difficult

As displayed in the Table 6.3, there are five levels of difficulty that these 30 questions are classified which are *'Very Easy', 'Quite Easy', 'Moderate'* and *'Quite Difficult', 'Very Difficult'*. The majority of the *difficulty level* fall to *'Moderate'* (14 questions) and *'Quite Difficult'* (10 questions) which shows that the quality of the test is quite high.

The validity of the test focuses on both the *difficulty level* and the *item discrimination* for each item ensuring that the one who gets the higher score is better than the others with lower scores.

6.1.2 Item discrimination(D_c)

Item discrimination(D_c) can be calculated from the difference between the numbers of participants who answer that item correctly. The 122 participants were split into 2 groups defined here as *high-score group* and *low-score group*. Members of *high-score group* are participants who have a score higher than percentile 50 and vice-versa for participants in low-score group.

The participants of both *high-score group* and *low-score group* are divided by number of either group high (N_H) or low (N_L).The N_{CH} stands for the number of participants in a *high-score group* who can answer that item correctly and N_{CL} stands for the number of participants in a *low-score group* who can answer that item correctly. D_c is calculated from an equation $\mathbf{D_C = (N_{CH} - N_{CL}) / N_H}$ and is classified in five ranges. Table 6.4 shows that the definitions of each range are '*Should be improved', 'Not so good', 'Good', 'Very good',* and *'Excellent'.*

Table 6.4. The ranges and definitions of *item discrimination*

Range definition of D_c	Range of D_c
Should be improved	$0 \le D_c \le 0.20$
Not so good	$0.21 \le D_c \le 0.40$
Good	$0.41 \le D_c \le 0.60$
Very good	$0.61 \le D_c \le 0.80$
Excellent	$0.81 \le D_c \le 1.00$

The value of $\mathbf{D_C}$ shows that each item can differentiate subjects in the *high-score group* to the *low-score group* correctly. An item with a high value of $\mathbf{D_C}$ is better at discriminating between two groups than a low value of $\mathbf{D_C}$.

According to the *difficulty level* of the 30 item test in Table 6.3, the result shows that the quality of this test is quite high. Together with the result of the item discrimination in Table 6.5 which shows that more than half of the questionnaires items are defined as '*Good*' and '*Very good*'. It can be confirmed that this test has quite a high quality for both *difficulty level* and item discrimination. Moreover the result after testing with 122 participants in Table 6.1 leads to the conclusion that *number-conversion* is the suitable content for this group of participants.

Table 6.5. The *item discrimination* of 30 items questionnaire

Item No.	N_{CH}	N_{LH}	D_C	Explanation
1	56	39	0.28	Not so good
2	47	22	0.41	Good
3	48	34	0.40	Not so good
4	57	39	0.30	Not so good
5	27	8	0.31	Not so good
6	30	12	0.30	Not so good
7	57	23	0.56	Good
8	56	30	0.43	Good
9	54	26	0.46	Good
10	40	15	0.41	Good
11	49	12	0.61	Very Good
12	45	22	0.38	Not so good
13	42	16	0.43	Good
14	46	15	0.51	Good
15	43	8	0.57	Good
16	40	14	0.43	Good
17	46	11	0.57	Good
18	48	17	0.51	Good
19	36	10	0.43	Good
20	28	6	0.36	Not so good
21	44	12	0.52	Good
22	36	10	0.43	Good
23	42	7	0.57	Good
24	25	1	0.40	Not so good
25	17	2	0.25	Not so good
26	42	13	0.48	Good
27	45	7	0.62	Very Good
28	50	25	0.41	Good
29	30	15	0.25	Not so good
30	19	9	0.16	Should be improved

6.2 Test for the Plausibility of the Paper-Based Design

Later, applying the paper-based design to produce the short version of what we design to 12 participants who are specifically assigned into 6 pairs. Firstly each participant does the 5 questions individually as a pre-test, and then does it again with others. At the stage of learning together, participants are allowed to communicate with each other using the provided phrases to compose a sentence. After finishing the five questions together, these participants then complete the same test individually as a post-test. The information of pre-test, group-test and post-test score and the comparison between these scores are displayed in Table 6.6.

Table 6.6. Information of pre-test, group-test and post-test score and the comparison between pretest and post-test and pre-test to group-test for 6 pairs of participants

Group Number	ID	Pre-test score	Group-test score	Post-test score	Post-test score is higher than pre-test sore	Group-test score is higher than pre-test score
group1	L1	5	4	5	No	No
	L2	3	4	5	Yes	Yes
group2	L3	4	5	5	Yes	Yes
	L4	3	5	5	Yes	Yes
group3	L5	2	1	1	No	No
	L6	1	1	3	Yes	Yes
group4	L7	1	5	5	Yes	Yes
	L8	4	5	5	Yes	Yes
group5	L9	5	5	5	No	No
	L10	3	5	3	No	Yes
group6	L11	4	4	5	Yes	Yes
	L12	1	4	3	Yes	Yes

The results show that from 12 participants, eight of them get a higher score in post-test compared to pre-test and a higher score in group-test compared to pre-test. There are four who do not obtain a higher score in both the post-test and group-test, two of them obtain the top score in the pre-test which cannot be increased. According to this result, it has been shown that participants can improve their potential performance when they learn with another and maintain that level of performance when they do it alone while using this designed system.

Referred to 'Low-technology Try-out summary' (See Appendix E), we will illustrate here for the correction among five parameters which are *correctness of the result*, *Agreement of the group answer*, *knowledge contribution*, *similarity of individual answers* and *the similarity of the final result* compared to *individual answers* of the group members.

Table 6.7. The effect of *individual answer*, *group answer* and on the correctness of the group result.

Agreement	Correctness of results	Are they contributing knowledge?	Individual result: Same		Individual result: Different		Total
			group: same	group: different	group: same	group: different	
participants agree on the group answer	correct	yes	6	1	11	1	19
		no	3	0	0	0	3
	incorrect	yes	0	0	1	0	1
		no	1	0	1	0	2
participants disagree on the group answer	correct	yes	0	0	0	0	0
		no	0	0	1	1	2
	incorrect	yes	0	0	1	2	3
		no	0	0	0	0	0
Total			10	1	15	4	30

The Table 6.7 displays how these 30 answers, which come from 6 groups work on five questions of the paper-based design are categorised. There are 22 answers that participants agree on the group answers which is correct, 3 of them is correct without any contribution from participants but the other 19 answers comes from participants who contribute knowledge before they agree on the final answer. The majority of incorrect answers come from the cases that participants have different *individual answers* together with either disagree on the group result or do not contribute any knowledge. There are 23 answers that participants contribute knowledge, 19 of them have correct results and the other 4 have incorrect results. This information leads to the conclusion that contributing knowledge when learning with others helps the participants to get the correct answer compared with saying nothing especially when the individuals' answers are different.

Before further work is done, the opinions of the 12 participants, which is displayed in Table 6.8 as a group opinion, will be taken into account to confirm that what we have done and will be doing are sensible and worth doing enough to help participants to improve their learning in the computer-based collaborative learning environment.

Table 6.8 shows that all of the groups agree that providing the student model as a *bar-chart* with the explanation is quite useful for doing this test as a group of two and suggest further that user manual should be contributed to participants before doing this test to make sure that they familiar with the system. Some of the groups suggest giving more examples of the *number-conversion*, choices of utterances, and tutorial may help them to use this system more effectively. The groups complained about too much information at a time during the communication session, but they agree on the well design of this paper-based design and suggested providing user manual before using the real system.

Table 6.8. The suggestions of 6 pairs after using the paper-based design to do the group test

Suggestion	Group Number					
	1	2	3	4	5	6
1. The system should provide an example of number based conversion of each concept to help participants to express their belief easily and sensibly.	√	√		√	√	
2. Should provide more utterance such as the negative one… rather than I think…or I belief…, I don't think…(negative) should be counted.		√			√	√
3. The user manual should be contribute to participants before doing this test to make sure that they familiar with the system. (The different version of question is applied for this matter)	√	√	√	√	√	√
4. The tutorial for using this system should be provided to make sure that participants understand how to use this system correctly.		√				
5. System is well design but too many information that have to be learned for doing this test may delay finishing time and obstruct their interest of learning so user manual is one of their suggestion.	√		√	√	√	
6. The system should provide explanation in either description or example for some vocabulary such as left bit of the decimal point (give participants the picture of what is the left and what is the right)		√	√	√	√	√
7. participants agree that Student Model that provide as a bar chart with the explanation below the chart for each concept quite useful for doing this test as a group of two.	√	√	√	√	√	√

6.3 Apply the Design System to Answer the Questions of This Thesis

In order to work on comparing the benefits of computer-based collaborative learning, we then set the learning environments into 3 types which are *Envi1:*a group of participants which is allowed to communicate and provide information of a learning performance as a graphical and textual format, *Envi2*: a group of participants which is allowed to communicate but not provide any information of learning performance and *Envi3*: a group of individual participants.

There are 120 participants who participated in this experiment. Firstly, all of these participants were asked to do the 30 items in the pre-test and then the test score was used to separate participants into three similar groups. In order to do this, participants will be separated into 2 groups according to their *testing-score* which are *high-score group* and *low-score group*. The *high-score group* is the group that participants have the score higher than the 50^{th} percentile while the *low-score group* is the group that participants have the score lower than or equal to the 50^{th} percentile. The 'matching technique' is used to group these participants into 3 similar groups for the 3 learning environments.

There are 36 participants in *Envi1*, 24 participants in *Envi2* and 25 participants in *Envi3*. In *Envi1*, there are 22 participants from the *high-score group* and 14 participants from the *low-score group*. In *Envi2*, there are 12 participants from each *high-score group* and *low-score group*. In *Envi3*, there are 13 participants from the *high-score group* and 12 participants from the *low-score group*.

The main goal of this research is to see whether or *not seeing* the information of learning as a group may help participants to benefit from learning in the computer-based collaborative learning environment. To achieve that goal, there are many variables and aspects that should be considered and will be represented under issues of 'c*ollaborative vs. individual learning*', learning performance in aspects of '*testing-score*' and '*concept-score*', '*self-peer-assessment* vs. *self-peer-actual-performance*', 'c*ommunication during the group-test',* and *'the opinions after participants applied each particular system'.*

6.3.1 Issue1: collaborative learning vs. individual learning.

This issue focuses on comparing the learning performance of collaborative learning and Individual learning especially when collaborative learning is on the computer-based learning environment in the aspect of . At this stage, three learning environments are taken into account. Two of which apply the concept of collaborative learning and the other one which applies the concept of individual learning. In order to compare these three learning environments, firstly the variables of the pre-test score from the 30 items test are investigated to confirm the similarity of participants of each group before assigning to particular learning environments. After having participated in the assigned learning environments, participants are required to do the same test again as a post-test. The result of the comparison among these post-test scores reveal whether or not participants benefit from collaborative learning the same way as individual learning.

6.3.1.1 Compare pre-test to confirm the similarity of the groups

To confirm that participants in these three learning environments are not different, the comparison of pre-test scores will be represented in three aspects which are consideration of *all participants*, and consideration of only the *high-score group*, and consideration of only the *low-score group* type of participants.

6.3.1.1.(a) All participants

First of all, the Analysis of Variance or ANOVA technique is used to compare the of three learning environments using the score of the 30 item pre-test. Table 6.9 shows that there is no significant difference at the 5% level among participants who were assigned to work in these particular learning environments.

Table 6.9. ANOVA of pre-test score from *all participants*

	Sum of Squares	df	Mean Square	F	p (Sig.)
Between Groups	31.839	2	15.920	.537	.586
Within Groups	2430.514	82	29.640		
Total	2462.353	84			

After considering the similarity of the participants for each learning environment without the concern of *Types of participants*, the further step is to look into *high-score group* and *low-score group* of participants separately beginning with the results of the *high-score group* participants and followed by the *low-score group* participants.

6.3.1.1(b) Participants in the high-score group

High-score group of participants will be considered at this time using Analysis of Variance technique to compare the *testing-score* of the 30 item pre-test of participants in three learning environments. Table 6.10 shows that there is no significant difference at the 5% level among participants who were assigned to work in these particular learning environments.

Table 6.10. ANOVA of pre-test score from participants in a *high-score group*

	Sum of Squares	df	Mean Square	F	p (Sig.)
Between Groups	1.945	2	.973	.234	.792
Within Groups	178.424	43	4.149		
Total	180.370	45			

6.3.1.1(c) Participants in the low-score group

Low-score group of participants will be considered at this time using Analysis of Variance technique to compare the *testing-score* of the 30 item pre-test of participants in three learning environments. The result shows that there is no significant difference at the 5% level among participants who were assigned to work in these particular learning environments.

Table 6.11. ANOVA of pre-test score from participants in a *low-score group*

	Sum of Squares	df	Mean Square	F	p (Sig.)
Between Groups	.940	2	.470	.097	.908
Within Groups	173.984	36	4.833		
Total	174.923	38			

Table 6.9, Table 6.10 and Table 6.11 show that there is no significant difference at the 5% level of the *testing-score* among participants in these three learning environments. Then the next step is to compare whether or not this computer-based collaborative learning will have the same result to other non-computer based learning when we compare it to the individual learning environment. Thus after assigning participants to work on the test in these particular learning environments, the 30 item post-test are applied and the *testing-score* is used as a measurement to see if there is significant difference between these learning environments.

6.3.1.2 Compare post-test score to see the difference between collaborative and individual learning

The results of the post-test among these three learning environments will be represented in respective aspects for *all participants*, *high-score group*, and *low-score group*. Ensuring that whatever group type of learner is considered the results remain the same.

6.3.1.2(a) All participants

All participants will be considered at this time using Analysis of Variance technique to compare the test score of the 30 item post-test of participants in three learning environments. Table 6.12 shows that there is a significant difference at the 0.2% level among participants who were assigned to work in these particular learning environments which means that at least one pair of learning environments is different.

Table 6.12. ANOVA of post-test score from *all participants*

	Sum of Squares	df	Mean Square	F	p (Sig.)
Between Groups	347.776	2	173.888	6.472	.002
Within Groups	2203.212	82	26.868		
Total	2550.988	84			

To look further into the detail of the comparison between each group as a pair using Tukey HSD, Table 6.13 shows that participants in *Envi1* are significantly different at the 0.2% level and have a mean score higher than in participants in *Envi3* by 2.47.

Table 6.13. The comparison between post-test as a pair using Tukey HSD from *all participants*

(I) Environment	(J) Environment	Mean difference (I-J)	Std. Error	p (Sig.)	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	2.47	1.366	.173	-.79	5.73
	3	4.83	1.349	.002	1.60	8.05
2	1	-2.47	1.366	.173	-5.73	.79
	3	2.35	1.481	.256	-1.18	5.89
3	1	-4.83	1.349	.002	-8.05	-1.60
	2	-2.35	1.481	.256	-5.89	1.18

After considering the difference among the participants for each learning environment without the concern of *Types of participants*, the next step is to look at the *high-score group* and *low-score group* separately. Beginning with the result of the *high-score group* participants and followed by the *low-score group* participants.

6.3.1.2(b) Participants in the high-score group

The *high-score group* of participants will be considered at this time using Analysis of Variance technique to compare the *testing-score* of the 30 item post-test of participants in three learning environments. Table 6.14 shows that there is a significant difference at the 4.6% level among participants who are assigned to work in these particular learning environments which means that at least one pair of learning environments are different.

Table 6.14. ANOVA of post-test score from participants in a *high-score group*

	Sum of Squares	df	Mean Square	F	p (Sig.)
Between Groups	71.868	2	35.934	3.317	.046
Within Groups	465.871	43	10.834		
Total	537.739	45			

To look in further detail at the comparison between each group as a pair using Tukey HSD, Table 6.15 shows that participants in *Envi1* are significantly different at the 5.0% level and have the mean score higher than in participants in *Envi3* by 2.87.

Table 6.15. The comparison between post-test as a pair using Tukey HSD from participants in a *high-score group*

(I) Environment	(J) Environment	Mean difference (I-J)	Std. Error	p (Sig.)	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	1.95	1.181	.234	-.91	4.82
	3	2.87	1.181	.050	.00	5.74
2	1	-1.95	1.181	.234	-4.82	.91
	3	.92	1.344	.775	-2.35	4.18
3	1	-2.87	1.181	.050	-5.74	.00
	2	-.92	1.344	.775	-4.18	2.35

6.3.1.2(c) Participants in the low-score group

The *low-score group* of participants will be considered at this time using Analysis of Variance technique to compare the *testing-score* of the 30 item post-test of participants in three learning environments. Table 6.16 shows that there is a significant difference at the 1.2% level among participants who are assigned to work in these particular learning environments which means that at least one pair of learning environments is different.

Table 6.16. ANOVA of post-test score from participants in a *low-score group*

	Sum of Squares	Df	Mean Square	F	p (Sig.)
Between Groups	169.209	2	84.604	4.987	.012
Within Groups	610.689	36	16.964		
Total	779.897	38			

To look in further detail at the comparison between each group as a pair using Tukey HSD, Table 6.17 shows that participants in *Envi1*are significantly different at the 1.0% level and have a mean score higher than participants in *Envi3* by 4.91.

Table 6.17. The comparison between post-test
as a pair using Tukey HSD from participants in a *low-score group*

(I) Environment	(J) Environment	Mean difference (I-J)	Std. Error	p (Sig.)	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	1.48	1.620	.637	-2.48	5.44
	3	4.91	1.586	.010	1.03	8.79
2	1	-1.48	1.620	.637	-5.44	2.48
	3	3.44	1.649	.107	-.59	7.47
3	1	-4.91	1.586	.010	-8.79	-1.03
	2	-3.44	1.649	.107	-7.47	.59

Table 6.13, Table 6.15, and Table 6.17 show that the post-test scores of participants in *Envi1* and *Envi3* are significantly different at the 0.2% level for *all participants*, at the 4.6% level for *high-score group*, and at the 1.0% level for *low-score group*. In order to see which learning environment participants have the higher post-test score, the value of mean difference is considered. The results show that participants in *Envi1* have an average post-test score higher than participants in *Envi3*. It can be concluded that collaborative learning which is applied here as a computer-based environment can help participants to get higher scores than learning individually in a specific *number-conversion* content.

6.3.1.3 Summary of Issue1: Collaborative vs. Individual Learning

Referring to Table 6.9, Table 6.10, and Table 6.11, it can be concluded that before applying participants to learn in *Envi1*, *Envi2* and *Envi3* the learning performance on *number-conversion* of the participants in each assigned group are not significantly different at the 5% level. These results are not different whether compared as *all participants*, *high-score group* or *low-score group* at a particular time.

After assigning participants to learn in *Envi1*, *Envi2* and *Envi3*, the results of the post-test from Table 6.13, Table 6.15 and Table 6.17 show that there are significant difference less than the 5% level between learning performance of participants in *Envi1* and *Envi3* whether compared as *all participants*, *high-score group* or *low-score group* at a particular time. It can be concluded that learning with each other in the specific content of *number-conversion*, participants can perform better than individually in the paper-based test.

The next step will be concerned about whether there is any difference in learning performance between the group that can see (*Envi1*) the learning performance in computer-based collaborative learning environment, and cannot see (*Envi2*) the group learning performance in computer-based collaborative learning environment.

6.3.2 Issue2: learning performance respectively to *seeing* and *not seeing IdealGLM* and *GLM*

The information represented here is aimed at comparing two computer-based collaborative learning environments by using *seeing* the learning performance and *not seeing* the learning performance as a controlled variable to differentiate these learning environments. In order to do that, *number-of-correct-answer* and *concept-score* are taken into account as the compared performance parameters. The *number-of-correct-answer* is the parameter to represent the number of questions that each participant answers correctly for both individual and group-test.

The *concept-score* is the parameter to show how well participants know about the particular six concepts of *number-conversion* content. The *concept-score* applied here will concerned with the matter of *degree of confidence* for each particular answer. In this issue, the statistical results will be explained regarding *number-of-correct-answer* and *concept-score* individually for pre-test, group-test and post-test and will compared to see whether there is any significant difference between *Envi1* and *Envi2*.

Moreover the concepts of, *pre-post-improve-number-of-correct-answer* and *pre-group-improve-number-of-correct-answer* will be introduced to illustrate how far each group can achieved when compared to *number-of-correct-answer* of pre-test to post-test and pre-test to group-test, while *pre-post-improved-score* and *pre-group-improved-score* are used to illustrate how far each group can achieve when compared to *concept-score* of pre-test to post-test and pre-test to group-test.

In order to compare the learning performance respectively to specific aspects, firstly the similarity of participants assigned in each particular learning environment is determined. After that the comparison of *number-of-correct-answer* and *concept-score* between specific learning environments will be illustrated for group-test and post-test. Later the percentage of learning improvement which is introduced respectively to the concepts of *pre-post-improve-number-of-correct-answer*, *pre-group-improve-number-of-correct-answer*, *pre-post-improved-score,* and *pre-group-improved-score* are explained.

6.3.2.1 Use *number-of-correct-answer* to confirm the similarity of participants

The *number-of-correct-answer* is the parameter which is used to tell how many questions each participants answers correctly. There are 4 question items assigned to participants for a whole testing process as a pre-test, group-test and post-test. For the pre-test, each participant will be assigned to do the test in a specific learning environment. The comparison of *number-of-correct-answer* between *Envi1* and *Envi2* will be compared in three aspects which are to confirm that there is no difference between the *number-of-correct-answer* before doing the test as a group.

6.3.2.1(a) All participants

All participants will be considered at this time using Independent T-test technique to compare the *number-of-correct-answer* of the 4 items pre-test of participants in *Envi1* and *Envi2*.

Table 6.18. The basic statistical information of
the *number-of-correct-answer* in pre-test of *all participants*

	Learning Environment	N	Mean	Std. Deviation	Std. Error Mean
4 items pre-test	1	36	3.33	1.069	.178
	2	24	3.29	1.083	.221

Table 6.18 shows that there are 36 participants occupied in *Envi1* having the means of *number-of-correct-answer* 3.33 and S.D. 1.069. While in *Envi2*, there are 24 participants having the means 3.29 and S.D. 1.083.

Table 6.19. 'T-test for Equality of means' in pre-test for *all participants*

T-test for Equality of means						
t	df	p (Sig.) (2-tailed)	Mean difference	Std. Error Difference	95% Confidence Interval of the Difference	
					Lower	Upper
.147	58	.884	.04	.283	-.525	.608

Comparing the means of *number-of-correct-answer* between *Envi1* and *Envi2*, Table 6.19 shows that there is not a significant difference at the 5% level for *all participants*.

6.3.2.1(b) Participants in the high-score group

The *high-score group* participants are considered at this time using Independent T-test technique to compare the *number-of-correct-answer* of the 4 items pre-test of participants in *Envi1* and *Envi2*.

Table 6.20. The information of the *number-of-correct-answer* in pre-test for participants in a *high-score group*

	Environment	N	Mean	Std. Deviation	Std. Error Mean
Pre-test 4 items	1	22	3.82	.664	.142
	2	12	3.75	.452	.131

Table 6.20 shows that there are 22 participants occupied in *Envi1* having the means of *number-of-correct-answer* 3.82 and S.D. 0.664. While in *Envi2*, there are 12 participants having the means 3.75 and S.D. 0.452.

Table 6.21. 'T-test for Equality of means' in pre-test for participants in a *high-score group*

T-test for Equality of means						
t	df	p (Sig.) (2-tailed)	Mean difference	Std. Error Difference	95% Confidence Interval of the Difference	
					Lower	Upper
.317	32	.754	.07	.215	-.370	.507

Comparing the means of *number-of-correct-answer* between *Envi1* and *Envi2*, Table 6.21 shows that there is not a significant difference at the 5% level for participants in *high-score group*.

6.3.2.1(c) Participants in the low-score group

The *low-score group* participants are considered at this time using Independent T-test technique to compare the *number-of-correct-answer* of the 4 items pre-test of participants in *Envi1* and *Envi2*.

Table 6.22. The information of the *number-of-correct-answer* in pre-test for participants in a *low-score group*

	Environment	N	Mean	Std. Deviation	Std. Error Mean
4 items pre-test	1	14	2.57	1.158	.309
	2	12	2.83	1.337	.386

Table 6.22 shows that there are 14 participants occupied in *Envi1* having the means of *number-of-correct-answer* 2.57 and S.D. 1.158. While in *Envi2*, there are 12 participants having the means 2.83 and S.D. 1.337.

Table 6.23. 'T-test for Equality of means' in pre-test for participants in a *low-score group*

T-test for Equality of means						
t	df	p (Sig.) (2-tailed)	Mean difference	Std. Error Difference	95% Confidence Interval of the Difference	
					Lower	Upper
-.535	24	.597	-.26	.489	-1.271	.748

Comparing the means of *number-of-correct-answer* between *Envi1* and *Envi2*, Table 6.23 shows that there is not a significant difference at the 5% level for participants in *low-score group*.

The information in 6.3.2.1(a), 6.3.2.1(b), and 6.3.2.1(c) shows that whatever the types of participants are, there is no significant difference at the 5% level between the means of *number-of-correct-answer* in pre-test for *Envi1* and *Envi2*. It can be concluded that in respect to the aspect of *number-of-correct-answer*, participants in *Envi1* and *Envi2* are not different.

6.3.2.2 Use *concept-score* to confirm the similarity of participants in *Envi1* and *Envi2*

Within this step we are concerned about the comparison between *concept-score* in pre-test for six learning concepts in two different learning environments introduced here as *Envi1* and *Envi2*. The *concept-score* is the parameter which is used to tell how well each participant performs in six learning concepts. *Concept-score* is calculated from the *result-of-the-answer* of each particular question and the *degree of confidence* that each participant states as a confirmation for that particular answer.

In the pre-test, the means of *concept-score* of each learning concept will be compared concept by concept respectively to type of participants which are firstly considered as all participant together, followed by *high-score group* and then *low-score group* to confirm the similarity of participants for each learning environment.

6.3.2.2(a) All participants

All participants are considered at this time using the Independent T-test technique to compare the *concept-score* in pre-test for six learning concepts in *Envi1* and *Envi2*.

Table 6.24. The information of *concept-score* of six learning concepts in pre-test for *all participants*

	Environment	N	Mean	Std. Deviation	Std. Error Mean
Pre-test score of concept1	1	36	63.97	35.453	5.909
	2	24	63.83	30.182	6.161
Pre-test score of concept2	1	36	71.17	32.113	5.352
	2	24	63.50	26.508	5.411
Pre-test score of concept3	1	36	67.53	31.071	5.178
	2	24	63.58	24.710	5.044
Pre-test score of concept4	1	36	69.72	32.382	5.397
	2	24	62.92	29.170	5.954
Pre-test score of concept5	1	36	64.22	40.564	6.761
	2	24	69.50	28.522	5.822
Pre-test score of concept6	1	36	63.08	39.051	6.509
	2	24	58.08	36.278	7.405

Table 6.24 shows that there are 36 participants occupied in *Envi1* and 24 participants occupied in *Envi2*. The means of *concept-score* in pre-test for six learning concepts are in the range of 58.08 and 71.17 while the S.D. are in the range of 24.71 and 40.564. The means of *concept-score* in pre-test for all learning concepts except concept5 are higher in *Envi1* than in *Envi2*.

Table 6.25. **'**T-test for Equality of means'of six learning concepts in pre-test for *all participants*

Pre-test *concept-score*s	T-test for Equality of means						
	t	df	p (Sig.) (2-tailed)	Mean difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Score for concept1	.016	58	.987	.14	8.818	-17.512	17.790
Score for concept2	.969	58	.336	7.67	7.910	-8.167	23.500
Score for concept3	.521	58	.604	3.94	7.568	-11.204	19.093
Score for concept4	.829	58	.410	6.81	8.208	-9.625	23.236
Score for concept5	-.592	58	.556	-5.28	8.922	-23.138	12.583
Score for concept6	.500	58	.619	5.00	10.007	-15.032	25.032

Comparing the means of *concept-score* in pre-test for six learning concepts in *Envi1* and *Envi2*, Table 6.25 shows that there is not a significant difference at the 5% level for all six learning concepts in respect to *all participants* at a time.

6.3.2.2(b) Participants in the high-score group

The *high-score group* participants are considered at this time using the Independent T-test technique to compare the *concept-score* in pre-test for six learning concepts within *Envi1* and *Envi2*.

Table 6.26. The information of *concept-score* of six learning concepts in pre-test for participants in a *high-score group*

	Environment	N	Mean	Std. Deviation	Std. Error Mean
Pre-test score of concept1	1	22	76.05	26.511	5.652
	2	12	77.25	16.063	4.637
Pre-test score of concept2	1	22	85.68	26.942	5.744
	2	12	75.83	20.094	5.801
Pre-test score of concept3	1	22	80.73	23.895	5.094
	2	12	76.50	13.873	4.005
Pre-test score of concept4	1	22	82.64	22.969	4.897
	2	12	77.25	16.063	4.637
Pre-test score of concept5	1	22	76.23	34.679	7.394
	2	12	82.67	14.950	4.316
Pre-test score of concept6	1	22	75.23	31.565	6.730
	2	12	71.67	26.572	7.671

Table 6.26 shows that there are 22 participants within *Envi1* and 12 participants within *Envi2*. The means of *concept-score* in pre-test for six learning concepts are in the range of 71.67 and 85.68 while the S.D.'s are in the range of 13.873 and 34.679. The means of *concept-score* in pre-test for all learning concepts exceptconcept2 and concept5 are higher in *Envi1* than in *Envi2*.

Comparing the means of *concept-score* in pre-test for six learning concepts in *Envi1* and *Envi2*. Table 6.27 shows that there is no significant difference at the 5% for all six learning concepts respectively to participants in *high-score group*.

Table 6.27. 'T-test for Equality of means'
of six learning concepts in pre-test for participants in a *high-score group*

Pre-test *concept-scores*	T-test for Equality of means						
	t	df	p (Sig.) (2-tailed)	Mean difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Score for concept1	-.165	32	.870	-1.20	7.311	-16.105	13.696
Score for concept2	1.106	32	.277	9.85	8.901	-8.282	27.979
Score for concept3	.561	32	.579	4.23	7.535	-11.121	19.576
Score for concept4	.720	32	.477	5.39	7.484	-9.858	20.631
Score for concept5	-.752	32	.458	-6.44	8.561	-23.902	11.023
Score for concept6	.331	32	.743	3.56	10.746	-18.328	25.449

6.3.2.2(c) Participants in the low-score group

low-score group participants are considered at this time using the Independent T-test technique to compare the *concept-score* in pre-test for six learning concepts in *Envi1* and *Envi2*.

Table 6.28. The information of *concept-score*
of six learning concepts in pre-test for participants in a *low-score group*

Pre-test *concept-score*	Environment	N	Mean	Std. Deviation	Std. Error Mean
Pre-test score of concept1	1	14	45.00	40.180	10.739
	2	12	50.42	35.410	10.222
Pre-test score of concept2	1	14	48.36	26.211	7.005
	2	12	51.17	27.085	7.819
Pre-test score of concept3	1	14	46.79	30.309	8.100
	2	12	50.67	26.837	7.747
Pre-test score of concept4	1	14	49.43	35.287	9.431
	2	12	48.58	32.754	9.455
Pre-test score of concept5	1	14	45.36	43.129	11.527
	2	12	56.33	33.153	9.571
Pre-test score of concept6	1	14	44.00	43.063	11.509
	2	12	44.50	40.536	11.702

Table 6.28 shows that there are 14 participants within *Envi1* and 12 participants within *Envi2*. The means of *concept-score* in pre-test for six learning concepts are in the range of 44.00 and 56.33 while the S.D.'s are in the range of 26.211 and 43.129. The means of *concept-score* in pre-test for all learning concepts except concept4 are higher in *Envi2* than in *Envi1*.

Table 6.29. 'T-test for Equality of means'
of six learning concepts in pre-test for participants in a *low-score group*

Pre-test *concept-scores*	T-test for Equality of means						
	t	df	p (Sig.) (2-tailed)	Mean difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Score for concept1	-.362	24	.721	-5.42	14.976	-36.326	25.492
Score for concept2	-.268	24	.791	-2.81	10.470	-24.419	18.800
Score for concept3	-.343	24	.735	-3.88	11.318	-27.240	19.478
Score for concept4	.063	24	.950	.85	13.434	-26.882	28.572
Score for concept5	-.733	24	.471	-10.98	14.982	-41.914	19.962
Score for concept6	-.030	24	.976	-.50	16.493	-34.540	33.540

Comparing the means of *concept-score* in pre-test for six learning concepts in *Envi1* and *Envi2*. Table 6.29 shows that there is no significant difference at the 5% for all six learning concepts in respect to participants in the *low-score group*.

The information in 6.3.2.2(a), 6.3.2.2(b), and 6.3.2.2(c) shows that whatever the types of participants are, there is no significant difference at the 5% level between the means of *concept-score* in pre-test for *Envi1* and *Envi2*. It can be concluded that in respect to the aspect of *concept-score*, participants in *Envi1* and *Envi2* are not different.

6.3.2.3 Compare learning performance using *concept-score* of six learning concept in group-test

This step is concerned about the comparison between *concept-score* in the group-test for six learning concepts in *Envi1* and *Envi2*. The means of *concept-score* for each learning concept will be compared respectively to type of participants which are considered firstly as all participant together, followed by *high-score group* and finishing with *low-score group* aspect to see what will happen when similar groups of participants are applied in different learning environments.

6.3.2.3(a) All participants

All participants are considered at this time using the Independent T-test technique to compare the *concept-score* in group-test for six learning concepts in *Envi1* and *Envi2*.

Table 6.30. The information of *concept-score* of six learning concepts in group-test for *all participants*

	Environment	N	Mean	Std. Deviation	Std. Error Mean
Group-test score for concept1	1	36	74.94	31.885	5.314
	2	24	68.75	21.598	4.409
Group-test score for concept2	1	36	76.22	26.290	4.382
	2	24	57.67	30.344	6.194
Group-test score for concept3	1	36	78.28	22.652	3.775
	2	24	63.92	22.073	4.506
Group-test score for concept4	1	36	81.78	29.165	4.861
	2	24	65.42	28.473	5.812
Group-test score for concept5	1	36	79.72	24.331	4.055
	2	24	69.50	20.908	4.268
Group-test score for concept6	1	36	76.22	26.290	4.382
	2	24	55.58	33.356	6.809

Table 6.30 shows that there are 36 participants within *Envi1* and 24 participants within *Envi2*. The means of *concept-score* in group-test for the six learning concepts are in the range of 74.94 and 81.78 for *Envi1*, and in the range of 55.58 and 69.50 for *Envi2*. The range of S.D.'s is between 22.652 and 31.885 for *Envi1* and between 20.908 and 33.356 for *Envi2*. The means difference in Table 6.31 shows that *concept-score* in group-test of all six learning concepts are higher in *Envi1* than in *Envi2*. Ensuring the significant difference of means for *concept-score* in group-test, T-test for equality of means is considered.

Table 6.31. 'T-test for Equality of means' of six learning concepts in group-test for *all participants*

Group-test *concept-score* s	T-test for Equality of means						
	t	df	p (Sig.) (2-tailed)	Mean difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Score for concept1	.897	58	.373	6.19	6.905	-7.627	20.016
Score for concept2	2.518	58	.016	18.56	7.370	3.8.3	33.309
Score for concept3	2.430	58	.018	14.36	5.909	2.532	26.190
Score for concept4	2.149	58	.036	16.36	7.614	1.121	31.602
Score for concept5	1.684	58	.098	10.22	6.070	-1.928	22.373
Score for concept6	2.673	58	.010	20.64	7.720	5.185	36.093

Table 6.31 shows that the means of *concept-score* in group-test for learning concept2, concept3, concept4 and concept6 are significantly different at the 1.6% level, the 1.8% level, the 3.6% level, and the 1.0% level. While the other two concepts, which are concept1 and concept5, are not significantly different at the 5% level in respect to *all participants*.

6.3.2.3(b) Participants in the high-score group

The *high-score group* participants are considered at this time using the Independent T-test technique to compare the *concept-score* in group-test for the six learning concepts within *Envi1* and *Envi2*.

Table 6.32. The information of *concept-score* of six learning concepts in group-test for participants in a *high-score group*

	Environment	N	Mean	Std. Deviation	Std. Error Mean
Group-test score of concept1	1	22	87.82	23.132	4.932
	2	12	78.67	10.120	2.922
Group-test score of concept2	1	22	85.32	21.408	4.564
	2	12	67.25	30.449	8.790
Group-test score of concept3	1	22	88.50	14.418	3.074
	2	12	74.42	18.865	5.446
Group-test score of concept4	1	22	91.77	16.707	3.562
	2	12	77.92	16.161	4.665
Group-test score of concept5	1	22	90.00	17.739	3.782
	2	12	77.17	16.954	4.894
Group-test score of concept6	1	22	85.32	21.408	4.564
	2	12	67.25	30.449	8.790

Table 6.32 shows that there are 22 participants within *Envi1* and 12 participants within *Envi2*. The means of *concept-score* in group-test for six learning concepts are in the range of 85.32 and 91.77 for *Envi1*, and in the range of 67.25 and 78.67 for *Envi2*. The range of the S.D. is between 14.418 and 23.132 for *Envi1* and between 10.120 and 30.449 for *Envi2*. The means difference in Table 6.33 shows that *concept-score* in group-test of all six learning concepts are higher in *Envi1* than in *Envi2*. Ensuring the significant difference of means for *concept-score* in group-test, T-test for equality of means is considered.

Table 6.33. 'T-test for Equality of means'
of six learning concepts in group-test for participants in a *high-score group*

Group-test *concept-score* s	T-test for Equality of means						
	t	df	p (Sig.) (2-tailed)	Mean difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Score for concept1	1.297	32	.204	9.15	7.054	-5.217	23.520
Score for concept2	2.023	32	.052	18.07	8.932	-.126	36.262
Score for concept3	2.440	32	.020	14.08	5.773	2.324	25.842
Score for concept4	2.337	32	.026	13.86	5.929	1.779	25.933
Score for concept5	2.047	32	.049	12.83	6.271	.061	25.606
Score for concept6	2.023	32	.052	18.07	8.932	-.126	36.262

Table 6.33 shows that the means of *concept-score* in group-test for learning concept 3, concept4 and concept5 are significantly different at the 2.0% level, the 2.6% level, and the 4.9% levels. While the other three concepts, which are concept1, concept2 and concept6, are not significantly different at the 5% level in respect to participants in the *high-score group*. It can be concluded that in the *high-score group*, learners in Envi1 perform significantly better than Envi2 in using an arithmetic equation to calculate values of both within bits (Concept3) and between bits (Concept4), and transform the given number of the left-hand side of the decimal point into other forms (Concept5).

6.3.2.3(c) Participants in the low-score group

The *low-score group* participants are considered at this time using the Independent T-test technique to compare the *concept-score* in group-test for six learning concepts in *Envi1* and *Envi2*.

Table 6.34 shows that there are 14 participants within *Envi1* and 12 participants within *Envi2*. The means of *concept-score* in group-test for six learning concepts are in the range of 54.71 and 66.07 for *Envi1* and in the range of 43.92 and 61.83 for *Envi2*. The range of S.D. is between 21.309 and 37.475 for *Envi1*, and between 20.549 and 33.2 for *Envi2*. The means difference in Table 6.35 shows that *concept-score* in group-test of all six learning concepts are higher in *Envi1* than in *Envi2*. Ensuring the significant difference of means for *concept-score* in group-test, T-test for equality of means is considered.

Table 6.34. The information of *concept-score*
of six learning concepts in group-test for participants in a *low-score group*

	Environment	N	Mean	Std. Deviation	Std. Error Mean
Group-test score for concept1	1	14	54.71	33.933	9.069
	2	12	58.83	25.658	7.407
Group-test score for concept2	1	14	61.93	27.575	7.370
	2	12	48.08	28.244	8.153
Group-test score for concept3	1	14	62.21	24.309	6.497
	2	12	53.42	20.549	5.932
Group-test score for concept4	1	14	66.07	37.475	10.016
	2	12	52.92	33.060	9.544
Group-test score for concept5	1	14	63.57	25.016	6.686
	2	12	61.83	22.323	6.444
Group-test score for concept6	1	14	61.93	27.575	7.370
	2	12	43.92	33.200	9.584

Table 6.35 shows that the means of *concept-score* in group-test for all six learning concepts are not significantly different at the 5% level in respect to participants in *low-score group*.

Table 6.35. 'T-test for Equality of means'
of six learning concepts in group-test for participants in a *low-score group*

Group-test *concept-score* s	T-test for Equality of means						
	t	df	p (Sig.) (2-tailed)	Mean difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Score for concept1	-.344	24	.734	-4.12	11.968	-28.819	20.581
Score for concept2	1.262	24	.219	13.85	10.969	-8.794	36.485
Score for concept3	.987	24	.334	8.80	8.916	-9.604	27.199
Score for concept4	.941	24	.356	13.15	13.973	-15.685	41.995
Score for concept5	.185	24	.854	1.74	9.371	-17.602	21.078
Score for concept6	1.512	24	.144	18.01	11.913	-6.576	42.600

The information in 6.3.2.3(a) shows that comparing all participants of Envi1 to Envi2 that there are four learning concepts which the means are significantly different under the 5% level. Considering participants in high-score group in 6.3.2.3(b), there are three learning concepts which the means are significantly different less than the 5% level; two of these – concept3, and concept4, are the same concepts as the result from Table 6.31. Considering only participants in *low-score group* in 6.3.2.3(c), there no significant differences at the 5% level between the means of *concept-score* in group-test.

6.3.2.4 Compare learning performance using *concept-score* of six learning concepts in post-test

This step is concerned with the comparison between *concept-score* in the post-test for six learning concepts in *Envi1* and *Envi2*. The means of *concept-score* for each learning concept will be compared in respect to the type of participants which are considered for *all participants* together, followed by *high-score group*, and finished with *low-score group* aspect to see what will happen when similar groups of participants are within different learning environments.

6.3.2.4(a) All participants

All participants are considered at this time using the Independent T-test technique to compare the *concept-score* in group-test for six learning concepts in *Envi1* and *Envi2*.

Table 6.36. The information of *concept-score*
of six learning concepts in post-test for *all participants*

Post-test *concept-score*	Environment	N	Mean	Std. Deviation	Std. Error Mean
Post-test score for concept1	1	36	82.08	30.900	5.150
	2	24	71.04	33.621	6.863
Post-test score for concept2	1	36	85.00	21.941	3.657
	2	24	72.92	29.522	6.026
Post-test score for concept3	1	36	83.61	23.689	3.948
	2	24	72.88	27.701	5.654
Post-test score for concept4	1	36	83.33	24.172	4.029
	2	24	71.46	31.605	6.451
Post-test score for concept5	1	36	82.08	30.900	5.150
	2	24	71.04	33.621	6.863
Post-test score for concept6	1	36	85.00	21.941	3.657
	2	24	74.58	27.462	5.606

Table 6.36 shows that there are 36 participants within *Envi1* and 24 participants within *Envi2*. The means of *concept-score* in post-test for six learning concepts are in the range of 82.08 and 85.00 for *Envi1*, and in the range of 71.04 and 74.58 for *Envi2*. The range of S.D. is between 21.941 and 30.90 for *Envi1* and between 27.462 and 33.621 for *Envi2*. The means difference in table 6.37 shows that *concept-score* in post-test of all six learning concepts are higher in *Envi1* than in *Envi2*. Ensuring the significant difference of means for *concept-score* in post-test, T-test for equality of means is considered.

Table 6.37. 'T-test for Equality of means'
of six learning concepts in post-test for *all participants*

Post-test *concept-score*	T-test for Equality of means						
	t	df	p (Sig.) (2-tailed)	Mean difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Score for concept1	1.309	58	.196	11.04	8.435	-5.842	27.925
Score for concept2	1.818	58	.074	12.08	6.647	-1.221	25.388
Score for concept3	1.607	58	.114	10.74	6.682	-2.639	24.111
Score for concept4	1.647	58	.105	11.88	7.211	-2.559	26.309
Score for concept5	1.309	58	.196	11.04	8.435	-5.842	27.925
Score for concept6	1.628	58	.109	10.42	6.399	-2.392	23.225

Table 6.37 shows that the means of *concept-score* in post-test for all six learning concepts are not significantly different at the 5% level in respect to *all participants*.

6.3.2.4(b) Participants in the high-score group

The *high-score group* participants are considered at this time using the Independent T-test technique to compare the *concept-score* in group-test for six learning concepts in *Envi1* and *Envi2*.

Table 6.38. The information of *concept-score*
of six learning concepts in post-test for participants in a *high-score group*

Post-test *concept-score*	Environment	N	Mean	Std. Deviation	Std. Error Mean
Post-test score for concept1	1	22	97.73	7.356	1.568
	2	12	86.25	14.943	4.314
Post-test score for concept2	1	22	97.95	5.038	1.074
	2	12	88.33	14.822	4.279
Post-test score for concept3	1	22	97.91	4.058	.865
	2	12	87.33	10.129	2.924
Post-test score for concept4	1	22	96.36	7.588	1.618
	2	12	87.50	14.538	4.197
Post-test score for concept5	1	22	97.73	7.356	1.568
	2	12	86.25	14.943	4.314
Post-test score for concept6	1	22	97.95	5.038	1.074
	2	12	88.33	14.822	4.279

Table 6.38 shows that there are 22 participants within *Envi1* and 12 participants within *Envi2*. The means of *concept-score* in post-test for six learning concepts are in the range of 96.36 and 97.95 for *Envi1*, and in the range of 86.25 and 88.33 for *Envi2*. The range of S.D. is between 4.058 and 7.588 for *Envi1* and between 10.129 and 14.943 for *Envi2*. The means difference in Table 6.37 shows that *concept-score* in post-test of all six learning concepts are higher in *Envi1* than in *Envi2*. Ensuring the significant difference of means for *concept-score* in post-test, T-test for equality of means is considered.

Table 6.39. 'T-test for Equality of means'
six learning concepts in post-test for participants in a *high-score group*

Post-test *concept-score*	T-test for Equality of means						
	t	df	p (Sig.) (2-tailed)	Mean difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Score for concept1	2.501	32	.025	11.48	4.590	1.631	21.324
Score for concept2	2.181	32	.049	9.62	4.412	.044	19.199
Score for concept3	3.468	32	.004	10.58	3.049	3.986	17.166
Score for concept4	2.350	32	.025	8.86	3.771	1.182	16.546
Score for concept5	2.501	32	.025	11.48	4.590	1.631	21.324
Score for concept6	2.181	32	.049	9.62	4.412	.044	19.199

Table 6.39 shows that the means of *concept-score* in post-test for all six learning concepts are significantly different less than the 5% level. The significant difference of the means is at the 2.5% level for learning concept1, at the 4.9% level for learning concept2, at the 0.4% level for learning concept3, at the 2.5% level for learning concept4, at the 2.5% level for learning concept5 and at the 4.9% level for learning concept6.

6.3.2.4(c) Participants in the low-score group

The *low-score group* participants are considered at this time using the Independent T-test technique to compare the *concept-score* in group-test for six learning concepts in *Envi1* and *Envi2*.

Table 6.40 shows that there are 14 participants within *Envi1* and 12 participants within *Envi2*. The means of *concept-score* in post-test for six learning concepts are in the range of 57.50 and 64.64 for *Envi1*, and in the range of 55.42 and 60.83 for *Envi2*. The range of S.D. is between 22.910 and 37.660 for *Envi1* and between 30.736 and 40.443 for *Envi2*. The means difference in Table 6.41 shows that *concept-score* in post-test of all six learning concepts are higher in *Envi1* than in *Envi2*. Ensuring the significant difference of means for *concept-score* in post-test, T-test for equality of means is considered.

Table 6.40. The information of *concept-score* of six learning concepts in post-test for participants in a *low-score group*

Post-test *concept-score*	Environment	N	Mean	Std. Deviation	Std. Error Mean
Post-test score for concept1	1	14	57.50	37.660	10.065
	2	12	55.83	40.443	11.675
Post-test score for concept2	1	14	64.64	22.910	6.123
	2	12	57.50	32.926	9.505
Post-test score for concept3	1	14	61.14	24.384	6.517
	2	12	58.42	32.338	9.335
Post-test score for concept4	1	14	62.86	27.225	7.276
	2	12	55.42	36.273	10.471
Post-test score for concept5	1	14	57.50	37.660	10.065
	2	12	55.83	40.443	11.675
Post-test score for concept6	1	14	64.64	22.910	6.123
	2	12	60.83	30.736	8.873

Table 6.41 shows that the means of *concept-score* in post-test are not significantly different at the 5% level for all six learning concepts in respect to participants in the *low-score group*.

Table 6.41. 'T-test for Equality of means' of six learning concepts in post-test for participants in a *low-score group*

Post-test *concept-scores*	T-test for Equality of means						
	t	df	p (Sig.) (2-tailed)	Mean difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Score for concept1	.109	24	.914	1.67	15.327	-29.966	33.300
Score for concept2	.650	24	.522	7.14	10.995	-15.550	29.836
Score for concept3	.245	24	.809	2.73	11.136	-20.258	25.711
Score for concept4	.597	24	.556	7.44	12.468	-18.293	33.174
Score for concept5	.109	24	.914	1.67	15.327	-29.966	33.300
Score for concept6	.362	24	.721	3.81	10.536	-17.936	25.555

The information in *6.3.2.4(a)* shows that comparing the means of *concept-score* for *all participants* in pre-test, there is not significant difference under the 5% level. However considering participants in *high-score group* in 6.3.2.4(b), the result shows that the means of all six learning concepts are significantly different less than the 5% level. Even though after considering the participants in the *low-score group* (See 6.3.2.4(c)); the results turn out the same way for *all participants*.

6.3.2.5 The improved of learning performance based on *result-of-the-answer*

6.3.2.5(a) The improved of 'result-of-the-answer' of pre-test vs. group-test

The difference of *result-of-the-answer* between pre-test and group-test or *pre-group-result-of-the-answer* is classified into *'Improved',* and *'Not improved'.* The *'Improved'* is assigned if the *result-of-the-answer* of the group-test is higher than the pre-test and vice-versa for *'Not improved'*. However *'Not improved'* does not mean that these participants cannot do any better but maybe because the *results-of-the-answer* are correct already for the pre-test. Therefore *'Not improved'* here are considered within two situations which are *correct* for the results that already correct for both pre-test and group-test, and *incorrect* for any situation that the result of the group-test is incorrect.

Table 6.42. The improved of *result-of-the-answer*
when comparing pre-test to group-test.

Learning Environment	Improved		Not improved	
	For all cases	Only cases that can be improved	Correct	Incorrect
Envi1	50.46%	67.28%	25.00%	24.54%
Envi2	46.53%	53.60%	13.19%	40.28%

Table 6.42 shows that 50.46% of participants in *Envi1* are defined as *'Improved'* and 49.54% are defined *'Not improved'*. A further look into the detail of *'Not improved'* itself, reveals 25% of which answer both pre-test and group-test correctly while the other 24.54% answer the group-test incorrectly. In *Envi2*, the 46.53% of participants are defined *'Improved'* and 55.47% is defined *'Not improved'*. When looking into the detail of *'Not improved'* itself, 13.19% of which answer both pre-test and group-test correctly while the other 40.48% answer the group-test incorrectly.

In order to see the improved of *result-of-the-answer*, only the cases of *'Improved'* and *incorrect* are considered as cases of *potential-to-be-improved*. Comparing the number of participants who are assigned as *'Improved'* to participants who have potential to be improved, the result shows that 67.28% of *Envi1* and 53.60% *Envi2* are assigned as *'Improved'*.

6.3.2.5(b) The improved of 'result-of-the-answer' of pre-test vs. post-test

The difference of *result-of-the-answer* between pre-test and post-test or *Pre-Post-result-of-the-answer* is classified into *'Improved'*, *'Not improved'*. The *'Improved'* is assigned if the *result-of-the-answer* of the post-test is higher than the pre-test and vice-versa for *'Not improved'*.

However *'Not improved'* does not mean that these participants cannot do any better but maybe because the *results-of-the-answer* are correct already for the pre-test. Therefore *'Not improved'* here is considered as two situations which are *Correct* for the results that already correct for both pre-test and post-test, and *incorrect* for any situation that the result of the post-test is incorrect.

Table 6.43. The improved of *result-of-the-answer* when compare pre-test to post-test.

Learning Environment	Improved		Not improved	
	For all cases	For cases that can be improved	Correct	Incorrect
Envi1	60.65%	82.91%	26.85%	12.50%
Envi2	60.42%	69.60%	13.19%	26.39%

Table 6.43 shows that 60.65% of participants in *Envi1* are defined as *'Improved'* and 39.35% are defined as *'Not improved'*. A further look into the detail of *'Not improved'* itself, shows 26.85% of which answer both pre-test and post-test correctly while the other 12.50% answer the post-test incorrectly. In *Envi2*, 60.42% of participants are defined as *'Improved'* and 39.58% are defined as *'Not improved'*. When looking into the detail of *'Not improved'* itself, 13.19% answer both pre-test and post-test correctly while the other 26.39% answer the post-test incorrectly.

In order to see the improved of *result-of-the-answer*, the only cases of *'Improved'* and *incorrect* are considered as cases of *potential-to-be-improved*. Comparing the number of participants who are assigned as *'Improved'* to participants who have potential to be improved, the result shows that 82.91% of *Envi1* and 69.60% *Envi2* are assigned as *'Improved'*.

6.3.2.6 The improved of learning performance based on *concept-score*

6.3.2.6(a) The improved of concept-score from pre-test vs. group-test for particular six concepts

The difference of *concept-score* between pre-test and group-test or *pre-group-concept-score* is classified into *'Improved',* and *'Not improved'.* The *'Improved'* is assigned if the *concept-score* of the group-test is higher than the pre-test and vice-versa for *'Not improved'*. However *'Not improved'* does not mean these participants cannot do any better but maybe because the *concept-score* have met the ceiling for the pre-test. Therefore the factor of meeting the ceiling point will be taken into account as *'Meet-ceiling'* and *'Under-ceiling'* for *'Not improved'* situations.

Table 6.44. The improved of *concept-score* when compare pre-test to group-test.

Learning Environment	Improved		Not improved	
	Of all cases	Of cases that can be improved	Meet-ceiling	Under-ceiling
Envi1	15.3%	43.3%	64.8%	19.9%
Envi2	22.2%	50.8%	56.3%	21.5%

Table 6.44 shows that 15.3% of participants in *Envi1* are defined as *'Improved'* and 84.7% are defined as *'Not improved'*. A further look into the detail of *'Not improved'* itself, shows 64.8% of which answer both pre-test and group-test correctly while the other 19.9% answer the group-test incorrectly. In *Envi2*, 22.2% of participants are defined as *'Improved'* and 77.8% are defined as *'Not improved'*. When looking into the detail of *'Not improved'* itself, 56.3% of which answer both pre-test and group-test correctly while the other 21.5% answer the group-test incorrectly.

In order to see the improved of *concept-score*, the only cases of *'Improved'* and *'Under-ceiling'* are considered as cases of *potential-to-be-improved*. Comparing the number of participants who are assigned as *'Improved'* to participants who have potential to be improved, the result shows that 43.3% of *Envi1* and 50.8% of *Envi2* are assigned as *'Improved'*.

6.3.2.6(b) The improved of concept-score of pre-test vs. post-test

The difference of *concept-score* between pre-test and post-test or *Pre-Post-concept-score* is classified into *'Improved',* and *'Not improved'*. The *'Improved'* is assigned if the *concept-score* of the post-test is higher than the pre-test and vice versa for *'Not improved'*. However *'Not improved'* does not mean these participants cannot do any better but maybe because the *concept-score* have met the ceiling for the pre-test. Therefore the factor of meeting the ceiling point will be taken into account as *'Meet-ceiling'* and *'Under-ceiling'* for *'Not improved'* situations.

Table 6.45. The improved of *concept-score* when compare pre-test to post-test.

Learning Environment	Improved		Not improved	
	Of all cases	Of cases that can be improved	Meet-ceiling	Under-ceiling
Envi1	9.0%	33.3%	73.0%	18.0%
Envi2	6.0%	25.0%	76.0%	18.0%

Table 6.45 shows that 9.0% of participants in *Envi1* are defined as *'Improved'* and 91.0% are defined as *'Not improved'*. A further look into the detail of *'Not improved'* itself, shows 73.0% of participants are assigned as *'Meet-ceiling'* while the other 18.0% are assigned as *'Under-ceiling'*. In *Envi2*, 6.0% of participants are defined *'Improved'* and 94.0% are assigned as *'Not improved'*. When looking into the detail of *'Not improved'* itself, 76.0% of participants are assigned as *'Meet-ceiling'* while the other 18.0% are assigned as *'Under-ceiling'*.

In order to see the improved of *concept-score*, the only cases of *'Improved'* and *'Under-ceiling'* are considered as cases of *potential-to-be-improved*. Comparing number of participants who are assigned as *'Improved'* to participants who have potential to improved, the result shows that 33.3% of *Envi1* and 25.0% of *Envi2* are assigned as *'Improved'*.

6.3.2.7 Summary of Issue2:Learning Performance respectively to *seeing* and *not seeing IdealGLM* and *GLM*

After comparing the learning performance as a pre-test in respect to the specific aspects, it can be concluded that participants in *Envi1* and *Envi2* are not significantly different at the 5% level whether considering the type of participants as *all participants*, *high-score group* or *low-score group* in both aspects of *number-of-correct-answer* (see Table 6.19, Table 6.21 and Table 6.23) and *concept-score* (see Table 6.25, Table 6.27 and Table 6.29)

Later considering the group-test, the mean score of *Envi1* is higher than *Envi2* whether or not considering the type of participants. After comparing *concept-score* of *Envi1* and *Envi2* using 'Independent T-test', the results show that there are four *concept-score* for *all participants*, three *concept-score* for *high-score group* which are significantly different under the 5% level. In post-test, the mean score of *Envi1* is still higher than *Envi2* whether or not considering the type of participants. After comparing *concept-score* of *Envi1* and *Envi2* using 'Independent T-test', the results show that there is one *concept-score* for *all participants*, all six *concept-score* for *high-score group* are significantly different under the 5% level.

For the cases for which the participants had a chance to improve, we examine the improvement in learning performance based on *result-of-the-answer* for the two comparisons pre-test/group-test and pre-test/post-test. Table 6.42 and Table 6.43 show the percentage of participants who are assigned as *'Improved'* is higher in Envi1 than Envi2. For the improvement in learning performance based on *concept-score* when comparing pre-test to post-test, Table 6.44 shows that the percentage of participants who are assigned as *'Improved'* is higher in Envi1 than Envi2. However the result does not work the same way when comparing pre-test to group-test for the same aspect.

Respectively to the evidence here, it cannot be concluded that the participants who are assigned in *Envi1* perform better than participants in *Envi2* for all aspects. However some evidence leads us to look further for other supportive information that may reveal what really happened during the group-test. The next issue is focusing on how well participants assess themselves and their pairs together with whether or not the accuracy of the assessment has an affect on the improved of learning performance.

6.3.3 Issue3: Effect of *seeing* and *not seeing* the learning performance on *self-peer-assessment* comparing to *self-peer-actual-performance*

This issue is concern with *seeing* and *not seeing* the learning performance as *IdealGLM* (before doing the group-test) and as *GLM* (during and after doing the group-test). In order to see whether or not there is any effect of *seeing* (*Envi1*) and *not seeing* (*Envi2*) on the accuracy of *self-assessment* and *peer-assessment*. Furthermore is there any correlation between the accuracy *self-assessment* and *peer-assessment* between themselves and to the improvement of learning performance. One way of knowing ones' thoughts is to ask them to express information in explicit ways.

In this work, we provide questionnaires in both computer-based and paper-based format to participants so they can assess themselves and their peers during working as a group. After having the explicit information of how participants thought about themselves and their peers, the *self-assessment* and *self-actual-performance* will be compared using the 'Pair-T-Test technique'. Followed by the comparison between *peer-assessment* and *peer-actual-performance*.

6.3.3.1 Correlation between *self-assessment* and *self-actual-performance*

The result of *self-assessment* and *self-actual-performance* is compared in order to see how accurate participants assess themselves after they perform the individual task and see the *IdealGLM*. As seen in Table 6.46, there are basic statistical values of mean and S.D. for *self-assessment* and *self-actual-performance*.

After using 'Pair Sample T-test' technique, the results in Table 6.48 show that there is no significant difference at the 5% level between variables of *self-assessment* and *self-actual-performance* for both *Envi1* and *Envi2*. However considering the correlation between these two variables (See Table 6.47) in *Envi1*, shows that there is a highly significant correlation of 0.842 which confirms that the two variables are related. While in *Envi2* the correlation is not significant.

Table6.46. Paired Samples Statistics:
self-assessment and *self-actual-performance* of *Envi1*and *Envi2*

Learning Environment	Pair	Mean	N	Std. Deviation	Std. Error Mean
Envi1	self-assessment	7.556	36	2.5122	0.4187
	self-actual-performance	7.528	36	2.8620	0.4770
Envi2	self-assessment	6.792	24	1.5317	0.3127
	self-actual-performance	6.037	24	2.6834	0.5477

Table 6.47. Paired Samples Correlations:
self-assessment and *self-actual-performance* of *Envi1* and *Envi2*

Learning Environment	Pair	N	Correlation	p (Sig.)
Envi1	self-assessment & self-actual-performance	36	0.842	0.000
Envi2	self-assessment & self-actual-performance	24	0.312	0.138

Table 6.48. Paired Samples Test:
self-assessment and *self-actual-performance* of *Envi1*and *Envi2*

Pair1	Paired Differences		t	df	p (Sig.) (2-tailed)
	Mean	Std. Deviation			
Envi1: self-assessment - self-actual-performance	0.028	1.5464	0.108	35	0.915
Envi2: self-assessment - self-actual-performance	0.754	2.6425	1.398	23	0.175

The information in Table 6.46, Table 6.47 and Table 6.48 infers that participants in *Envi1* assess themselves more precisely than participants in *Envi2*. It is plausible to say that learners who know more - by seeing the group learner model - assess what they don't know better - by giving information of what they know (*self-assessment*) and what they don't know but their peers might know (*peer-assessment*). The next step will be looking further into whether or not there is a consistency between the accuracy of *self-assessment* and *peer-assessment*.

6.3.3.2 Correlation between *peer-assessment* and *peer-actual-performance*

The result of *peer-assessment* and *peer-actual-performance* is compared in order to see how accurate participants assess their peers after performing the individual task and *seeing* the *IdealGLM*. As seen in Table 6.49, there are basic statistical values of mean and S.D. for *peer-assessment* and *peer-actual-performance*.

After using 'Pair Sample T-test' technique, the results in Table 6.51 show that there is no significant difference at the 5% level between the variables of *peer-assessment* and *peer-actual-performance* for both *Envi1* and *Envi2*. However considering to the correlation between these two variables (See Table 6.50) in *Envi1*, shows a highly significant correlation of 0.854 which confirms that the two variables are related. While in *Envi2* the correlation is not significant.

Table 6.49. Paired Samples Statistics:
peer-assessment and *peer-actual-performance* of *Envi1* and *Envi2*

Learning Environment	Pair	Mean	N	Std. Deviation	Std. Error Mean
Envi1	peer-assessment	7.639	36	2.3923	0.3987
	peer-actual-performance	7.528	36	2.8620	0.4770
Envi2	peer-assessment	7.000	24	0.9780	0.1996
	peer-actual-performance	6.037	24	2.6834	0.5477

Table 6.50. Paired Samples Correlations:
peer-assessment and *peer-actual-performance* of *Envi1* and *Envi2*

Learning Environment	Pair	N	Correlation	p (Sig.)
Envi1	peer-assessment & peer-actual-performance	36	0.854	0.000
Envi2	peer-assessment & peer-actual-performance	24	0.350	0.094

Table 6.51. Paired Samples Test:
peer-assessment and *peer-actual-performance* of *Envi1* and *Envi2*

Pair1	Paired Differences		t	df	p (Sig.) (2-tailed)
	Mean	Std. Deviation			
Envi1: peer-assessment - peer-actual-performance	0.111	1.4897	0.448	35	0.657
Envi2: peer-assessment - peer-actual-performance	0.963	2.5144	1.875	23	0.074

The information in Table 6.49, Table 6.50 and Table 6.51 infers that participants in *Envi1* assess the performance of their peers more precisely than participants in *Envi2*. Referring to the consistency between the accuracy of *self-assessment* and *peer-assessment* of participants in *Envi1* and *Envi2*, the results show that the participants in *Envi1* can assess themselves and their peers better than the participants in *Envi2*. It can be inferred that *seeing* the learning performance as *IdealGLM* and *GLM* helps participants gain more accuracy in assessing themselves and their peers. Later the information of *seeing* both

IdealGLM and *GLM* for participants in *Envi1* will be illustrated as evidence to support the helpfulness of providing participants the group learning performance.

6.3.3.3 The helpfulness of *IdealGLM* and *GLM* in *Envi1*

This step is focusing on the matter *seeing* the *GLM* and *IdealGLM* and whether there is any helpfulness in *self-assessment*, *peer-assessment*. Beginning with *seeing IdealGLM* in 6.3.3.3(a), the number of participants who required to see the *IdealGLM* is illustrated first, followed by information of how well they think they and their peers are, in 6.3.3.3(b), and finishing with the helpfulness of *IdealGLM* on *self-assessment* and *peer-assessment* in 6.3.3.3(c). Later in 6.3.3.3(d), the information of *seeing GLM* after performing each question of the group-test is introduced in quite a similar aspect to *IdealGLM*.

6.3.3.3(a) Result of participants who asked to see IdealGLM and GLM

Table 6.52 shows that there are 36 participants within this this learning environment, 2 of which required not to see while the rest of 34 required to see the *IdealGLM*.

Table 6.52. Number and percentage of participants who require to see the *IdealGLM*

To see or Not to see the *GLM*	count	Percent
Not See *IdealGLM*	2	5.6%
See *IdealGLM*	34	94.4%
Total	36	100.0%

After *seeing* the *IdealGLM*, participants illustrate their opinions on self and peer performance on *number-conversion*. The ranges of performance levels and definitions is given first, followed by the number of cases that participants state on themselves and their peers' performance and finishing with the mean level of both *self-assessment* and *peer-assessment.*

Table 6.53. The ranges of performance level for *seeing IdealGLM*

Range	Definition
Between level 1.0 - 2.79	**Not good at all** at *number-conversion*
Between level 2.80 - 4.59	**Rarely good** at *number-conversion*
Between level 4.60 - 6.39	**Fairly good** at *number-conversion*
Between level 6.40 - 8.19	**Good** at *number-conversion*
Between level 8.20 - 10.00	**Very good** at *number-conversion*

According to Table 6.53, there are five ranges of performance level which are defined as '*Not good at all', 'Rarely good', 'Fairly good', 'Good',* and '*Very good'.*

Table 6.54. Information of performance level on *self-assessment* and *peer-assessment*.

	Not good at all	Rarely good	Fairly good	Good	Very good
self-assessment	5.56%	11.11%	5.56%	38.89 %	38.89%
peer-assessment	5.56%	8.33%	11.11%	36.11 %	38.89%

For the information of how well participants think they are on the *number-conversion* content, Table 6.54 shows that the majority of participants assess themselves as *'Very good',* and *'Good'* with the same amount (38.89%). This information is consistent with *peer-assessment* which has the majority of participants assess their peers as *'Very good'* (38.89%) and *'Good'* (36.11%).

6.3.3.3(b) Result of 'how well participants think they and their friends are in number-conversion'

Table 6.55. The ranges of Helpfulness level for *seeing IdealGLM*

Range	Definition
Between level 1.0 - 1.79	Not helpful at all
Between level 1.80 - 2.59	Slightly helpful
Between level 2.60 - 3.39	Fairly helpful
Between level 3.40 - 4.19	Much helpful
Between level 4.20 - 5.00	Very much helpful

From Table 6.55, there are five ranges which are used to classify helpfulness levels after *seeing* the *IdealGLM* for *self-assessment* and *peer-assessment*. These ranges are defined as '*Not helpful at all', 'Slightly helpful', 'Fairly helpful', 'Much helpful',* and '*Very much helpful'.*

Table 6.56. Information of helpfulness levels on *self-assessment* and *peer-assessment*

	Not helpful at all	Slightly helpful	Fairly helpful	Much helpful	Very much helpful
self-assessment	11.11%	0.0%	5.56%	58.33%	25.00%
peer-assessment	5.56%	0.0%	8.33%	55.56%	30.56%

As seen in Table 6.56, for the majority of participants the helpfulness of '*seeing IdealGLM*' is the same level as *'Much helpful'* for both *self-assessment* and *peer-assessment*. This confirms the satisfaction of *seeing IdealGLM* for the helpfulness of assessing themselves and others.

6.3.3.3(c) Result of seeing the group learner model (GLM)

Table 6.57. Number and percentage of participants who require *seeing* the *GLM*

seeing and *not seeing GLM*	Usefulness of *seeing* and *not seeing GLM*	Question1	Question2	Question3	Question4
Not See *GLM*	Not useful	4	4	4	4
See *GLM*	Useful	32	32	32	32
Total	Total	36	36	36	36

As displayed in Table 6.57, there are 36 participants within this learning environment, of which require not to see the *GLM* while the rest of the 32 participants request to see all four questions. The 32 participants who require *seeing* the *GLM* state that *GLM* is useful for them for doing a group-test.

Table 6.58. The ranges of helpfulness level for *seeing GLM*

Range	Definition
Between level 1.0 - 2.79	Not helpful at all
Between level 2.80 - 4.59	Rarely helpful
Between level 4.60 - 6.39	Fairly helpful
Between level 6.40 - 8.19	Much helpful
Between level 8.20 - 10.00	Very much helpful

In Table 6.58, there are five ranges to classify levels of helpfulness from *seeing the GLM* after finishing doing question 1 to 4 as a group. These ranges are defined as '*Not helpful at all', 'Slightly helpful', 'Fairly helpful', 'Much helpful',* and *'Very much helpful'*.

Table 6.59. The ranges of helpfulness level for *seeing GLM*

Helpfulness of *GLM* on 4 questions	Rarely helpful	Fairly helpful	Much helpful	Very much helpful
Question1	18.75%	6.25%	12.50%	62.50%
Question2	6.25%	12.50%	15.62%	65.63%
Question3	3.13%	15.62%	15.62%	65.63%
Question4	6.25%	9.38%	15.62%	68.75%

For the information of helpfulness of *seeing GLM* for 4 question in Table 6.59, the majority of participants go for '*Very much helpful'* for all four questions. Moreover the percentage of participants who agree on this level of helpfulness is increased during working on question1 through question4.

After providing the evidence of *seeing IdealGLM* and *seeing GLM*, It can be inferred that both help participants to assess themselves and others more accurately. What will be considered next is the relationship between *self-assessment* and the improvement of learning performance. Whether there is any significant correlation between these variables.

6.3.3.3(d) The relationship between self-assessment and the improvement of learning performance

Referring to ZPD, this concept is about the potential performance of individual learners who cannot do something on their own but can do it with others. This potential performance can be changed to the actual performance if learners can prove that again they can do it on their own. Nothing can guarantee the duration and process of changing potential performance into actual performance. Therefore the improvement of performance after the group-test can only be used to anticipate the post-test but cannot confirm the result until the actual performance has taken place.

Table 6.60. The relationship between the improvement of *concept-score* comparing the group-test to pre-test and post-test to pre-test. The number in the brackets () is the count.

Environment	the improvement of *concept-score* comparing *pre-test* to *group-test*	the *improvement of concept-score* comparing *pre-test* to *post-test*			
		Improved	Meet-ceiling	Not Improved	Total
Envi1 (36)	Improved	36.1% (13)	0.0% (0)	8.3% (3)	44.4% (16)
	Meet-ceiling	0.0% (0)	16.7% (6)	0.0% (0)	16.7% (6)
	Not Improved	25.0% (9)	5.6% (2)	8.3% (3)	38.9% (14)
Envi2 (24)	Improved	50.0% (12)	0.0% (0)	4.2% (1)	54.2% (13)
	Meet-ceiling	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)
	Not Improved	41.6% (10)	0.0% (0)	4.2% (1)	45.8% (11)

The result in Table 6.60 shows that the majority of participants in both *Envi1* and *Envi2* for the post-test are assigned as *'Improved'*. Leading to the *'Improved'* of learning performance in post-test, there are two types of learning performance in group-test which are *'Improved'* and *'Not improved'*. Even though the percentage of *'Improved'* for learning performance is higher in *Envi2* than *Envi1*, it cannot judge the quality of *'Improved'* from this provided information. This result here can only confirm that the percentage of participants who are assigned as *'Improved'* in post-test is higher in *Envi2* than in *Envi1*.

Regarding the ZPD concept (Vygotsky, 1978) in terms of what learners cannot do at first on their own but can do later with others. This ZPD concept can be examined by comparing pre-test and group-test results and focusing only on what is defined as *'Improved'*. The results in Table 6.60 show that, for *Envi1*, 44.4% of participants are defined as *'Improved'*, 16.7% are defined as *'Meet-ceiling'*, and 38.9% are defined as *'Not improved'*. For *Envi2*, 54.2% of participants are defined as *'Improved'*, and 45.8% are defined as *'Not improved'*.

Table 6.61. The relationship between the *accuracy of self-assessment* and the *improvement of concept-score* for the group-test.

Environment	Self-assessment	The comparison of average *concept-score* between *pre-test* and *group-test*			
		Improved	Meet-ceiling	Not Improved	Total
Envi1 (36)	Over-Estimated	27.8% (10)	0.0% (0)	13.8% (5)	100% (36)
	Precise-Estimated	2.8% (1)	16.7% (6)	5.6% (2)	
	Under-Estimated	11.1% (4)	0.0% (0)	22.2% (8)	
Envi2 (24)	Over-Estimated	33.3% (8)	0.0% (0)	20.8% (5)	100% (24)
	Precise-Estimated	0.0% (0)	0.0% (0)	4.3% (1)	
	Under-Estimated	20.8% (5)	0.0% (0)	20.8% (5)	

The result in Table 6.61 shows the majority of participants who are assigned the learning performance as *'Improved'* in group-test in *Envi1* are from *'Over-Estimated'* group of participants which is similar to the result of *Envi2*. The participants in *Envi1* who are assigned the learning performance as *'Meet-ceiling'*, all of them are from the *'Precise-Estimated'* group of participants. For the *'Not improved'* of learning performance, the majority of participants who are assigned in this group are from the *'Over-Estimated'* group of participants both in *Envi1* and in *Envi2*.

Table 6.62. The relationship between the '*accuracy of self-assessment'* and the '*improvement of concept-score'* for the individual post-test. The number in the brackets () is the count.

Environment	self-assessment	The comparison of average *concept-score* between pre-test and post-test			
		Improved	Meet-ceiling	Not Improved	Total
Envi1 (36)	Over-Estimated	36.1% (13)	0.0% (0)	5.6% (2)	100% (36)
	Precise-Estimated	0.0% (0)	19.4% (7)	5.6% (2)	
	Under-Estimated	27.8% (10)	2.8% (1)	2.8% (1)	
Envi2 (24)	Over-Estimated	54.1% (13)	0.0% (0)	0.0% (0)	100% (24)
	Precise-Estimated	4.2% (1)	0.0% (0)	4.2% (1)	
	Under-Estimated	33.3% (8)	0.0% (0)	4.2% (1)	

The result in Table 6.62 shows the majority of participants who are assigned the learning performance as *'Improved'* in post-test in *Envi1* are from *'Over-Estimated'* group of participants which is similar to the result of *Envi2*. The participants in *Envi1* who are assigned the learning performance as *'Meet-ceiling'* are all from the '*Precise-Estimated'* group of participants. For the *'Not improved'* of learning performance, the majority of participants who are assigned in this group are equally from both *'Over-Estimated'* and '*Precise-Estimated'* groups of participants in *Envi1*. While in *Envi2*, the majority of participants who are assigned in this group are equally from both '*Precise-Estimated'* and '*Under-Estimated'* groups of participants

The similarity of the result for the improvement of learning performance in Table 6.61 and Table 6.62 is that the majority of participants in both *Envi1* and *Envi2* for group-test and post-test are assigned as *'Improved'*. Moreover the majority of participants who are assigned the learning performance as *'Improved'* are from the *'Over-Estimated'* group of participants. It can be inferred that participants who are *'Over-Estimated'*, intend to improve when doing a group-test and post-test.

6.3.3.4 Summary of Issue3: Effect of *seeing* and *not seeing* the learning performance on *self-peer-assessment* comparing to *self-peer-actual-performance.*

The result of *self-assessment* and *self-actual-performance* is compared in order to see how accurate participants assess themselves after they perform the individual task and see the *IdealGLM*. The information in Table 6.46, 6.47, and 6.48 infer that participants in *Envi1* assess themselves more precisely than participants in *Envi2*. A further look into whether or not there is a consistency between the accuracy of *self-assessment* and *peer-assessment*. The information in Table 6.49, 6.50, and 6.51 infers that participants in *Envi1* assess performance of their peers more precisely than participants in *Envi2*. It can be confirmed that *seeing* the learning performance as *IdealGLM* and *GLM* helps participants get more accuracy to assess themselves and their peers.

In order to assure that the provided *IdealGLM* and *GLM* are helpful, the questionnaires is provided to participants in *Envi1*. Table 6.59 shows that the majority of participants go for '*Very much helpful'* for all four questions. Moreover the percentage of participants who agree on this level of helpfulness is increased during working on question1 through question4.

Even though there is evidence showing that *seeing IdealGLM* and *seeing GLM* help participants to assess themselves and their peers more accurately. However being accurate in *self-assessment* or *peer-assessments* cannot guarantee the improvement of the group-test and post-test. As stated in 6.3.3.4, the participants who have self *'Over-Estimated'*, tend to improve when doing a group-test and post-test. Therefore what we better look further into is the story during the group-test which allow participants to exchange information via the provided *chat-tool*. To reveal this information, each conversation that the participants composed is investigated.

6.3.4 Issue4: Communication during the group-test

Rather than using the group answer as the final result to judge learning performance, the information of what participants communicate with peers will be considered respectively to *the group agreement, the similarity of the individual answers,* the *correctness of the individual answer,* and the *knowledge contribution*.

6.3.4.1 The relationship between '*correctness of individual answers*' vs. '*correctness of the group answer*'.

Table 6.63. The relationship between '*correctness of individual answers*' vs. '*correctness of the group result'*. The number in the brackets () is the count.

Environment	Correctness (C: Correct; Ic: Incorrect) of at least one *individual answer*	Correctness (C: Correct; Ic: Incorrect) of the group answer for Question 1-4							
		Question1		Question2		Question3		Question4	
		C	Ic	C	Ic	C	Ic	C	Ic
Envi1 (18 pairs)	C	**77.8% (14)**	11.1% (2)	**94.4% (17)**	0.0% (0)	**72.2% (13)**	0.0% (0)	**88.9% (16)**	0.0% (0)
	Ic	0.0% (0)	11.1% (2)	0.0% (0)	5.6% (1)	22.2% (4)	5.6% (1)	5.6% (1)	5.6% (1)
Envi2 (12 pairs)	C	**100% (12)**	0.0% (0)	**75% (9)**	0.0% (0)	**66.7% (8)**	25% (3)	**83.8% (10)**	16.7% (2)
	Ic	0.0% (0)	0.0% (0)	8.3% (1)	16.7% (2)	0.0% (0)	8.3% (1)	0.0% (0)	0.0% (0)

Table 6.63 shows that the majority pairs of the participants who perform in the group-test, have at least one *individual answer* which is correct before doing the test with their peers. Moreover almost all of these pairs in *Envi1* (77.8% from question1, 94.4% from question2, 72.2% from question3, and 88.9% from question4) and *Envi2* (100.0% from question1, 75.0% from question2, 66.7% from question3, and 83.3% from question4) perform the group-test correctly for all four questions. From the relationship between correctness of *individual answers* and correctness of group answers, it can be concluded that for both *Envi1* and *Envi2* if at least one member of the group has the correct *individual answers* in the first place, they later tend to have the correct answer for the group-test.

6.3.4.2 The relationship between '*knowledge contribution'* vs. '*correctness of the group answer'*

Table 6.64 shows that the majority of the pairs of participants, who perform in the group-test, do not contribute anything, but only state the group answer with a *degree of confidence* during the group-test. Most of these pairs in *Envi1* (61.1% from question1, 72.2% from question2 and question3, and 94.4% from question4) and *Envi2* (83.3% from question1 and question2, and 75.0% from question4) still get the correct group answer even though they do not exchange any knowledge concept at all.

However referring to the result in Table 6.63, it can be concluded that participants who do not contribute to others during the group-test but have the correct group answer might have at least one correct *individual answer* before performing a group-test.

Table 6.64. The relationship between '*knowledge contribution'* vs. *'correctness-of-the-group-answer'*. The number in the brackets () is the count.

Environment	knowledge contribution of the group members on the group answer	Correctness (C: Correct; Ic: Incorrect) of the group answer for Question 1-4							
		Question1		Question2		Question3		Question4	
		C	Ic	C	Ic	C	Ic	C	Ic
Envi1 (18 pairs)	Contribute	16.7% (3)	16.7% (3)	22.2% (4)	0.0% (0)	5.6% (1)	5.6% (1)	0.0% (0)	5.6% (1)
	Not Contribute	**61.1% (11)**	5.6% (1)	**72.2% (13)**	5.6% (1)	**72.2% (13)**	16.7% (3)	**94.4% (17)**	0.0% (0)
Envi2 (12 pairs)	Contribute	16.7% (2)	0.0% (0)	0.0% (0)	8.3% (1)	**41.7% (5)**	16.7% (2)	8.3% (1)	0.0% (0)
	Not Contribute	**83.8% (10)**	0.0% (0)	**83.8% (10)**	8.3% (1)	33.3% (4)	33.3% (4)	**75% (9)**	16.7% (2)

6.3.4.3 The relationship between '*similarity of individual answers*' vs. '*knowledge contribution*'

Table 6.65 shows that the majority pairs of participants, who perform in the group-test, have similar *individual answers* before doing the test with peers. Moreover almost all of these pairs of participants in *Envi1* (55.6% from question1, 72.2% from question2, 77.8% from question3, and 83.3% from question4) and *Envi2* (67.7% from question1, 75.0% from question2, 50.0% from question3, and 66.7% from question4) do not contribute any knowledge but only express to confirm their group answer and *degree of confidence*.

Table 6.65. The relationship between '*similarity of individual answers'* vs. *'knowledge contribution'*. The number in the brackets() is the count.

Environment	Similarity of *individual answers*	knowledge contribution(Yes: Contribute; No: Not Contribute) of the group members on the group answer for Question 1-4							
		Question1		Question2		Question3		Question4	
		Yes	No	Yes	No	Yes	No	Yes	No
Envi1 (18 pairs)	Same	22.2% (4)	**55.6% (10)**	16.7% (3)	**72.2% (13)**	11.1% (2)	**77.8% (14)**	5.6% (1)	**83.3% (15)**
	Difference	11.1% (2)	11.1% (2)	11.1% (2)	0.0% (0)	0.0% (0)	11.1% (2)	0.0% (0)	11.1% (2)
Envi2 (12 pairs)	Same	8.3% (1)	**66.7% (8)**	8.3% (1)	**75% (9)**	8.3% (1)	**50% (6)**	0.0% (0)	**66.7% (8)**
	Difference	8.3% (1)	16.7% (2)	0.0% (0)	16.7% (2)	41.7% (5)	0.0% (0)	8.3% (1)	25% (3)

A minority of the pairs of participants keep contributing some information during the group-test no matter what the similarity of the *individual answers* of group members are. From the relationship between similarity of *individual answer* and *knowledge contribution*, it can be concluded that '*for both Envi1 and Envi2 if members of the group have the same individual answers in the first place, they tend not to contribute any knowledge to others in the group-test'*.

6.3.4.4 The relationship between '*similarity of individual answers*' vs. '*agreement on the group answer*'

Table 6.66. The relationship between '*similarity of individual answers'* vs. *'agreement on the group answer'*. The number in the brackets () is the count.

Environment	Similarity of *individual answers*	Agreement (A: Agree; D: Disagree) of the group members on the group answer for Question 1-4							
		Question1		Question2		Question3		Question4	
		A	D	A	D	A	D	A	D
Envi1 (18 pairs)	Same	**77.8% (14)**	0.0% (0)	**83.3% (15)**	5.6% (1)	**88.9% (16)**	0.0% (0)	**88.9% (16)**	0.0% (0)
	Difference	16.7% (3)	5.6% (1)	11.1% (2)	0.0% (0)	11.1% (2)	0.0% (0)	11.1% (2)	0.0% (0)
Envi2 (12 pairs)	Same	**66.7% (8)**	8.3% (1)	**83.8% (10)**	0.0% (0)	**58.3% (7)**	0.0% (0)	**66.7% (8)**	0.0% (0)
	Difference	25% (3)	0.0% (0)	16.7% (2)	0.0% (0)	41.7% (5)	0.0% (0)	33.3% (4)	0.0% (0)

Table 6.66 shows that the majority of pairs of participants, who perform in the group-test, have similar *individual answers* before doing the test with peers. Moreover almost all of these pairs of participants in *Envi1* (77.8% from question1, 83.3% from question2, 88.9% from question3 and question4) and participants in *Envi2* (66.7% from question1 and question 4, 58.3% from question2 and 66.7% from question3) – agree on these *individual answers* as a group answer for all 4 questions. It can be concluded that for both *Envi1* and *Envi2* that if members of the group have the same individual answers, later they tend to agree on the group answer.

6.3.4.5 The relationship between '*number of all contributed concepts*' vs. '*number of correct concepts*' for Question1 – Question4

During each question in the group-test, participants are allowed to communicate with peers via the *chat-tool*. Each sentence sent via this *chat-tool* will be investigated and classified as *correct* and *incorrect*. The result of correctness of each learning concept will be count and kept in the system. In 6.3.4.5(a) to 6.3.4.5(d), the relationship between *number of all contributed concepts* vs. *number of correct concepts* for Question1 to Question4 will be explained.

6.3.4.5(a) The relationship between 'number of all contributed concepts' vs. 'number of correct concepts' for Question1

Table 6.67. The relationship between '*number of all contributed concepts'* vs. '*number of correct concepts'* for Question1. The number in the brackets () is the count.

Environment	No. of Concepts that participants contribute	No. of Correct Concepts				
		0	1	2	3	4
Envi1 (18 pairs)	1	5.6% (1)	**61.1% (11)**	0.0% (0)	0.0% (0)	0.0% (0)
	3	5.6% (1)	5.6% (1)	5.6% (1)	0.0% (0)	0.0% (0)
	4	0.0% (0)	0.0% (0)	0.0% (0)	5.6% (1)	0.0% (0)
	5	5.6% (1)	0.0% (0)	0.0% (0)	0.0% (0)	5.6% (1)
Envi2 (12 pairs)	1	0.0% (0)	**91.7% (11)**	0.0% (0)	0.0% (0)	0.0% (0)
	3	0.0% (0)	0.0% (0)	8.3% (1)	0.0% (0)	0.0% (0)

Table 6.67 shows that for Quesiton1, the majority of the groups in both *Envi1* and *Envi2* contribute only one concept and that contributed concept is correct. Focusing separately on the aspect of the *number of all contributed concepts*, Figure 6.3 shows that the groups in both *Envi1* and *Envi2* mostly contribute only one learning concept. Later considering the aspect of the *number of correct concepts*, Figure 6.2 shows that the groups in both *Envi1* and *Envi2* mostly contribute one correct concept.

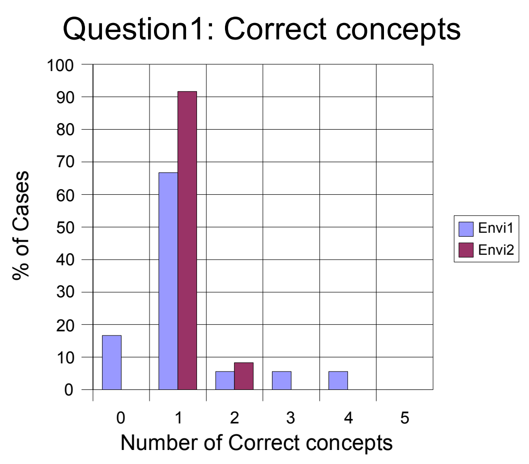


Figure 6.2. The detail of 'number of concepts' that participants in *Envi1* and *Envi2* contribute correctly for Question1

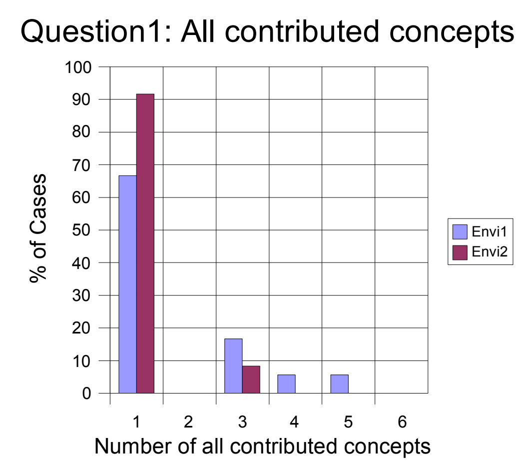


Figure 6.3. The detail of 'number of all concepts' that participants in *Envi1* and *Envi2* contribute for Question1

6.3.4.5(b) The relationship between 'number of all contributed concepts' vs. 'number of correct concepts' for Question2

Table 6.68. The relationship between '*Number of all contributed concepts*' vs. '*number of correct concepts*' for Question2. The number in the brackets () is the count.

Environment	No. of Concepts that participants contribute	No. of Correct Concepts	
		0	1
Envi1 (18 pairs)	1	5.6% (1)	**88.9% (16)**
	2	5.6% (1)	0.0% (0)
Envi2 (12 pairs)	1	8.3% (1)	**83.8% (10)**
	2	8.3% (1)	0.0% (0)

Table 6.68 shows that for Quesion2, the majority of the groups in both *Envi1* and *Envi2* contribute only one concept and that contributed concept is correct. Focusing separately on the aspect of the *number of all contributed concepts*, Figure 6.5 shows that the groups in both *Envi1* and *Envi2* mostly contribute only one learning concept. Later considering the aspect of the *number of correct concepts*, Figure 6.4 shows that the groups in both *Envi1* and *Envi2* mostly contribute one correct concept.

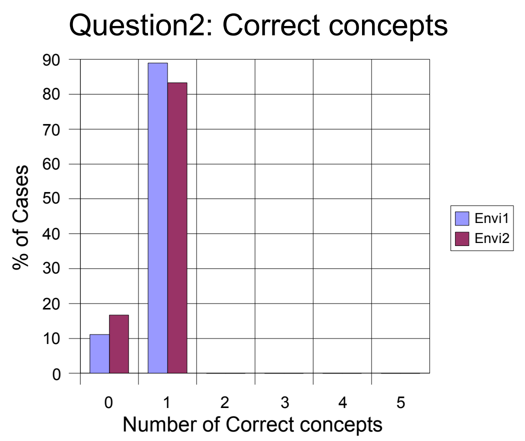


Figure 6.4. The detail of 'number of concepts' that participants in *Envi1* and *Envi2* contribute correctly for Question2

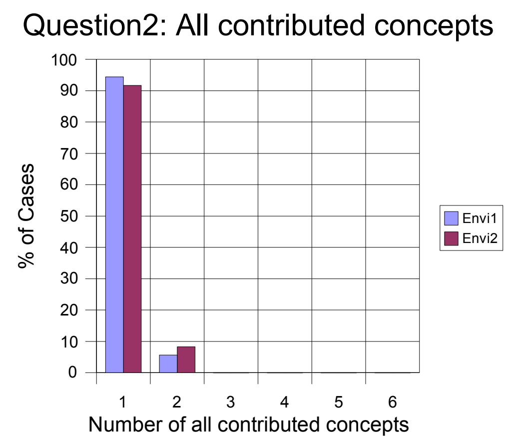


Figure 6.5. The detail of 'number of all concepts' that participants in *Envi1* and *Envi2* contribute for Question2

6.3.4.5(c) The relationship between 'number of all contributed concepts' vs. 'number of correct concepts' for Question3

Table 6.69. The relationship between '*number of all contributed concepts'* vs. *'number of correct concepts'* for Question3. The number in the brackets () is the count.

Environment	No. of Concepts that participants contribute	No. of Correct Concepts				
		0	1	2	3	5
Envi1 (18 pairs)	1	22.2% (4)	**66.7% (12)**	0.0% (0)	0.0% (0)	0.0% (0)
	4	0.0% (0)	0.0% (0)	0.0% (0)	5.6% (1)	0.0% (0)
	5	0.0% (0)	0.0% (0)	0.0% (0)	5.6% (1)	0.0% (0)
Envi2 (12 pairs)	1	8.3% (1)	**58.3% (7)**	0.0% (0)	0.0% (0)	0.0% (0)
	3	8.3% (1)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)
	4	0.0% (0)	0.0% (0)	8.3% (1)	0.0% (0)	0.0% (0)
	5	0.0% (0)	0.0% (0)	0.0% (0)	8.3% (1)	0.0% (0)
	6	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	8.3% (1)

Table 6.69 shows that for Quesion3, the majority of the groups in both *Envi1* (66.7%) and *Envi2* (58.3%) contribute only one concept and that contributed concept is correct. Focusing separately on the aspect of the *number of all contributed concepts*, Figure 6.7 shows that the groups in both *Envi1* and *Envi2* mostly contribute only one learning concept. Later considering the aspect of the *number of correct concepts*, Figure 6.6 shows that the groups in both *Envi1* and *Envi2* mostly contribute one correct concept.

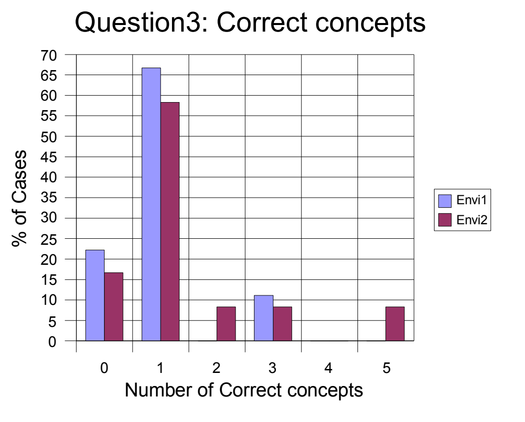


Figure 6.6. The detail of 'number of concepts' that participants in *Envi1* and *Envi2* contribute correctly for Question3

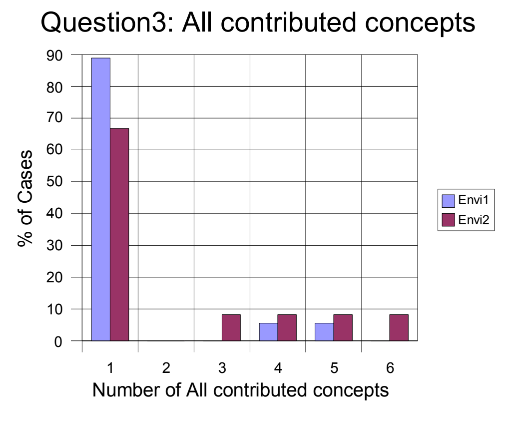


Figure 6.7. The detail of 'number of all concepts' that participants in *Envi1* and *Envi2* contribute for Question3

6.3.4.5(d) The relationship between 'number of all contributed concepts' vs. 'number of correct concepts' for Question4

Table 6.70. The relationship between *'number of all contributed concepts'* vs. '*number of correct concepts'* for Question4. The number in the brackets () is the count.

Environment	No. of Concepts that participants contribute	No. of Correct Concepts			
		0	1	3	5
Envi1 (18 pairs)	1	0.0% (0)	**94.4% (17)**	0.0% (0)	0.0% (0)
	6	0.0% (0)	0.0% (0)	5.6% (1)	0.0% (0)
Envi2 (12 pairs)	1	16.7% (2)	**75% (9)**	0.0% (0)	0.0% (0)
	6	0.0% (0)	0.0% (0)	0.0% (0)	8.3% (1)

Table 6.70 shows that for Quesion4, the majority of the groups in both *Envi1*(94.4%) and *Envi2* (75.0%) contribute only one concept and that contributed concept is correct. Focusing separately on the aspect of the *number of all contributed concepts*, Figure 6.9 shows that the groups in both *Envi1* and *Envi2* mostly contribute only one learning concept. Later considering the aspect of the *number of correct concepts*, Figure 6.8 shows that the groups in both *Envi1* and *Envi2* mostly contribute one correct concept.

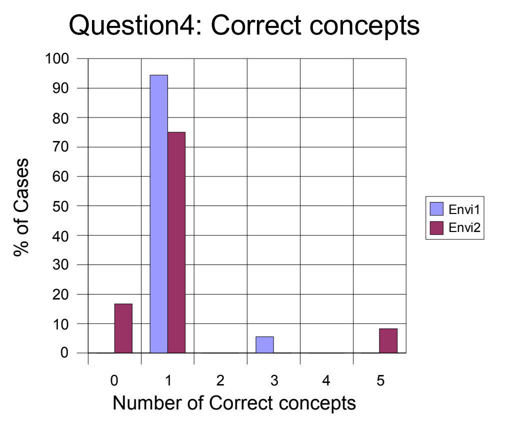


Figure 6.8. The detail of '*number of concepts*' that participants in *Envi1* and *Envi2* contribute correctly for Question4

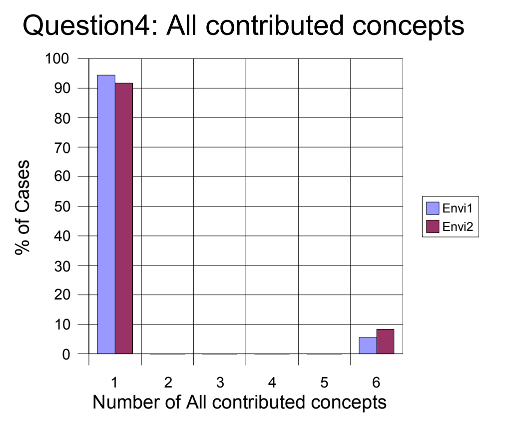


Figure 6.9. The detail of '*number of all concepts*' that participants in *Envi1* and *Envi2* contribute for Question4

6.3.4.6 The relationship between the *'correctness of an individual answer'*, the *'group agreement'* and the *'improvement of the group result'*.

Considering *number of all contributed concepts* in Table 6.67-6.70, there are 21 cases from four questions that participants contribute more than two learning concepts during the group-test.

Table 6.71. The further detail of the group number and question number from *The relationship between the individual answers*, *the group agreement* and *the improved of the group result.*

The correctness of *individual answers*	**Group agreement**	**The Improvement of the group result**		
		Decreased	**NoChange**	**Increased**
Both answers are correct and so does the group result	**Agree**	D1(q3)*	B5(q2), B6(q1), B2(q1). D2(q3)	-
	Disagree		B1(q4), C1(q2), D2(q1)	-
Both answers are incorrect and the group result is incorrect	**Agree**	-	B1(q1), B1(q2), B1(q3), C1(q1), F3(q2), C4(q3)	-
	Disagree	-	C4(q1)	-
One answer is correct but one is not and group result is correct	**Agree**	-	E3(q3)	C3(q1), F3(q4), F4(q1), F4(q3)
	Disagree	-	-	C3(q3)

Table 6.71 shows that one case is defined as *'Decreased'*, five cases are defined as *'Increased'* and the rest (fifteen cases) are defined as *'NoChange'*. Considering the group result in respect to the correction of *individual answer*, there are 8 cases that fit in the situation of *Both individual and group answers are correct,* one of which is classified as *'Decreased'* while the seven cases are classified as *'NoChange'.* In situations of *Both individual are incorrect and so is the group answer,* all of the seven cases are classified as *'NoChange'.* In the last situation which is '*one individual answer is correct but one is not and group result is correct',* there is one case classified as *'NoChange'* and the rest of the cases (five cases) are classified as *'Increased'.*

Rather than giving only just the number of cases of *The improvement of group result*, Table 6.72 provides further detail of what is exchanged and contributed during the group-test. (The details of each conversation can be found in Appendix E by using the name of each case.)

Table 6.72. The look-up table for more detail of conversation for each group on each question

No.	Abbreviation	Look up detail in	No.	Abbreviation	Look up for detail in
1	B1(q1)	Group B1: Question1	12	C4(q1)	Group C4: Question1
2	B1(q2)	Group B1: Question2	13	C4(q3)	Group C4: Question3
3	B1(q3)	Group B1: Question3	14	D1(q3)	Group D1: Question3
4	B1(q4)	Group B1: Question4	15	D2(q3)	Group D2: Question3
5	B2(q1)	Group B2: Question1	16	D2(q1)	Group D2: Question1
6	B5(q2)	Group B5: Question2	17	E3(q3)	Group E3: Question3
7	B6(q1)	Group B6: Question1	18	F3(q2)	Group E3: Question2
8	C1(q1)	Group C1: Question1	19	F3(q4)	Group E2: Question4
9	C1(q2)	Group C1: Question2	20	F4(q1)	Group E3: Question1
10	C3(q1)	Group C3: Question1	21	F4(q3)	Group E2: Question3
11	C3(q3)	Group C3: Question3			

6.3.4.7 Summary of Issue 4 :Communication during the group-test

During the group-test, is there any effect of *social interaction* on the improvement of learning performance? According to Table 6.63, it could be implied that if at least one member of the group had the correct *individual answers* in the first place, later they tended to have the correct answer for the group-test. Moreover the members tend not to contribute any knowledge and directly agree on the group answer if they both have the same *individual answer* in the first place (See Table 6.64, 6.65 and 6.66) and thought that it is correct.

Applying this group-test to 30 pairs of participants in *Envi1*and *Envi2*, forming 120 cases of conversion overall, there are 21 cases within the group of participants that contribute knowledge more than they confirm their answers. The number of what participants contribute somehow cannot guarantee the correctness of the group answer because some of what they contribute are defined as correct concepts and some are not (See Table 6.67-6.71 and Figure 6.2-6.9). Further information of these 21 cases can be seen in Table 6.72 and Appendix E.

6.3.5 Issue5: The opinions of using each particular system

In this issue, the opinions of participants on using the provided learning environment. Will be presented. Participants are considered in aspects of Performance assessment, User Interface, Content of the test and the Interaction design. The nineteen questionnaire items are classified respectively to these four aspects.

The questionnaire items in 6.3.5.1-6.3.5.6 represent the opinions respectively to *performance assessment*, the items in 6.3.5.7-6.3.5.11 represent the opinions respectively to *user interface*, the items in 6.3.5.12-6.3.5.14 represent the opinions respectively to *content of the test*, and the items in 6.3.5.15-6.3.5.19 represent the opinions respectively to *interaction design.*

Table 6.73. Levels of questionnaire items and related definitions

Level	Definition1	Definition2	Definition3
1	Not good at all	Not at all	Mostly disagree
2	Rarely good	Slightly	Sometimes disagree
3	Fairly good	Fairly	Often agree
4	Good	Much	Mostly agree
5	Very good	Very much	Absolutely agree

Table 6.73 shows that there are three definitions applied for five levels of questionnaire items. The definition1 is applied in questionnaire items of 6.3.5.1 and 6.3.5.2. The definition2 is applied for questionnaire items of 6.3.5.3-6.3.5.7, and the definition3 is applied for questionnaire items of 6.3.5.8-6.3.5.19.

6.3.5.1 How participants thought about 'How well they are doing a *number-conversion* individually?'

For the opinion of participants on how well they get use to the User Interface after using once, Table 6.72 shows that the majority of participants in *Envi1* go for *'Good'* (47.2%) while *Envi2* go for *'Fairly good'* (54.2%). Moreover there is slightly higher occurrence of 'Very good' and *'Good'* with the participants in *Envi1* when compared to *Envi2*.

Table 6.74. The opinion of participants on
'How well they are doing *number-conversion'* individually.

Environment	How well you are doing a '*number-conversion*'			
	Rarely good	Fairly good	Good	Very good
Envi1	11.1%	47.2%	30.6%	11.1%
Envi2	12.5%	41.7%	41.7%	4.2%

Table 6.74 shows that the majority of participants in *Envi1* think that they are *'Fairly good'* in *number-conversion* while the majority of participants in *Envi2* think that they are *'Fairly good'* and *'Good'* for the same amount. Considering to the ratio of participants who go for *'Good''* and *'Very good'* only the ratio of *'Very good'* has percentages of participants in *Envi1* that are 3 times higher than in *Envi2*.

6.3.5.2 How participants thought about 'How well they get use to this interface after using once?'

Table 6.75. The opinion of participants on
'How well they get use to this interface after using once'

Environment	How well participants get use to the User Interface after using once			
	Rarely good	Fairly good	Good	Very good
Envi1	5.6%	44.4%	47.2%	2.8%
Envi2	0.0%	54.2%	45.8%	0.0%

For the opinion of participants on how well they get use to the User Interface after using once**,** Table 6.75 shows that the majority of participants in *Envi1* go for *'Good'* (47.2%) while *Envi2* go for *'Fairly good'* (54.2%). Moreover there is slightly higher occurrence of *'Very good'* and *'Good'* among the participants in *Envi1* when compared to *Envi2*.

6.3.5.3 How participants thought about 'How much knowledge they contribute to their own peer?'

Table 6.76. The opinion of participants on
'How much knowledge they contribute to their own peer'

Environment	How much knowledge participants think they contribute to their own peers.			
	Slightly	Fairly much	Much	Very much
Envi1	2.8%	44.4%	44.4%	8.3%
Envi2	8.3%	66.7%	20.8%	4.2%

For the opinion of participants on 'How much knowledge they contribute to their own peer', Table 6.76 shows that the majority of the participants in *Envi1* go for both '*Fairly much*' and '*Much*' for the same amount (44.4%) while *Envi2* go for '*Fairly much*' (66.7%). Moreover there is about a two times higher occurrence both '*Very much*' and '*Much*' among participants in *Envi1* when compared to *Envi2*.

6.3.5.4 How participants thought about 'How much knowledge their peers contributed?'

Table 6.77. The opinion of participants on
'How much knowledge their peers contributed'

Environment	How much knowledge participants think their peers contributed?			
	Slightly	Fairly much	Much	Very much
Envi1	2.8%	44.4%	36.1%	16.7%
Envi2	12.5%	45.8%	37.5%	4.2%

For the opinion of participants on 'How much knowledge their peers contributed', Table 6.77 shows that the majority of participants in both *Envi1* (44.4%) and *Envi2* (45.8%) go for '*Fairly much*'. However there is about a four times higher occurrence of '*Very much*' among participants in *Envi1* when compared to *Envi2*.

6.3.5.5 How participants thought about 'How interesting is *number-conversion* content?'

Table 6.78. The opinion of participants on
'How interesting is *number-conversion* content'.

Environment	How interesting is '*number-conversion*' content?			
	Slightly	Fairly much	Much	Very much
Envi1	0.0%	36.1%	50.0%	13.9%
Envi2	8.3%	45.8%	41.7%	4.2%

For the opinion of participants on 'How much interesting is *number-conversion* content', Table 6.78 shows that the majority of participants in *Envi1* go for *'Much'* (50.0%) while *Envi2* go for *'Fairly much'* (41.7%). Moreover there is 7.7% higher occurrence of *'Very much'* and 8.3% higher occurrence of *'Much'* when compared *Envi1* to *Envi2*.

6.3.5.6 How participants thought about 'How much they improved after using this system?'

Table 6.79. The opinion of participants on
'How much they improved after using this system'

Environment	How much participants think they improved after using this system?			
	Slightly	Fairly much	Much	Very much
Envi1	5.6%	36.1%	41.7%	16.7%
Envi2	4.2%	58.3%	37.5%	0.0%

For the opinion of participants on how much they improved after using this system, Table 6.79 shows that the majority of participants in *Envi1* go for '*Much'* (41.7%) while *Envi2* go for '*Fairly much'* (58.3%). Moreover there is 16.7% higher occurrence of '*Very much'* and 4.2% higher occurrence of '*Much'* when compare *Envi1* to *Envi2*.

6.3.5.7 How participants agree on the statement of 'The User Interface is easy to use?'

Table 6.80. Agreement of participants on 'The user interface is easy to use'

Environment	The User Interface is easy to use			
	Sometimes disagree	Often agree	Mostly agree	Absolutely agree
Envi1	8.3%	33.3%	36.1%	22.2%
Envi2	8.3%	29.2%	54.2%	8.3%

For the agreement of participants on the statement of 'The user interface is easy to use', Table 6.80 shows that the majority of participants in both *Envi1* (36.1%) and *Envi2* (54.2%) go for '*Mostly agree'*. However when considering '*Absolutely agree'*, *Envi1* is higher than *Envi2* at 13.9% even though in *'Mostly agree'*, *Envi2* is higher than *Envi1* at 18.1%.

6.3.5.8 How participants agree on the statement of 'The graphics and text are used in the right amount?'

Table 6.81. Agreement of participants on
'The graphics and text are used in the right amount'

Environment	The graphics and text are in the right amount			
	Sometimes disagree	Often agree	Mostly agree	Absolutely agree
Envi1	0.0%	36.1%	44.4%	19.4%
Envi2	4.2%	29.2%	54.2%	12.5%

For the agreement of participants on the statement of 'The graphics and text are in the right amount', Table 6.81 shows that the majority of participants in both *Envi1* (44.4%) and *Envi2* (54.2%) go for *'Mostly agree'*. However with considering *'Absolutely agree'*, *Envi1* is higher than *Envi2* at 6.9% and for *'Mostly agree'*, *Envi2* is higher than *Envi1* at 9.8%.

6.3.5.9 How participants agree on the statement of 'The size of the graphical and text is suitable?'

Table 6.82. Agreement of participants on
'The size of the graphical and text is suitable'

Environment	The size of the graphical and text is suitable			
	Sometimes disagree	Often agree	Mostly agree	Absolutely agree
Envi1	0.0%	30.6%	44.4%	25.0%
Envi2	4.2%	41.7%	45.8%	8.3%

For the agreement of participants on the statement that 'The size of the graphical and text is suitable', Table 6.82 shows that the majority of participants in both *Envi1* (44.4%) and *Envi2* (45.8%) go for *'Mostly agree'*. However with considering *'Absolutely agree'*, *Envi1* is higher than *Envi2* at 16.7% even though when considering *'Mostly agree'*, *Envi2* is higher than *Envi1* at 1.4%.

6.3.5.10 How participants agree on 'Follow the system control, participants easily knows what to do next?'

Table 6.83. Agreement of participants on
'Follow the system control, participants easily knows what to do next'.

Environment	Follow the system control, participants easily know what to do next			
	Sometimes disagree	Often agree	Mostly agree	Absolutely agree
Envi1	2.8%	44.4%	38.9%	13.9%
Envi2	8.3%	66.7%	20.8%	4.2%

For the agreement of participants on the statement that 'Follow the system control, participants easily know what to do next', Table 6.83 shows that the majority of participants in both *Envi1* (44.4%) and *Envi2* (66.7%) go for *'Often agree'*. However there is 9.7% higher occurrence of *'Absolutely agree'* and 1.4% higher occurrence of *'Mostly agree'* when comparing *Envi1* to *Envi2*.

6.3.5.11 How participants agree on 'The colours applied in the user interface is suitable to participants?'

Table 6.84. Agreement of participants on
'The colours applied in the user interface is suitable to participants'

Environment	The colours applied in the user interface is suitable to participants			
	Sometimes disagree	Often agree	Mostly agree	Absolutely agree
Envi1	2.8%	27.8%	47.2%	22.2%
Envi2	0.0%	54.2%	33.3%	12.5%

For the agreement of participants on the statement that 'The colours applied in the user interface is suitable to participants', Table 6.84 shows that the majority of participants in *Envi1* go for *'Mostly agree'* (47.2%) while *Envi2* go for *'Often agree'* (54.2%). Moreover there is 9.7% higher occurrence of *'Absolutely agree'* and 13.9% higher occurrence of *'Mostly agree'* when comparing *Envi1* to *Envi2*.

6.3.5.12 How participants agree on the statement 'The content of questions is suitable for participants?'

Table 6.85. Agreement of participants on
'The content of questions are suitable for participants'

Environment	The content of questions are suitable for participants			
	Sometimes disagree	Often agree	Mostly agree	Absolutely agree
Envi1	0.0%	30.6%	33.3%	36.1%
Envi2	8.3%	29.2%	50.0%	12.5%

For the agreement of participants on the statement that 'The content of questions are suitable for participants', Table 6.85 shows that the majority of participants in *Envi1* go for *'Absolutely agree'* (36.1%) while *Envi2* go for *'Mostly agree'* (50.0%). Moreover when considering *'Absolutely agree'*, *Envi1* is higher than *Envi2* at 13.6% even though for *'Mostly agree' Envi2* is higher than *Envi1* at 16.7%.

6.3.5.13 How participants agree on the statement of 'The question detail has a clear explanation?'

Table 6.86. Agreement of participants on
'The question detail has a clear explanation'

Environment	The question detail has a clear explanation		
	Often agree	Mostly agree	Absolutely agree
Envi1	33.3%	47.2%	19.4%
Envi2	62.5%	25.0%	12.5%

For the agreement of participants on the statement 'The question detail has a clear explanation', Table 6.86 shows that the majority of participants in *Envi1* go for *'Mostly agree'* (47.2%) while *Envi2* go for *'Often agree'* (54.2%). Moreover there is 6.9% higher occurrence of *'Absolutely agree'* and 22.2% higher occurrence of *'Mostly agree'* when comparing *Envi1* to *Envi2*.

6.3.5.14 How participants agree on the statement of 'The difficulty level of the test suitable for participants' peers?'

Table 6.87. Agreement of participants on
'The *difficulty level* of the test suitable for participants' peers'

Environment	The *difficulty level* of the test suitable for participants' peers			
	Sometimes disagree	Often agree	Mostly agree	Absolutely agree
Envi1	0.0%	38.9%	41.7%	19.4%
Envi2	4.2%	62.5%	33.3%	0.0%

For the agreement of participants on the statement 'The *difficulty level* of the test suitable for participants' peers', Table 6.87 shows that the majority of participants in *Envi1* go for *'Mostly agree'* (41.7%) while *Envi2* go for *'Often agree'* (62.5%). Moreover there is 19.4% higher occurrence of *'Absolutely agree'* and 8.4% higher occurrence of *'Mostly agree'* when comparing *Envi1* to *Envi2*.

6.3.5.15 How participants agree on the statement of 'Participants can exchange what they believes with their peers?'

Table 6.88. Agreement of participants on
'Participants can exchange what they beliefs with their peers'

Environment	Participants can exchange what they beliefs with their peers			
	Sometimes disagree	Often agree	Mostly agree	Absolutely agree
Envi1	0.0%	33.3%	30.6%	36.1%
Envi2	4.2%	37.5%	45.8%	12.5%

For the agreement of participants on the statement 'Participants can exchange what they beliefs with their peers', Table 6.88 shows that the majority of participants in *Envi1* go for *'Absolutely agree'* (36.1%) while *Envi2* go for *'Mostly agree'* (45.8%). Moreover with considering *'Absolutely agree'*, *Envi1* is higher than *Envi2* at 23.6% even though in the occurrence of *'Mostly agree'* within *Envi2* is higher than *Envi1* at 15.2%.

6.3.5.16 How participants agree on the statement of 'Provided *utterances* and *sentence openers* are easy to use?'

Table 6.89. Agreement of participants on
'Provided *utterances* and *sentence openers* are easy to use'.

Environment	The provided utterances and sentence openers are easy to use			
	Sometimes disagree	Often agree	Mostly agree	Absolutely agree
Envi1	2.8%	33.3%	36.1%	27.8%
Envi2	4.2%	58.3%	25.0%	12.5%

For the agreement of participants on the statement 'The provided utterances and sentence openers are easy to use', Table 6.89 shows that the majority of participants in *Envi1* go for *'Mostly agree'* (36.1%) while *Envi2* go for *'Often agree'* (58.3%). Moreover there is 15.3% higher occurrence of *'Absolutely agree'* and 11.1% higher occurrence of *'Mostly agree'* when comparing *Envi1* to *Envi2*.

6.3.5.17 How participants agree on the statement of 'Participants improve knowledge from what they exchanged in peer via the provided *chat-tool*?'

Table 6.90. Agreement of participants on 'Participants improve knowledge from what they exchanged in peer via the provided *chat-tool.'*

Environment	Participants improve knowledge from what they exchanged in peer via the provided *chat-tool*.		
	Often agree	Mostly agree	Absolutely agree
Envi1	33.3%	36.1%	30.6%
Envi2	58.3%	29.2%	12.5%

For the agreement of participants on the statement 'Participants improve knowledge from what they exchanged in peer via the provided chat-tool', Table 6.90 shows that the majority of participants in *Envi1* go for *'Mostly agree'* (36.1%) while *Envi2* go for *'Often agree'* (58.3%). Moreover there is 18.1% higher occurrence of *'Absolutely agree'* and 6.9% higher occurrence of *'Mostly agree'* when comparing *Envi1* to *Envi2*.

6.3.5.18 How participants agree on the statement of 'The turn given by the system is suitable to the need of participants?'

Table 6.91. Agreement of participants on
'The turn given by the system is suitable to the need of participants'.

Environment	The turn given by the system is suitable to the need of participants			
	Sometimes disagree	Often agree	Mostly agree	Absolutely agree
Envi1	2.8%	36.1%	38.9%	22.2%
Envi2	0.0%	66.7%	29.2%	4.2%

For the agreement of participants on the statement 'The turn given by the system is suitable to the need of participants', Table 6.91 shows that the majority of participants in *Envi1* go for *'Mostly agree'* (38.9%) while *Envi2* go for *'Often agree'* (66.7%). Moreover there is 18.0% higher occurrence of *'Absolutely agree'* and 9.7% higher occurrence of *'Mostly agree'* when comparing *Envi1* to *Envi2*.

6.3.5.19 How participants agree on the statement of 'Exchange beliefs with others help them to get higher degree of confidence on learning in *number-conversion* content?'

Table 6.92. Agreement of participants on 'Exchange beliefs with others help then to get higher degree of confidence on learning in *number-conversion* content'.

Environment	Exchange beliefs with others help participants to get higher *degree of confidence* on learning in *number-conversion* content		
	Often agree	Mostly agree	Absolutely agree
Envi1	33.3%	41.7%	25.0%
Envi2	58.3%	25.0%	16.7%

For the agreement of participants on the statement 'Exchange beliefs with others help then to get higher degree of confidence on learning in *number-conversion* content', Table 6.92 shows that the majority of participants in *Envi1* go for *'Mostly agree'* (41.7%) while *Envi2* go for *'Often agree'* (58.3%). Moreover there is 8.3% higher occurrence of *'Absolutely agree'* and 16.7% higher occurrence of *'Mostly agree'* when comparing *Envi1* to *Envi2*.

6.3.5.20 Summary of Issue5: The opinions of using each particular system

The opinion of using each particular learning environment – *Envi1* and *Envi2*, can be categorized into two groups. The first group of questionnaire items is the group that participants from both *Envi1* and *Envi2* have the same level of voting result. These questionnaire items consist of item numbers 1, 4, and 7 which are voted for level '3' while item numbers 8, 9, and 10 are voted for level '4'.

The second group of questionnaire items is the group that participants from *Envi1* have higher level of voting result than *Envi2*. This group consist of item numbers 2, 3, 5, 6, 11, 13, 14, 16, 17, 18, and 19 which the majority of participants in *Envi1* vote for level '4' while *Envi2* vote for level '3', and item numbers 12 and 15 which the majority of participants in *Envi1* vote for level '5' while *Envi2* vote for level '4'.

Table 6.93. Mean values of voting level for 19 questionnaire items of using *Envi1* and *Envi2*.

Item No.	Questionnaire details	*Envi1* (Mean)	*Envi2* (Mean)	Mean Diff (*Envi1*-*Envi2*)
1	How well they are doing a '*number-conversion*' individually?	3.42	3.38	0.04
2	How well they get use to this interface after using once	3.47	3.46	0.01
3	How much knowledge they contribute to their own peer?	3.58	3.21	0.37
4	How much knowledge their peers contributed?	3.67	3.33	0.34
5	How interesting is '*number-conversion*' content	3.78	3.42	0.36
6	How much they improved after using this system?	3.70	3.33	0.37
7	The User Interface is easy to use	3.72	3.63	0.09
8	The graphics and text are used in the right amount	3.83	3.75	0.08
9	The size of the graphical and text is suitable	3.94	3.58	0.36
10	Follow the system control, participants easily know what to do next	3.64	3.21	0.43
11	The colours applied in the user interface is suitable to participants	3.89	3.58	0.31
12	The content of questions are suitable for participants	4.06	3.67	0.39
13	The question detail has a clear explanation	3.86	3.50	0.36
14	The *difficulty level* of the test suitable for participants' peers	3.81	3.29	0.52
15	Participants can exchange what they beliefs with their peers	4.03	3.67	0.36
16	Provided utterances and sentence openers are easy to use	3.89	3.46	0.43
17	Participants improve knowledge from what they exchanged in peer via the provided *chat-tool*	3.97	3.54	0.43
18	The turn given by the system is suitable to the need of participants'	3.81	3.38	0.43
19	Exchange beliefs with others help them to get higher *degree of confidence* on learning in '*number-conversion*' content	3.92	3.58	0.34

To make the comparison between opinions of using *Envi1* and *Envi2*, the average value of level that is calculated from the data in Table 6.74-6.92 is represented as Table 6.93. The information of Table 6.93 shows that the difference between the mean values of voting levels varies between the range of 0.01 and 0.52. It can be implied that learning in *Envi1* where participants are able to see group learner model as *IdealGLM* and *GLM*, participants are satisfied with and benefit from learning in the particular learning environment compared to the participants in *Envi2*.

6.4 Summary

The focus of this chapter is to test whether learners can benefit from learning in a collaborative learning environment where learners are able to know how well the group performs by *seeing IdealGLM* and *GLM*. What we really want to know from doing this research is about the comparison between individual and collaborative learning, and the comparison between two collaborative learning environments which focus on *seeing* and *not seeing* the *IdealGLM* and *GLM*.

In the condition of *seeing* and *not seeing IdealGLM* and *GLM* in the computer-based collaborative learning environment, is there any significant difference between *concept-score* between groups of participants in *Envi1* and *Envi2*? The results of the comparison between two collaborative learning environments show that participants benefits from learning in *Envi1* more than *Envi2*. This can be confirmed by the mean difference of learning score which shows that participants in *Envi1* have a higher score than participants in *Envi2* (See Table 6.13, 6.15 and 6.17). Together with the confirmation in Table 6.30-6.41 which shows that participants in *Envi1* still get a higher *concept-score* of post-test and group-test higher than participants in *Envi2*.

Moreover for the matter of assessment ability, the results show that there is a strong correlation between *self-assessment* and *self-actual-performance,* and between *peer-assessment* and *peer-actual-performance* only for participants in *Envi1* but not for *Envi2* (See Table 6.46-6.51). Together with slightly higher level of vote (*Envi1* > *Envi2*) for all 19 questionnaire items (See Table 6.74-6.93), and the majority of votes from participants on the 'helpfulness' of *seeing IdealGLM* and *GLM* which confirms the satisfaction of using

Envi1 (See Table 6.52-6.59). It can be implied that the learning process of *Envi1*, which is different from *Envi2* only in the ability of learners to see *IdealGLM* and *GLM*, has an impact on learning which of them achieve higher post-test *concept-score*s.

In the computer-based collaborative learning environment, whether or not learners can perform better than learning individually in a non computer-based learning environment? In the view point of 'non-computer-based individual learning vs. computer-based collaborative learning', the result from the 30 items post-test shows that the participants in *Envi1* get a higher score than in *Envi3* with significant difference under the 5% level. Even though there is no significant difference between post-test score of participants in *Envi2* and *Envi3* and the mean difference, which is displayed in Tables 6.13, 6.15 and 6.17, shows that participants in *Envi2* have a higher post-test score than in *Envi3*. This can lead to the conclusion that by comparing learning as individual and collaborative, learners can perform better – by getting either higher *concept-score* or *degree of confidence* – when learning collaboratively with others.

In the *social interaction* point of view, the way of judging is more complicated than we can imagine. What we have seen during the research is that some cases have consistency of learning result from pre-test, group-test and post-test but some have not. Some participants have accuracy self and peer assessment but still cannot improve their learning performance. Contributing something to others cannot guarantee the correctness of the group result. These results reveal some signs of something behind the scenes which worth while for us to look further even though there is no significant result to show the impact of *social interaction* on the improvement of learning performance.

Chapter 7

Discussion, Conclusion and Future Work

In this chapter, we start with the discussion of which factors can be used as evidence to support whether or not seeing *IdealGLM* and *GLM* helps learners to improve their learning performance. The discussion focuses on two respects of comparison between individual's performance in different learning environments. The first respect is to compare individual's performances between participants in a non computer-based individual learning environment and a computer-based collaborative learning environment.

The second respect is to compare the results of learning – in aspects of *concept-score*, accuracy of *self-assessment,* and opinion of using particular learning environments, rating of helpfulness of *seeing* the learner model, etc.; in two different computer-based collaborative learning environments – *Envi1* and *Envi2*, which are only different in the matter of *seeing* and *not seeing IdealGLM* and *GLM*. In *Envi1*, participants are assigned to work with GOLeM while participants in *Envi2* are assigned to work in the similar system to GOLeM but are not provided with *GLM* and *IdealGLM*.

These two respects of comparison are tested to provide answers for four questions that relate to the aim of the thesis. These four questions are below

1. In the computer-based collaborative learning environments, is there any impact of *seeing* and *not seeing* the *GLM* and *IdealGLM* on learning score and degree of confidence?
2. Is there any difference in the learning *concept-score* or *degree of confidence* when comparing the result of collaborative learning with learning individually?
3. Is there any impact of *self-regulation* on the improvement of learning performance focusing on the improvement of *concept-score* and *degree of confidence*?

4. Is there any impact of *social interaction* on the improvement of learning performance focusing on the *improvement of concept-score* and *degree of confidence*?

After discussing the result from the four questions, the conclusion outlines the significance of the work and what we plan to do next are shortly introduced in the chapter.

7.1 Discussion

As introduced in previous chapters, collaborative learning is used to encourage learners to achieve more than their individual performance when performing with others. OLM is used as the way to see how well they perform in order to improve their learning performance. The worth of applying GOLeM which combined both the benefit of collaborative learning and OLM (Brna et al, 1999; Bull et al, 1995; Bull & Nghiem, 2002; Kay, 2000; Dimitrova, 2003; Zapata-Rivera & Greer, 2004) is aimed at finding evidence to support whether or not opening a *group learner model* – such as *IdealGLM* and *GLM* – can provide learners in a specific collaborative learning environment with any benefits for their learning.

In order to meet this aim, we firstly scoped the development of our learning environments into 3 types: *Envi1* – a collaborative learning environment in which learners were able to see their group model (*IdealGLM* and *GLM*), and have *social interaction* via a *chat-tool*; *Envi2* – a collaborative learning environment in which learners were able to have *social interaction* via the *chat-tool* but had no access to their group model; and *Envi3* – an individual learning environment. These three learning environments provided the same content – that of *number-conversion*.

Secondly, these three learning environments were used with groups of participants who had a background in computing. The 120 undergraduate students from the Department of Computer Science and Technology, Kanchanaburi Rajabhat University, Thailand were involved as participants. After applying the 30-item questionnaire test (See section 6.1 for the validity of the test), participants were assigned into three similar groups (See section 6.3 for the details about grouping).

In section 6.3.1.1, Tables 6.9, 6.10, and 6.11 show that there was no significant difference at 5% level for pre-test scores among the participants who were assigned to study in these three learning environments. Hence, the participants for the three different environments can be regarded as having the same basic skills/understanding.

According to various socio-constructivist theories (Piaget, 1928 & 1932; Vygotsky, 1978) and empirical study of learning, learners can improve their own cognitive understanding and performance in some area of interest after having *social interaction* concerning the area (Doise, Mugny, & Perret-Clermont, 1975). In this research, we compare the improvement of individual's performance in two respects.

The first respect is regarding the first question that aims at *seeing* whether collaborative learning helps to improve the individual's performance when the focus is on the issue as to whether the learners can – or cannot see the *IdealGLM* and *GLM*. This respect of can – or cannot see while learning collaboratively in the computer-based learning environment plays a crucial part for this research.

On this issue, we are concerned not only with the score learners achieve both individually and as a group but also with explanations of the results obtained in terms of theory of mind which seeks to understand how modelling the other's thought, combined with *self-assessment* obtained by reflecting on the learner's own self knowledge and performance is used as a method to estimate how well they, their group and their peers perform. Moreover the attitude of participants in *Envi1* on how helpful *IdealGLM* and *GLM* help them estimate how well they and their peers are in *self-assessment* and *peer-assessment*.

In terms of comparing score between *Envi1* and *Envi2*, the mean difference between *Envi1* and *Envi2* shows that learners in *Envi1* have higher scores than participants in *Envi2* (See Tables 6.13, 6.15 and 6.17). This implies that the learning process of *Envi1*, which is different from *Envi2* only in the matter of *seeing* the *IdealGLM* and the *GLM*, has an impact on learning – as indicated by achieving a higher post-test score.

In order to investigate further the learning process in *Envi1* and *Envi2* to see what is going on within the particular learning environments, the four question items of *number-conversion* were assigned in pre-test, group-test, and post-test and used by participants of both learning environments. The learning performance that we measure within using *Envi1* and *Envi2* are represented in term of *concept-score* that is generated from the combination of the *correctness of the answer*, and the *degree of confidence* for each particular answer. The information from Table 6.30-6.41 still confirms that from applying the four question test, participants in *Envi1* still get a higher post-test and group-test *concept-score* than participants in *Envi2*.

In looking further into the details of group-test and post-test for participants with respect to types of participants: *all participants*, *high-score group* of participants, and *low-score group* of participants, the results show that in the group-test, there are significant differences at the 5% level for four learning concepts of *all participants*, three learning concepts of *high-score group* of participants but there is no learning concepts of *low-score group* of participants that are significantly different at the 5% level. In the post-test, there are no *concept-score*s of any learning concepts for *low-score group* of participants, and *all participants* that are significantly different at the 5% level from the pre-test. However the *concept-score* of these six learning concepts are significantly different at the 5% level for the *high-score group* of participants.

Regarding the results of *concept-score* for six learning concepts, Table 6.35 and Table 6.39 show that for the *high-score group*, there are three learning concepts for the group-test and six learning concepts for the post-test that participants have *concept-scores* significantly different from the pre-test at the 5% level. While there is no learning concept that participants in a *low-score group* have *concept-score* significantly different at the 5% level in both group-test and post-test. This suggests that OLM is certainly significantly useful for *high-score group* of participants. Furthermore it would be sensible to speculate why the same results for *high-score group* of participants were not found for the *low-score group* of participants. To do that, it is suggested that a larger group of participants should be tested to obtain stronger evidence.

The higher *concept-score* of participants in *Envi1* confirms our belief that providing a group learner model might help learners to improve their performance. However this evidence is not strong enough to conclude that this kind of result will happen every time we run such experiments. Therefore we expect to test our learning system with a larger group of participants for better evidence to support whether there is any significant difference of *concept-score* in six learning concepts between learning in *Envi1* and *Envi2*. Furthermore looking into detail of other factors that might effect on learning improvement especially on collaborative learning environment is taken place.

The second respect is regarding the second question which aims at comparing the individual learning environment with the collaborative learning environments to see which one provides better help for learners to improve their individual understanding and performance (see more details in section 6.3.1). The results from Tables 6.13, 6.15, and 6.17 show that there are significant differences at the 5% level of the post-test score between the performance of participants in *Envi1* and *Envi3* whether one compares all participants, the *high-score group* or the *low-score group*.

Even though there is no significant difference between the post-test scores for *Envi2* and *Envi3*, the mean differences in Tables 6.13, 6.15 and 6.17 show further detail – in particular, that participants using *Envi2* had higher post-test scores than participants in *Envi3*. In the comparison of individual learning with collaborative learning, it can be concluded that learners better improved their performance when learning collaboratively rather than individually. This is consistent with other research on the performance of dyads on collaborative tasks (Dillenbourg & Baker, 1996; Soller et al., 1999**)**

Regarding the third question that aims at *seeing* whether there is any impact of *self-regulation* on the improvement of learning performance focusing on the improvement of score and *degree of confidence*? Defined by Wilson (1998, p. 14), "Metacognition is the knowledge and awareness one has of their own thinking processes and strategies and the ability to evaluate and regulate one's own thinking processes" In this thesis, regulatory checklists are used as a metacognitive control to monitor for *self-assessment* and in regards to metacognition. These are questions that applied from Schraw's regulatory checklist (see Figure 3.1): *How much does my peer know?* (For learners assessing their peers), *How much prior knowledge do I have?* (For learners assessing themselves)

For the matter of assessment ability, the results in Table 6.46-6.51 show that there are strong correlations between *self-assessment* and *self-actual performance*, and between *peer-assessment* and *peer-actual-performance* only for participants in *Envi1* but not for *Envi2*. This can be used to infer that *seeing IdealGLM* and *GLM* has an impact on the accuracy of *self-assessment* which according to Gama's work (2004) suggests that accuracy of *self-assessment* might help learner to improve their learning performance – in this case to get a higher *concept-score*.

From that result, we then move our focus further onto whether there is any impact of the accuracy of *self-assessment* and *peer-assessment* on the improvement of learning performance. Table 6.61 that combines the concepts of *self-assessment* and ZPD shows that for both *Envi1* and *Envi2*, participants who were classified as '*Over-Estimated'* tend to improve in group-test and post-test more than the other group of *'Precise-Estimated'* and *'Under-Estimated'*. That might be because the dropping of *degree of confidence* causes the lower *concept-score* therefore case by case should be investigated further. Moreover the majority of *'Precise-Estimated'* participants of *Envi1* are from the ones who have *concept-score* at the highest level (near the ceiling) for the whole learning process, while this type of participant in *Envi2* does not improve in both group and post-test (See table 6.61 and 6.62).

In this case, even though there is some evidence showing that participants in *Envi1* have higher accuracy on *self-assessment* and there is no concrete information to confirm that accuracy of assessment helps learners to improve their individual performance. However we still believe that if we run this experiment with larger groups of participants – either with the same groups more than one time or with different groups of participants that have a similar background; we then should have stronger evidence leading to the conclusion whether or not the accuracy of *self-assessment* and *peer-assessment* has an impact on individuals' learning performance.

Furthermore the consistency of *concept-score* during the learning process which concerns the pre-test, group-test and post-test (See Table 6.60) shows that there is a higher percentage of participants who improve their *concept-score* in the group-test and post-test in *Envi2* more than in *Envi1*. Even though the consistency of *concept-score* in *Envi2* seems to be higher than in *Envi1* if we look further into the details of learning performance that are classified as *'Not improved'*, it can be that either having the score meet the ceiling (Full score) all over the learning process – pre-test, group-test and post-test, or having correct learning concept but the *degree of confidence* is dropped down.

Regarding the ZPD concept (Vygotsky, 1978) that is concerned about what first learners cannot do individually on their own but can do later with others. This ZPD concept is matched with the comparing *result-of-the-answer* (see Table 6.42)*, concept-score* (see Table 6.60) between pre-test and group-test. In regards to the *result-of-the-answer*, Table 6.42 shows that participants in *Envi1* improved better than participants in *Envi2* for both considering to *all cases* and *only cases that can be improved*.

Furthermore, the *improvement of concept-score* from Table 6.60 shows that if considered only on the matter of '*Improved'* that participants in *Envi2* (54.2%) have a slightly higher percentage than participants in *Envi1* do (44.4%). It implies that with regards to ZPD concept, participants in *Envi2* better benefit from group-test than participants in *Envi1*. However, if considered only on the matter of '*Not improved'* that participants in *Envi2* (45.8%) have a higher percentage than participants in *Envi1* (38.9%). This implies that with regards to ZPD concept, participants in *Envi1* better benefit from group-test than participants in *Envi2*. In this case, the matter of '*Meet ceiling'* causes a lack of clarity of this result as to whether *Envi1* or *Envi2* is better for group learning with respect to ZPD concept. That is because without the ceiling, the participants in Meet ceiling can either be defined as *'Improved'* or *'Not improved'*.

As that result, we still believe that if trying to avoid the ceiling effect together with running this experiments with larger groups of participants – either with the same groups more than one time or with different groups of participants that have a similar background; we should then have stronger evidence leading to the conclusion whether or not can see – and can't see *IdealGLM* and *GLM* have an impact on consistency between pre-test, group-test and post-test.

Regarding the fourth question that aimed at *seeing* whether during the group-test, there is any effect of *social interaction* on the improvement of learning performance. According to the information in Table 6.63-6.70 and Figure 6.2-6.9, participants contribute their knowledge only when they do not agree on the answer or *degree of confidence*. Otherwise they only confirm the answer and *degree of confidence* as the group answers that are counted as one knowledge contribution.

For all 120 cases of conversation performed by pairs of participants in *Envi1* and *Envi2*, there are 21 instances in which a group of participants contribute other knowledge rather than confirmation of their answers. The number of cases that learners contributed something to their peers seems small. However according to Azmitia and Montgomery (1993), the level of friendship between peers can have an impact on their group learning performance - learners perform that group-test better when they do it with friends rather than acquaintances. There may also be other factors that determine the degree of contribution including the learning culture, the need to "keep face" and so on.

In our work, the participants who were assigned to learn in each learning environments were friends or colleagues for at least 3 years so they might have some ideas about each other skills/knowledge. That might be a major reason why learners did not contribute anything but still got the correct group answers. In order to confirm the impact of relationship between peers on the improvement of learning performance a further study should be carried out.

Further information of these 21 cases can be seen in Table 6.72 and Appendix F. For the opinion of participants about using *Envi1* and *Envi2*, Table 6.74-6.93 show that participants in *Envi1* vote for a slightly higher level than participants in *Envi2* for all 19 questionnaire items with having the mean difference of each vote between the range of 0.01 to 0.52.

To confirm the satisfaction of using *Envi1* in which learners are able to see *IdealGLM* and *GLM*, the results in Table 6.52-6.59 show that almost all (94%) of participants require *seeing IdealGLM*. They stated the helpfulness of *seeing IdealGLM* for *self-assessment* and *peer-assessment* as '*Much helpful*' (See Table 6.54 and 6.56). Furthermore they stated the helpfulness of *seeing GLM* as '*Very much helpful*', which is the highest level that represents the helpfulness of *seeing GLM* (See Table 6.59). The majority of votes of participants on the helpfulness then confirm our belief about the impact of providing group learner model on collaborative learning.

As a result of voting on 19 questionnaire items together with helpfulness on *self-assessment* and, it could be concluded that *seeing IdealGLM* and *GLM* helps learners to improve their learning performance.

7.2 Summary of the results

According to what we have already presented as evidence to support our answers to the questions related to the aim of our thesis, it can be concluded that 'able' to see group learning performance as *IdealGLM* and *GLM*, which is represented in terms of *bar-chart* and textual explanation, helps learners to get a higher *concept-score* in both group-test and post-test.

1.Considering the matter of ‘can see’ and ‘cannot see’ the group learner model in GOLeM-like environments, the results of Table 6.30-6.41 show that participants who can see the group learner models have concept-scores on group-test and post-test higher than ones who cannot see the group model. Moreover considering the improved learning performance based on result-of-the-answer (See Table 6.42 and 6.43) and based on concept-score (See Table 6.44 and 6.45) show that in the cases that participants can improve, ones who can see the group learner model (Envi1) improved at least in post-test more than ones who cannot see the group learner model (Envi2).

2.The results in Table 6.12-6.17 show that participants who learn in both computer-based collaborative learning environments have post-test score higher than ones who learn individually in a non computer-based individual learning environment. Moreover the significant difference of the scores between Envi1 and Envi3 can be used to confirm my belief that learning with peers help learners to improve their learning performance better than learning alone, and they can improve even better when they ‘can see’ the learning performance as a group learner model. Furthermore the higher level of voting in all 19 items questionnaire (See Figure 6.73 - 6.93) can be implied that learners are more satisfied to learn in *Envi1* than in *Envi2*.

3. Results in Table 6.46-6.51 show that ‘seeing’ group learner model helps learners to assess themselves and their peer more accuracy. Moreover as suggested by Gama (2004) the accuracy of assessment helps learners to improve their individual performance. Given the results obtained regarding matters of self-assessment and peer-assessment together with the post-test score, it can be concluded that *seeing IdealGLM* and *GLM* helps improve their learning performance. Moreover learners who ‘had seen’ the group learner model voted

that ‘seeing’ the *IdealGLM* is ‘Much helpful’ for them to assess themselves and their peers, and ‘seeing’ the GLM is ‘Very much helpful’ for finishing all 4 questions during the group test.

4. As already stated above that learners better improve when they do learn with peers rather than on their own. The ‘social interaction’ or the actions of exchanging beliefs is considered here as a possible factor supporting learners to increase their learning performance in collaborative learning environment. In this work, enabling the system to investigate for what learners exchanged during the group-test might help to understand for ‘how come the group answers’ better than seeing only the group answer alone.

Moreover according to the result of the group answer that each group has (See Table 6.63 – 6.70) , it could be implied that if at least one member of the group had correct individual answers, later they tended to have the correct answer for the group-test without any contribution of knowledge. Moreover learners tend not to contribute any knowledge and directly agree on the group answer if they both have the same individual answer in the first place and thought that it is correct.

According to the results we have here, it can be concluded that in the computer-based collaborative learning environments that allow learners to communicate with peers via the *chat-tool*, ones who 'can see' the group learner models improved more in both group-test and post-test, than one who ‘cannot see’ the group learner model. Moreover the results regarding 'self-regulation' and 'social interaction' show that accuracy of self and peer assessment, and the exchanged beliefs during the group-test help learners to improved learning performance. Though this evidence is not as strong as we might wish to guarantee the result of the further studies, this thesis has provided the most thorough empirical examination of the benefit of a GOLM so far

7.3 Contribution

In this thesis we aimed at building the system called 'GOLeM' that encourages learners to benefit from *seeing* their learning performance as a group learner model – *IdealGLM* and *GLM*, in a computer-based collaborative learning environment. The GOLeM helps learners to exchange beliefs with peers via the *chat-tool* through applying the concept of *dialogue game* (Dimitrova, 2001; Burton, 1998) and *sentence openers* (Soller, 1999 & 2001 & 2002).

GOLeM is designed and evaluated for both paper-based and computer-based versions. The paper-based version is built to test for the plausibility of learning content and user interface with six pairs of undergraduate students. The computer-based version of GOLeM is implemented taking the results from the previous version into account. The Ethics committees from the Faculty of Education, Glasgow University, approved all documents that were used in this version.

The computer-based GOLeM (*Envi1*) is tested against other two learning environments – *Envi2* and *Envi3*. *Envi2* is an environment that is similar to GOLeM but not provide *GLM* and *IdealGLM,* while *Envi3* is a non-computer-based environment for individual learning. The evaluation of results after applied with 85 participants (See detail in Chapter 6) shows that learning with peers using GOLeM, participants get higher score and *degree of confidence* than other two learning environments. Moreover when focusing on the results of two computer-based collaborative learning environments (*Envi1* vs. *Envi2*), the evidence shows that participants who see the *GLM* and *IdealGLM* have slightly higher score, *degree of confidence*, and satisfaction level of using GOLeM.

There are some works (Dimitrova, 2001 & 2003; Brna et al., 1999; Bull et al., 1995; Bull et al., 1999; Bull & Nghiem, 2002) that are concerned about open learner modelling but most of them focus on representing the individual learner model for either group learning or solitary learning. This work is different from others on the representation of the learner model that focuses only on *group learner model*. Introducing two types of *group learner models* as *IdealGLM* and *GLM*, rather than individual learner model aims to encourage *self-regulation* that is concerned with what might help learners to improve their individual performance. The *IdealGLM* is used to represent what GOLeM expects group members to achieve if they perform the group-test together. While the *GLM* is used to represent what the system believes about how well the group performs in the group-test.

Applying the simplest set of moves for a *dialogue game* (*'Questioning*' and *'Informing'*) with fourteen *sentence openers* are mainly used in a *chat-tool*. Each *utterance* that is used to complete each sentence are related to six concepts of *number-conversion*. This *chat-tool* is used by learners to exchange their beliefs and used by GOLeM to investigate what learners believe and how they perform during the group-test.

Each move that learners made is justified and used to manage the learner model with respect to six learning concepts. The way of representing our conceptual knowledge is in between an overlay model and a probabilistic model. What we applied from the concept of overlay model is that the knowledge that a learner has is a subset of the system. Any beliefs not recognised as correct are regarded as misconceptions. However the value that represents conceptual knowledge in an overlay model is not suitable for uncertain situations e.g. it cannot be absolutely known or not known if learners do a similar task more than one time but still get inconsistent results. Therefore the simplified version of a probabilistic model is utilised in this thesis for dealing with uncertain situations.

Both CSCL and AIED communities can study the GOLeM itself further. Regarding the AIED community, GOLeM can be used for the further study on the benefits of *seeing* learning performance as a *group learner model – IdealGLM* and *GLM*. Regarding the CSCL community, using this GOLeM with either a larger or a wider variety of groups of learners focusing on knowledge contribution during the group-test for the concrete evidence to support that *social interaction* has an impact on collaborative learning.

7.4 Future Work

7.4.1 Extend to test with larger group of participants

Regarding the information in Table 6.61 – 6.62, the evidence show that participants in *Envi1* have higher accuracy on *self-assessment* than participants in *Envi2*. However there is no concrete information to confirm that accuracy of assessment helps learners to improve their individual performance. As well as the view of communication dialogue that there are only 21 of 120 cases that learners contribute knowledge that cannot be used as concrete evidence to conclude whether contribution leads to gaining more knowledge.

Therefore what we plan to do next is to run these experiments with larger groups of participants – either with the same groups more than one time or with different groups of participants that have a similar background. We expect that the larger group of participants might provide stronger evidence leading to the conclusion as to whether or not the accuracy of *self-assessment* and *peer-assessment*, and the contribution of something during the conversation other than confirming the answer has an impact on individuals' learning performance.

Moreover regarding the information in Table 6.33 and 6.39, the results show that participants of *high-score group* in *Envi1* perform better than participants in *Envi2* significantly different at the 5% level relative to the pre-test for three learning concepts of the group-test, and all six learning concepts of the post-test.

However in *low-score group* of participants, there is none of these six learning concepts that have a *concept-score* significantly different at the 5% level. In order to speculate why the same results of *high-score group* of participants did not happen for *low-score group* of participants, the larger group of samples are suggested to apply for the better evidence. Whether there still is any significant difference between *concept-score* of participants who applied in *low-score group* in *Envi1* than in *Envi2*.

7.4.2 Extend the learning platform to Web-based

What we have done here with GOLeM, is to connect two computers to share information and enable work to be done on the same task. At this point the peer-to-peer type of connection is used to allow two learners to work together as a group. As the results, for the environment of GOLeM is based on only two learners at a time there is only an expectation that it might work the same way when applied to larger groups of learners.

When considering how to assign more than two learners to access the system at the same time, the competitive option is to choose a web-based approach. That is because a web-based environment not only supports distance learning but also allows more than two learners access at the same time. As a result of that, the web-based GOLeM is planned to be implemented in the future but this will still use the same characteristics of peer learning as it was for the peer-to-peer GOLeM.

7.4.3 Extend to consider about applying individual learner model in GOLeM

What we have done in the thesis is mainly to focus on comparing the benefit of *seeing* and *not seeing* the group learner model of *GLM* and *IdealGLM* for a computer-based collaborative learning environment. What we plan to do next is to bring the matter of *seeing* the 'Individual learner model' into account. This can lead to three areas of consideration.

The first area of interest is to see whether an individual learner model helps learners who do the test with peers in the group learning getting higher *concept-score* or *degree of confidence* when compared with learners who do the test individually. (Individual learning with *seeing ILM* (Individual Learner Model) vs. group learning with *seeing ILM*)

The second interest is that in a collaborative learning environment, is there any impact on score or *degree of confidence* if one group is able to see an individual learner model together with *GLM* and *IdealGLM* but another can see only the Individual learner model. (Group learning with *seeing ILM* vs. group learning with *seeing ILM*, *GLM* and *IdealGLM*)

The third area of interest is even simpler than the previous two. This focuses on how the results would have come out if the students had only seen their individual models and never seen the group model? (Group learning with *seeing ILM* vs. group learning with *seeing GLM* and *IdealGLM*)

We expect that after continuing our study further on these three areas of interest, we can come to a conclusion on how individual learner model and group learner model – represented here as *GLM* and *IdealGLM* have any impact on learning performance especially on learning score and *degree of confidence*. Moreover the results would lead to the suggestion of which learning environment – collaborative learning vs. solitary learning, and which way of representing the learner model is the most beneficial for learners for the content of *number-conversion*.

7.5.4 Extend the way of managing individual learner model in the GOLeM

As already stated in 7.5.3 regarding the idea of providing an individual learner model to learners that we plan to do in the future, here we are concerned with how the individual learner model is updated during the group-test in which learners are able to exchange information via the *chat-tool*. In this case we consider the way of updating this individual learner model in two respects.

The first respect is to use what each member has done and said via the *chat-tool* to update their own learner models individually (Assumption for this belief is that what learners express is what they believe and this belief might not be conveyed from what has been done in the group).

The second respect is to use the information that the group has done to update their own individual learner model (Assumption for this belief is that the group beliefs might convey individual beliefs after doing the test with peers).

7.5.5 Extend to apply questionnaires in all pre-test, group-test and post-test

In this thesis, we applied a questionnaire asking learners to state their *self-assessment* and *peer-assessment* only when they finished the pre-test and group-test but did not do it for the post-test. Therefore we missed the chance to see how well *GLM* and *IdealGLM* helped learners to improve the accuracy of their assessment performance including the consistency of the assessment performance when considered through the learning process of pre-test, group-test, and post-test.

Moreover this information might help us obtain more evidence for the correlation between the impact of assessment performance on the improvement of learning score and *degree of confidence*. Thus what we plan to do next is to include the questionnaire for learners to elicit *self-assessment* and *peer-assessment* after doing to the post-test for more concrete evidence to support for what we missed in this thesis.

7.4.6 Extend the way of pairing group members

Considering *I-Help* (Greer et al., 2001) in which each learner who uses this system, has their own personal agent that does things on behalf of their learners (negotiate, or require some help from the other agents). In order to ask for help from others, what learners do is to give their requirements to their personal agents. Apart from that, the personal agent has to connect and match for that agent that is most suitable for the requirements. The way which personal agents work for doing things on behalf of learners are kept behind the scene as a black box – require for what they (personal agents) want from learners and provide what they think learners want from them.

However there might be some cases that either you cannot agree on pairing with another or vice-versa. Therefore the idea of an artificial peer (Bull et al., 1999) is then taken into account. Considering how to apply an artificial peer to work with a learner instead of a human peer, the variety types of peers becomes an issue. Each type of artificial peer might be good at some specific learning concepts to encourage learners to experience on choosing peers who might help them most.

7.4.7 Extend to apply to other aspects of metacognition

Defined by Wilson (1998, p. 14), “Metacognition is the knowledge and awareness one has of their own thinking processes and strategies and the ability to evaluate and regulate one's own thinking processes” In this thesis, we used regulatory checklists (see Figure 3.1) that were derived from Schraw's work (1998), to explicitly elicit what learners thought, said, or did. The questions that we used are *how much does my peer knows* (*peer-assessment*), and *how much prior knowledge do I have* (*self-assessment*). What we are concerned further with is how to applied *theory of mind* to work with metacognition in order to be aware of '*what we know about what beliefs, desires and intentions learners are aware of about themselves or about others*'.

We are aware that during the learning process learners may have their own beliefs, desires and intention for doing things. However in this thesis, GOLeM is not designed to deal with the explicit way to elicit desires, intentions or other beliefs that are not related to the learning concepts. Moreover, the beliefs that learners can expressed, are only those related to the learning concepts that might stop them from showing their exact desires and intentions. As a result, what we expect to do further is to apply more questions in the regulatory checklists to elicit what learners have in mind for their beliefs, desires, and intentions during the group learning process in order to provide the right information to suit their needs at a particular time.

7.4.8 Extend to way of working on the results

We are aware that people who stay in the ZPD for some concepts/skill over the whole course of the study improve on some specific concepts/skills between the pre-test and the group-test but do not necessarily show improvement between the pre-test and the post-test. What we represented here is the result of overall six learning concepts that learners achieved in pre-test, group-test and post-test (See Table 6.60). However what is not displayed here but considered to be done as a future work is the study of the pattern that appears when look at individual learning concepts. We hope that the revealed information of individual learning concepts might be used as evidence to support the conclusion of the results.

7.5 Summary

This thesis involved building GOLeM – a learning environment that obtains the benefits of both concepts of collaborative learning and open learner modelling. The focus of GOLeM has two aspects. The first is to compare the learning performance of a collaborative learning environment (*Envi1*) against an individual learning environment (*Envi3*). The second one is to compare whether *seeing* (*Envi1*) and *not seeing* (*Envi2*) *GLM* and *IdealGLM* have an impact on learning performances. The learning performance used in this thesis is concerned with *concept-score* and *degree of confidence*.

GOLeM contains rules of *number-conversion* as domain knowledge. *Dialogue games* and *sentence openers* are used to implement a *chat-tool* to exchange beliefs between peers. Bar-charts and textual explanations are used as external representations of learning performance for both *GLM* and *IdealGLM*. The GOLeM was implemented and tested in two versions: paper-based, for the plausibility of the content and the user interface; and computer-based, for comparing the learning results among three different learning environments (*Envi1*, *Envi2* and *Envi3*).

Comparing learning performance between *Envi1* and *Envi3*, the results shows that there is a significant difference between learning score and *degree of confidence* at the 5% level (*Envi1* > *Envi3*). This leads to the conclusion that learners better improve their learning performance when they work with peers than on their own. Moreover with the respect of *seeing* and *not seeing* the *group learner model – GLM* and *IdealGLM* the results show that there is a slightly higher score (from the group-test and post-test), *degree of confidence*, and satisfaction levels of learning (from the given questionnaires providing during pre-test, post-test, and after finished using the GOLeM) in *Envi1* than *Envi2*.

It leads to the conclusion that in these specific circumstances, learners benefit more from learning in *Envi1* than *Envi2*. However the evidence that we have here is not sufficient to answer whether it is likely to be true that *Envi1*-like environments will always lead to better learning. As a result, we plan to continue our work on both similar and different directions to improve the strength of the conclusion that GOLeM helps learners to benefit from learning.

What we have done in the thesis is to explore a specific area of using *group learner models – GLM* and *IdealGLM*, whether it helps learners benefit in a collaborative learning environment. Nevertheless we already have in mind that there are many respects using to measure the improved of learning performance apart from providing *GLM* and *IdealGLM*.

What we are considered about as possible aspects that can be worked on in the future fall into these questions: *Do we ever need to have the individual model when working in groups?*, If so *how can we manage this individual model?*, *Shall we represent individual model together with group learner model?*, *Which type of learner model that might provide the best help to learners in a collaborative learning environment?, Is the result being the same if we change the learning platform from peer-to-peer to web-based?* If not, *what might cause the difference?*, *which type of pair that might be the best suit for learning with GOLeM?, if applied non-human peer to GOLeM will the result turn out the same way as human peer, if not what might cause the different?* Some of these questions are already mention in this thesis as a future work.

The evidence that we have found suggests that being able to see a GOLM improves learning. Though this evidence is weak, this thesis has provided the most thorough empirical examination of the benefits of a GOLM so far.

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Appendix A

30 Items Questionnaire Test

In appendix A, there are six documents that are used in order to validate the plausibility of '*number-conversion'* content. Section A.1 to A.6 contain detail of '*Questionnaire Invigilator Instruction'*, '*The 30 items questionnaire test*' and '*The answer sheet'* that used in the test for both Thai (See section A.1, A.3 and A.5) and English version (See section A.2, A.4, A.6).

A.1 A Thai version of Questionnaire Invigilator Instruction.

ข้อชี้แจงสำหรับผู้ควบคุมการทดสอบ

1 ห้ามแจ้งผู้ทำแบบทดสอบล่วงหน้า ถึงเนื้อหาที่จะทำการทดสอบ เพื่อวัดความรู้ความสามารถที่แท้จริง
2 นัดหมายและประกาศวันเวลา และสถานที่ สำหรับการทดสอบให้ผู้ทดสอบซึ่งเป็นนักศึกษาทุกชั้นปีของโปรแกรมวิชาคอมพิวเตอร์ คณะวิทยาศาสตร์และเทคโนโลยี สถาบันราชภัฏกาญจนบุรี ได้ทราบโดยทั่วกัน
3 จัดห้องในลักษณะเดียวกันกับการสอบกลางภาค และปลายภาค (ประมาณ 30-40 ที่นั่ง ต่อห้อง)
4 อนุญาตให้ผู้ทดสอบเข้านั่งในห้องสอบก่อนเวลาประมาณ 5 นาที
5 ผู้ควบคุมการทดสอบ ใช้เวลาประมาณ 10 นาที สำหรับการแจกแบบทดสอบ อธิบายขั้นตอนการทำแบบทดสอบ ตลอดจนตอบข้อซักถามของผู้ทดสอบ

    5.1 แจ้งให้ผู้ทดสอบตรวจสอบความสมบูรณ์ของแบบทดสอบ ซึ่งประกอบด้วยเอกสารทั้งสิ้น 5 แผ่น ประกอบด้วย เป้าหมายและวัตถุประสงค์ (หน้า 1), ตัวแบบทดสอบ (หน้า 2-4), กระดาษคำตอบ (หน้า 5)
    5.2 แจ้งให้ผู้ทดสอบกรอกข้อมูล<u>ส่วนตัว</u>ลงในแบบทดสอบให้สมบูรณ์
    5.3 แจ้งให้ผู้ทดสอบอ่านทำความเข้าใจแบบทดสอบ ก่อนลงมือทำ
    5.4 แจ้งเวลาให้ผู้ทดสอบทราบว่า เวลาที่ใช้ในการทดสอบมีเพียง 1 ชั่วโมง

6 เมื่อไม่มีข้อซักถามใดๆ จากผู้ทดสอบ อนุญาตให้ผู้ทดสอบลงมือทำแบบทดสอบได้
7 ให้ผู้ควบคุมการทดสอบ แจ้งเวลาเริ่มต้นและสิ้นสุดการทดสอบไว้บนกระดานดำ

8 ห้ามขัดจังหวะ หรือชี้แนะข้อมูลอันใดที่เกี่ยวข้องกับคำถามผู้ทดสอบ
9 ประกาศแจ้งเวลา เมื่อผ่านไป 30 นาที และประกาศอีกก่อนหมดเวลา 5 นาที
10 เมื่อครบ 1 ชั่วโมง ประกาศแจ้งให้ผู้ทดสอบ หยุดทำแบบทดสอบ
11 ผู้ควบคุมการทดสอบ ตรวจเช็คแบบทดสอบเพื่อให้มั่นใจว่า ผู้ทดสอบตอบทุกคำถามทุกข้ออย่างครบถ้วน
12 ตรวจเช็คว่า กระดาษคำตอบถูกเย็บติดกับแบบทดสอบอย่างเรียบร้อย
13 ขอบคุณผู้ทดสอบทุกคนที่ให้ความร่วมมือในการทำแบบทดสอบ
14 เก็บแบบทดสอบในที่ปลอดภัยและเป็นความลับ ก่อนที่จะนำส่งให้กับผู้วิจัยเพื่อทำการวิเคราะห์ข้อมูล

A.2 An English version of Questionnaire Invigilator Instruction.

Instruction for the Questionnaire invigilators

1. Do not tell the students about the topic in advance in order to measure the actual performance.
2. Make an appointment and then announce the exact date and time to all the students from the Department of Computer Science and Technology, Kanchanaburi Rajabhat University.
3. Set the rooms in the same way as you would when having an examination (30-40 places for each class/year)
4. Allow students to sit on their seats 5 minutes before the start.
5. The invigilator should spend 10 minutes distributing the questionnaire, giving the instruction and answering questions from the students.

   5.1 Ask students to check that they have all the sections of the questionnaire: goal and objective of the test (page1), main body of the test (page 2-4), answer sheet (page 5)

   5.2 Remind students to fill in all personal information in the space provided.

   5.3 Remind students to read the questionnaire to make sure that they understand it clearly before starting the test.

   5.4 Remind students that the test will take approximately one hour.

6. If there are no further questions, allow students to start answering the questionnaire.
7. Write down the start and finish time on the black board.
8. Do not intervene, or even give any information relating to the question.
9. Announce the time after 30 minutes and then again 5 minutes before the end of the examination.
10. After an hour, ask students to stop answering.
11. The invigilator should check the questionnaire to ensure that all items have been answered.
12. Make sure that the questionnaire is attached to the answer sheet.
13. Thank the students for their participation.
14. Keep questionnaires safe and confidential before passing them to the researcher for analysis.

A.3 The 30 items questionnaire test (Thai Version)

This questionnaire test is contained in four pages. The first page shows researchers name and address, objectives of the research, objectives of this specific 30 item test and confirmation of the confidentially of the test results. The second page contains the explanation of how to do this test and the remaining contain the test items.

A.3.1 Page 1 of questionnaire test (Thai)

คณะศึกษาศาสตร์
การแปลงเลขฐาน
ผลกระทบของการแสดงข้อมูลของผู้เรียนแบบกลุ่ม
ที่มีต่อการเรียน แบบเรียนรู้ร่วมกันผ่านสื่อทางคอมพิวเตอร์*

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วัตถุประสงค์ของการทดสอบ

เพื่อหาข้อมูลสนับสนุนในการจัดเตรียมเนื้อหาบทเรียนที่สอดคล้องกับความต้องการของผู้เรียน เพื่อใช้ในสร้างโปรแกรมคอมพิวเตอร์สำหรับการเรียนรู้แบบกลุ่ม โดยอนุญาตให้ผู้เรียนสนทนากับสมาชิกในกลุ่มระหว่างที่ทำงานกลุ่มโดยใช้โปรแกรมการสนทนาที่จัดเตรียมไว้ เนื้อหาบทเรียนที่ใช้ในการทดสอบครั้งนี้ คือเรื่องการแปลงเลขฐาน

แบบทดสอบชุดนี้ จะถูกนำไปใช้เป็นแบบสอบสำหรับวัดความรู้ของผู้เรียนในเรื่องการแปลงเลขฐาน ทั้งก่อนและหลังใช้โปรแกรมคอมพิวเตอร์สำหรับการเรียนรู้แบบกลุ่ม เพื่อตรวจสอบว่า หลังจากที่เรียนรู้ร่วมกันกับเพื่อนโดยใช้โปรแกรมคอมพิวเตอร์ที่จัดเตรียม ผู้เรียนสามารถเพิ่มความรู้ หรือความมั่นใจในเรื่องของการแปลงเลขฐานหรือไม่ อย่างไร

แบบทดสอบชุดนี้ ถูกออกแบบมาเพื่อใช้ทดสอบนักศึกษาที่กำลังศึกษาอยู่ระหว่างชั้นปีที่ 1 ถึงชั้นปีที่ 4 โปรแกรมวิชาคอมพิวเตอร์ คณะวิทยาศาสตร์และเทคโนโลยี มหาวิทยาลัยราชภัฏกาญจนบุรี โดยผู้เรียนเหล่านี้จะถูกแบ่งให้เรียนรู้เกี่ยวกับการแปลงเลขฐานในสภาพแวดล้อมการเรียนที่กำหนดเพื่อศึกษาว่า เป็นไปได้หรือไม่ที่การเรียนรู้ร่วมกันโดยที่รับรู้ข้อมูลความสามารถของกลุ่มมีส่วนช่วยในการเพิ่มพูนความรู้ ความสามารถของผู้เรียน

จุดประสงค์ของแบบทดสอบ:

1. เพื่อวัดความรู้ของผู้เรียนในการแปลงเลขฐาน จากฐานสอง, ฐานแปด และฐานสิบหกเป็นฐานสิบ
2. เพื่อวัดความรู้ของผู้เรียนในการบอกค่าประจำตำแหน่งของตัวเลขแต่ละบิต
3. เพื่อวัดความรู้ของผู้เรียนในการแปลงค่าของตัวเลข ให้อยู่ในรูปแบบต่างๆ ได้
4. เพื่อวัดความรู้ของผู้เรียนในการแปลงค่าของตัวเลขฐานต่างๆ ให้อยู่ในรูปของสมการของการแปลงเลขฐานได้
5. เพื่อวัดความรู้ของผู้เรียนในการคำนวณเพื่อหาผลลัพธ์ของการแปลงเลขฐานต่างๆ ให้เป็นฐานสิบได้

ขอให้มั่นใจว่า ข้อมูลที่ท่านได้ทำการทดสอบในครั้งนี้จะถูกเป็นความลับ และคะแนนที่ได้จากการทดสอบจะไม่มีผลเกี่ยวข้องใดๆ ทั้งสิ้นกับการคะแนนในชั้นเรียน ของท่าน

* งานวิจัยนี้ เป็นส่วนหนึ่งของการศึกษาระดับปริญญาเอก ที่ได้รับทุนสนับสนุนจากรัฐบาลไทย

A.3.2 Page 2, 3 and 4 of questionnaire test (Thai)

ข้อตกลงในการทำแบบทดสอบ

1. แบบทดสอบนี้เป็นแบบเลือกตอบสี่ตัวเลือก จำนวนทั้งสิ้น 30 ข้อ
2. โปรดเลือกกากบาทในช่อง **ก, ข, ค, ง** สำหรับตัวเลือกที่เห็นว่าถูกต้อง----- หรือ **จ** สำหรับข้อที่คิดว่าไม่มีตัวเลือกที่ถูกต้อง
3. อนุญาตให้ทำการคำนวณ ลงบนกระดาษคำถาม ส่วนคำตอบให้เขียนในกระดาษคำตอบที่จัดหาไว้ให้เท่านั้น
4. แบบทดสอบชุดนี้ใช้เวลาในการทำทั้งสิ้น 60 นาที

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1. ตัวเลขในตำแหน่งที่ขีดเส้นใต้ของ $\mathbf{\underline{1}011_2}$ เมื่อแปลงเป็นเลขฐานสิบ แล้ว มีค่าเท่ากับเท่าไร?
   - ก 6
   - ข 8
   - ค 12
   - ง 16
2. ตัวเลขในตำแหน่งที่ขีดเส้นใต้ของ $\mathbf{0.1\underline{1_2}}$ เมื่อแปลงเป็นเลขฐานสิบ แล้ว มีค่าเท่ากับเท่าไร?
   - ก 0.01
   - ข 0.25
   - ค 0.625
   - ง 0.75
3. ตัวเลขในตำแหน่งที่ขีดเส้นใต้ของ $\mathbf{\underline{1}10.\underline{1}1_2}$เมื่อแปลงเป็นเลขฐานสิบ แล้ว มีค่าเท่ากับเท่าไร?
   - ก 6 และ 0.5
   - ข 4 และ 0.25
   - ค 4 และ 0.5
   - ง 8 และ 0.25
4. ตัวเลขในตำแหน่งที่ขีดเส้นใต้ของ $\mathbf{\underline{1}011_2}$ เมื่อแปลงเป็นเลขฐานสิบ แล้ว มีค่าเท่ากับเท่าไร?
   - ก 1×10^3
   - ข 2+2+2
   - ค 2 x 3
   - ง 8
5. ตัวเลขในตำแหน่งที่ขีดเส้นใต้ของ $\mathbf{0.01\underline{1}_2}$ เมื่อแปลงเป็นเลขฐานสิบ แล้ว มีค่าเท่ากับเท่าไร?
   - ก 1×2^{-2}
   - ข 1/(2x2x2)
   - ค 0.001
   - ง 0.4

6. ตัวเลขในตำแหน่งที่ขีดเส้นใต้ของ $\mathbf{\underline{1}110.01\underline{1}_2}$ เมื่อแปลงเป็นเลขฐานสิบ แล้ว มีค่าเท่ากับเท่าไร?
   - ก 8 และ 1×2^{-2}
   - ข 16 และ 1/(2x2x2)
   - ค 2^3 และ 0.125
   - ง 8 และ 0.4

7. ตัวเลขในตำแหน่งที่ขีดเส้นใต้ของ $\mathbf{1\underline{110}_2}$ เมื่อแปลงเป็นฐานสิบ มีค่าตรงกับรูปสมการในข้อใด?
   - ก $(1 \times 2^2) +(1 \times 2^1) +(0 \times 2^0)$
   - ข $(1 + 2^2) \times (1 + 2^1) \times (0+ 2^0)$
   - ค $(1 \times 2^3) +(1 \times 2^2) +(0 \times 2^1)$
   - ง $(1 + 2^3) \times (1 + 2^2) \times (0 + 2^1)$

8. ตัวเลขในตำแหน่งที่ขีดเส้นใต้ของ $\mathbf{0.\underline{11}1_2}$ เมื่อแปลงเป็นฐานสิบ มีค่าตรงกับรูปสมการในข้อใด?
   - ก $(1 \times 2^0) +(1 \times 2^{-1})$
   - ข $(1 + 2^0) \times (1 + 2^{-1})$
   - ค $(1 \times 2^{-1}) +(1 \times 2^{-2})$
   - ง $(0 + 2^{-2}) \times (1 + 2^{-1})$

9. ตัวเลข $\mathbf{10111_2}$ เมื่อแปลงเป็นเลขฐานสิบ แล้ว มีค่าเท่ากับเท่าไร?
   - ก 21
   - ข 23
   - ค 25
   - ง 39

10. ตัวเลข $\mathbf{0.101_2}$ เมื่อแปลงเป็นเลขฐานสิบ แล้ว มีค่าเท่ากับเท่าไร?
    - ก 0.101
    - ข 0.5
    - ค 0.625
    - ง 0.75

11. ตัวเลขในตำแหน่งที่ขีดเส้นใต้ของ $\mathbf{\underline{1}11_8}$ เมื่อแปลงเป็นเลขฐานสิบ แล้ว มีค่าเท่ากับเท่าไร?
    - ก 32
    - ข 64
    - ค 100
    - ง 512

12. ตัวเลขในตำแหน่งที่ขีดเส้นใต้ของ $\mathbf{0.\underline{1}1_8}$ เมื่อแปลงเป็นเลขฐานสิบ แล้ว มีค่าเท่ากับเท่าไร?
    - ก 0.1
    - ข 0.125
    - ค 0.25
    - ง 0.5

13. ตัวเลขในตำแหน่งที่ขีดเส้นใต้ของ $\mathbf{1\underline{1}0.\underline{1}1}_8$ เมื่อแปลงเป็นเลขฐานสิบ แล้ว มีค่าเท่ากับเท่าไร?

ก 4 และ 0.25

ข 8 และ 0.25

ค 8 และ 0.125

ง 64 และ 0.125

14. ตัวเลขในตำแหน่งที่ขีดเส้นใต้ของ $\mathbf{\underline{1}01}_8$ เมื่อแปลงเป็นเลขฐานสิบ แล้ว มีค่าเท่ากับเท่าไร?

ก 1×10^3

ข 1+(8x8)

ค 8 x 3

ง 1×8^2

15. ตัวเลขในตำแหน่งที่ขีดเส้นใต้ของ $\mathbf{0.0\underline{1}}_8$ เมื่อแปลงเป็นเลขฐานสิบ แล้ว มีค่าเท่ากับเท่าไร?

ก 1×8^{-1}

ข 1/(8x8)

ค 0.64

ง 0.01

16. ตัวเลขในตำแหน่งที่ขีดเส้นใต้ของ $\mathbf{\underline{5}5.\underline{4}}_8$ เมื่อแปลงเป็นเลขฐานสิบ แล้ว มีค่าเท่ากับเท่าไร?

ก 40 และ 0.4

ข 40 และ 0.5

ค 50 และ 0.4

ง 50 และ 0.5

17. ตัวเลขในตำแหน่งที่ขีดเส้นใต้ของ $\mathbf{7\underline{156}}_8$ เมื่อแปลงเป็นฐานสิบ มีค่าตรงกับรูปสมการในข้อใด?

ก $(1 \times 8^2) +(5 \times 8^1) +(6 \times 8^0)$

ข $(1 + 8^2) \times(5 + 8^1) \times(6+ 8^0)$

ค $(1 \times 8^3) +(5 \times 8^2) +(6 \times 8^1)$

ง $(1 + 8^3) \times(5 + 8^2) \times(6 + 8^1)$

18. ตัวเลขในตำแหน่งที่ขีดเส้นใต้ของ $\mathbf{0.\underline{42}1}_8$ เมื่อแปลงเป็นฐานสิบ มีค่าตรงกับรูปสมการในข้อใด?

ก $(4 \times 8^0) +(2 \times 8^{-1})$

ข $(4 + 8^0) \times(2 + 8^{-1})$

ค $(4 \times 8^{-1}) +(2 \times 8^{-2})$

ง $(4 + 8^{-2}) \times(2 + 8^{-1})$

19. ตัวเลข $\mathbf{75}_8$ เมื่อแปลงเป็นเลขฐานสิบ แล้ว มีค่าเท่ากับเท่าไร?

ก 56

ข 61

ค 75

ง 96

20. ตัวเลข **0.60_8** เมื่อแปลงเป็นเลขฐานสิบ แล้ว มีค่าเท่ากับเท่าไร?
    - ก 0.48
    - ข 0.6
    - ค 0.625
    - ง 0.75

21. ตัวเลขในตำแหน่งที่ขีดเส้นใต้ของ **<u>1</u>11**$_{16}$ เมื่อแปลงเป็นเลขฐานสิบ แล้ว มีค่าเท่ากับเท่าไร?
    - ก 16
    - ข 32
    - ค 64
    - ง 256

22. ตัวเลขในตำแหน่งที่ขีดเส้นใต้ของ **0.<u>1</u>**$_{16}$ เมื่อแปลงเป็นเลขฐานสิบ แล้ว มีค่าเท่ากับเท่าไร?
    - ก 0.1
    - ข 0.16
    - ค 0.0625
    - ง 0.625

23. ตัวเลขในตำแหน่งที่ขีดเส้นใต้ของ **<u>1</u>10.<u>1</u>1**$_{16}$ เมื่อแปลงเป็นเลขฐานสิบ แล้ว มีค่าเท่ากับเท่าไร?
    - ก 100 และ 0.1
    - ข 16 และ 0.05
    - ค 256 และ 0.05
    - ง 256 และ 0.0625

24. ตัวเลขในตำแหน่งที่ขีดเส้นใต้ของ **<u>1</u>11**$_{16}$ เมื่อแปลงเป็นเลขฐานสิบ แล้ว มีค่าเท่ากับเท่าไร?
    - ก 1×10^2
    - ข 16x16x16
    - ค 16 x 3
    - ง 64

25. ตัวเลขในตำแหน่งที่ขีดเส้นใต้ของ **0.01<u>1</u>**$_{16}$ เมื่อแปลงเป็นเลขฐานสิบ แล้ว มีค่าเท่ากับเท่าไร?
    - ก 1×16^{-2}
    - ข 1/(16x16)
    - ค 16/1000
    - ง 0.001

26. ตัวเลขในตำแหน่งที่ขีดเส้นใต้ของ **<u>5</u>5.<u>8</u>**$_{16}$ เมื่อแปลงเป็นเลขฐานสิบ แล้ว มีค่าเท่ากับเท่าไร?
    - ก 50 และ 0.8
    - ข 50 และ 8/(16)
    - ค 16 x 5 และ 0.5
    - ง 16 x 5 และ 0.4

27. ตัวเลขในตำแหน่งที่ขีดเส้นใต้ของ $\mathbf{1\underline{451}_{16}}$ เมื่อแปลงเป็นฐานสิบ มีค่าตรงกับรูปสมการในข้อใด?

ก $(4 \times 16^{2}) + (5 \times 16^{1}) + (1 \times 16^{0})$

ข $(1 \times 16^{2}) \times (5 \times 16^{1}) \times (4 \times 16^{0})$

ค $(4 \times 16^{3}) + (5 \times 16^{2}) + (1 \times 16^{1})$

ง $(1 + 16^{3}) \times (5 + 16^{2}) \times (4 + 16^{1})$

28. 28. ตัวเลขในตำแหน่งที่ขีดเส้นใต้ของ $\mathbf{0.\underline{12}1_{16}}$ เมื่อแปลงเป็นฐานสิบ มีค่าตรงกับรูปสมการในข้อใด?

ก $(1 \times 16^{0}) + (2 \times 16^{-1})$

ข $(2 \times 16^{0}) + (1 \times 16^{-1})$

ค $(1 \times 16^{-1}) + (2 \times 16^{-2})$

ง $(1 + 16^{-2}) \times (2 + 16^{-1})$

29. ตัวเลข $\mathbf{123_{16}}$ เมื่อแปลงเป็นเลขฐานสิบ แล้ว มีค่าเท่ากับเท่าไร?

ก 123

ข 135

ค 279

ง 291

30. ตัวเลข $\mathbf{0.88_{16}}$ เมื่อแปลงเป็นเลขฐานสิบ แล้ว มีค่าเท่ากับเท่าไร?

ก 0.55

ข 0.60

ค 0.625

ง 0.75

ขอขอบคุณทุกท่าน สำหรับความร่วมมือ

A.4 : The 30 items questionnaire test (English Version)

This questionnaire test is contained in four pages. The first page shows researchers name and address, objectives of the research, objectives of this specific 30 item test and confirmation of the confidentially of the results. The second page contains the explanation of how to do this test and the remaining pages contain the test items.

A.4.1 Page 1 of questionnaire test (English)

Faculty *of* Education

NUMBER CONVERSION

The Impact of a Group Open Learner Model on Learning in a Computer-based Collaborative Learning Environment.*

Researcher: Miss Nilubon Tongchai (PhD student)
Email: nilubont@educ.gla.ac.uk Tel: 07921186383
Address: Room 445, St Andrew's Building,
Glasgow University, Glasgow, G3 6NH

Supervisor: Prof. Paul Brna (Principal Supervisor)
Email: paul.brna@scre.ac.uk Tel: 0141-3301917
Address: The SCRE Centre, St Andrew's Building,
Glasgow University, Glasgow, G3 6NH

Goal of the test:

To provide information that will help me build the computer system, Tutor Peer-OLM, that allows learners to communicate while doing the task and then giving help by intervening at the right time, in the specific context which is *number-conversion*.

This questionnaire will be used as a pre-test and post-test for measuring knowledge of learners in the context of number conversion, which consists of the conversion of decimal into binary, octal and hexadecimal numbers, in order to see that after learning with friends in this computer-based collaborative learning environment, learners can get higher score or improved degree of confidence.

This questionnaire is administered to undergraduate students in the Department of Computer Science and Technology, Kanchanaburi Rajabhat University. These students will be arranged to learn in three different learning environments to prove that learning with friends and seeing how well the group perform may help learners improve their knowledge.

Objectives of the test:

1. To measure knowledge of converting a number from Binary to Decimal
2. To measure knowledge of converting a number from Octal to Decimal
3. To measure knowledge of converting a number from Hexadecimal to Decimal
4. To measure knowledge of using the right weight for each bit position
5. To measure knowledge of transforming provided values into other formats.
6. To measure knowledge of using an equation and replacing values into correct bit positions.
7. To measure knowledge of calculating for the final solution of each question.

Please be assured that your response will be completely confidential and that your score has absolutely no effect on any of your academic performance.

* This research is funded by a studentship from the Royal Thai Government

A.4.2: Page 2, 3 and 4 of questionnaire test (English)

Instructions:

1. This test contains 30 multiple choice questions.
2. Please select either **a, b, c, d** ------or **e** in case that none of the provided answers is correct.
3. You may do calculations on the questionnaire but provide your answer only on the answer sheet.
4. Please finish the test within 1 hour.

---

1. What is the value of the underlined position of $\mathbf{\underline{1}011_2}$ after being converted into **Base10**?
   a. 6
   b. 8
   c. 12
   d. 16

2. What is the value of the underlined position of $\mathbf{0.1\underline{1}_2}$ after being converted into **Base10**?
   a. 0.01
   b. 0.25
   c. 0.625
   d. 0.75

3. What are values of underlined positions of $\mathbf{\underline{1}10.\underline{1}1_2}$ after being converted into **Base10**?
   a. 6 and 0.5
   b. 4 and 0.25
   c. 4 and 0.5
   d. 8 and 0.25

4. What has the same value as the underlined position of $\mathbf{\underline{1}011_2}$ after being converted into **Base10**?
   a. 1×10^3
   b. 2+2+2
   c. 2 x 3
   d. 8

5. What has the same value as the underlined position of $\mathbf{0.01\underline{1}_2}$ after being converted into **Base10**?
   a. 1×2^{-2}
   b. 1/(2x2x2)
   c. 0.001
   d. 0.4

6. What has the same values as the underlined positions of $\mathbf{\underline{1}110.01\underline{1}}_2$ after being converted into **Base10**?
   a. 8 and $1 \text{ x } 2^{-2}$
   b. 16 and 1/(2x2x2)
   c. 2^3 and 0.125
   d. 8 and 0.4

7. What is the value of the underlined positions of $\mathbf{1\underline{110}}_2$ in term of equation after being converted into **Base10**?
   a. $(1 \text{ x } 2^2) + (1 \text{ x } 2^1) + (0 \text{ x } 2^0)$
   b. $(1 + 2^2) \text{ x}(1 + 2^1) \text{ x}(0 + 2^0)$
   c. $(1 \text{ x } 2^3) + (1 \text{ x } 2^2) + (0 \text{ x } 2^1)$
   d. $(1 + 2^3) \text{ x}(1 + 2^2) \text{ x}(0 + 2^1)$

8. What is the value of the underlined positions of $\mathbf{0.\underline{11}1}_2$ in term of equation after being converted into **Base10**?
   a. $(1 \text{ x } 2^0) + (1 \text{ x } 2^{-1})$
   b. $(1 + 2^0) \text{ x}(1 + 2^{-1})$
   c. $(1 \text{ x } 2^{-1}) + (1 \text{ x } 2^{-2})$
   d. $(0 + 2^{-2}) \text{ x}(1 + 2^{-1})$

9. What is the value of $\mathbf{10111}_2$ after being converted into **Base10**?
   a. 21
   b. 23
   c. 25
   d. 39

10. What is the value of $\mathbf{0.101}_2$ after being converted into **Base10**?
   a. 0.101
   b. 0.5
   c. 0.625
   d. 0.75

11. What is the value of the underlined position of $\mathbf{\underline{1}11}_8$ after being converted into **Base10**?
   a. 32
   b. 64
   c. 100
   d. 512

12. What is the value of the underlined position of $\mathbf{0.\underline{1}1}_8$ after being converted into **Base10**?
   a. 0.1
   b. 0.125
   c. 0.25
   d. 0.5

13. What are values of underlined positions of $\mathbf{1\underline{1}0.\underline{1}1}_8$ after being converted into **Base10**?
    a. 4 and 0.25
    b. 8 and 0.25
    c. 8 and 0.125
    a. 64 and 0.125

14. What has the same value as the underlined position of $\mathbf{\underline{1}01}_8$ after being converted into **Base10**?
    a. 1×10^3
    b. 1+(8x8)
    c. 8 x 3
    d. 1×8^2

15. What has the same value as the underlined position of $\mathbf{0.0\underline{1}}_8$ after being converted into **Base10**?
    a. 1×8^{-1}
    b. 1/(8x8)
    c. 0.64
    d. 0.01

16. What has the same values as the underlined positions of $\mathbf{\underline{5}5.\underline{4}}_8$ after being converted into **Base10**?
    a. 40 and 0.4
    b. 40 and 0.5
    c. 50 and 0.4
    d. 50 and 0.5

17. What is the value of the underlined positions of $\mathbf{7\underline{156}}_8$ in term of equation after being converted into **Base10**?
    a. $(1 \times 8^2) + (5 \times 8^1) + (6 \times 8^0)$
    b. $(1 + 8^2) \times (5 + 8^1) \times (6 + 8^0)$
    c. $(1 \times 8^3) + (5 \times 8^2) + (6 \times 8^1)$
    d. $(1 + 8^3) \times (5 + 8^2) \times (6 + 8^1)$

18. What is the value of the underlined positions of $\mathbf{0.\underline{42}1}_8$ in term of equation after being converted into **Base10**?
    a. $(4 \times 8^0) + (2 \times 8^{-1})$
    b. $(4 + 8^0) \times (2 + 8^{-1})$
    c. $(4 \times 8^{-1}) + (2 \times 8^{-2})$
    d. $(4 + 8^{-2}) \times (2 + 8^{-1})$

19. What is the value of $\mathbf{75}_8$ after being converted into **Base10**?
    a. 56
    b. 61
    c. 75
    d. 96

20. What is the value of $\mathbf{0.60}_{8}$ after being converted into **Base10**?
    a. 0.48
    b. 0.6
    c. 0.625
    d. 0.75

21. What is the value of the underlined position of $\mathbf{\underline{1}11}_{16}$ after being converted into **Base10**?
    a. 16
    b. 32
    c. 64
    d. 256

22. What is the value of the underlined position of $\mathbf{0.\underline{1}}_{16}$ after being converted into **Base10**?
    a. 0.1
    b. 0.16
    c. 0.0625
    d. 0.625

23. What are values of underlined positions of $\mathbf{\underline{1}10.\underline{1}1}_{16}$ after being converted into **Base10**?
    a. 100 and 0.1
    b. 16 and 0.05
    c. 256 and 0.05
    d. 256 and 0.0625

24. What has the same value as the underlined position of $\mathbf{\underline{1}11}_{16}$ after being converted into **Base10**?
    a. 1×10^{2}
    b. 16x16x16
    c. 16 x 3
    d. 64

25. What has the same value as the underlined position of $\mathbf{0.01\underline{1}}_{16}$ after being converted into **Base10**?
    a. 1×16^{-2}
    b. 1/(16x16)
    c. 16/1000
    d. 0.001

26. What has the same values as the underlined positions of $\mathbf{\underline{5}5.\underline{8}}_{16}$ after being converted into **Base10**?
    a. 50 and 0.8
    b. 50 and 8/(16)
    c. 16 x 5 and 0.5
    d. 16 x 5 and 0.4

27. What is the value of the underlined positions of **1451**$_{16}$ in term of equation after being converted into **Base10**?
    e. $(4 \times 16^2) + (5 \times 16^1) + (1 \times 16^0)$
    f. $(1 \times 16^2) \times (5 \times 16^1) \times (4 \times 16^0)$
    g. $(4 \times 16^3) + (5 \times 16^2) + (1 \times 16^1)$
    h. $(1 + 16^3) \times (5 + 16^2) \times (4 + 16^1)$

28. What is the value of the underlined positions of **0.121**$_{16}$ in term of equation after being converted into **Base10**?
    a. $(1 \times 16^0) + (2 \times 16^{-1})$
    b. $(2 \times 16^0) + (1 \times 16^{-1})$
    c. $(1 \times 16^{-1}) + (2 \times 16^{-2})$
    d. $(1 + 16^{-2}) \times (2 + 16^{-1})$

29. What is the value of **123**$_{16}$ after being converted into **Base10**?
    a. 123
    b. 135
    c. 279
    d. 291

30. What is the value of **0.88**$_{16}$ after being converted into **Base10**?
    a. 0.55
    b. 0.60
    c. 0.625
    d. 0.75

Thank You Very Much For Your Participation

A.5 : The Answer Sheet (Thai Version)

กระดาษคำตอบสำหรับแบบทดสอบการแปลงเลขฐาน

ชื่อ-สกุล ______________________________รหัสประจำตัว_____________ชั้นปี______

วันที่ทำแบบทดสอบ ____________ (วันที่ / เดือน / ปีพ.ศ.) ใช้เวลาทำแบบทดสอบ ______นาที

เมื่อเสร็จสิ้นการทำแบบทดสอบ ขอให้ผู้ทดสอบเติมตัวเลขลงในข้อ 1-4 ให้สอดคล้องกับความสามารถของตนเอง (โปรดตรวจสอบว่า ค่าที่กำหนดลงในข้อ 1, 2, 3 และ 4 เมื่อรวมกันแล้ว มีค่าเท่ากับ 30)

1. ฉันมั่นใจที่สุดว่า คำตอบจำนวน______ข้อ ถูกต้องทั้งหมด
2. ฉันมั่นใจว่า คำตอบจำนวน______ข้อ ถูกต้องทั้งหมด
3. ฉันไม่ค่อยมั่นใจว่า คำตอบจำนวน______ ข้อ ถูกต้องทั้งหมด
4. ฉันรู้ว่ามีจำนวนข้อที่ทำผิดทั้งสิ้น ______ ข้อ

กรุณาเติมสัญลักษณ์ X’ ลงในข้อ ก, ข, ค, ง ----------- หรือ จ ในกรณีที่ไม่มีตัวเลือกใดที่เหมาะสม

ตัวเลือก /เลขข้อ	ก	ข	ค	ง	จ		ตัวเลือก /เลขข้อ	ก	ข	ค	ง	จ
1	( )	( )	( )	( )	( )		**16**	( )	( )	( )	( )	( )
2	( )	( )	( )	( )	( )		**17**	( )	( )	( )	( )	( )
3	( )	( )	( )	( )	( )		**18**	( )	( )	( )	( )	( )
4	( )	( )	( )	( )	( )		**19**	( )	( )	( )	( )	( )
5	( )	( )	( )	( )	( )		**20**	( )	( )	( )	( )	( )
6	( )	( )	( )	( )	( )		**21**	( )	( )	( )	( )	( )
7	( )	( )	( )	( )	( )		**22**	( )	( )	( )	( )	( )
8	( )	( )	( )	( )	( )		**23**	( )	( )	( )	( )	( )
9	( )	( )	( )	( )	( )		**24**	( )	( )	( )	( )	( )
10	( )	( )	( )	( )	( )		**25**	( )	( )	( )	( )	( )
11	( )	( )	( )	( )	( )		**26**	( )	( )	( )	( )	( )
12	( )	( )	( )	( )	( )		**27**	( )	( )	( )	( )	( )
13	( )	( )	( )	( )	( )		**28**	( )	( )	( )	( )	( )
14	( )	( )	( )	( )	( )		**29**	( )	( )	( )	( )	( )
15	( )	( )	( )	( )	( )		**30**	( )	( )	( )	( )	( )

A.6 The Answer Sheet (English Version)

Answer Sheet for Number Conversion Test

Name/Surname: ________________ID ___________Year____________

Date of testing: ______________ (Day/Month/Year) Finish the test in ________minutes

---

After finishing the test, please fill in the blank areas of items 1-4 with numbers that related to your real performance. (Please make sure that the addition of values in 1, 2, 3 and 4 equal 30)

1. I am very confident that ________items have been answered correctly
2. I am confident that _________items have been answered correctly
3. I am not very confident that _________ items have been answered correctly
4. I know I have answered _________ items incorrectly.

Please use the symbol ‘X’ in either A, B, C or D ------ or E in case that no choice is correct

ตัวเลือก /เลขข้อ	**ก**	**ข**	**ค**	**ง**	**จ**		**ตัวเลือก /เลขข้อ**	**ก**	**ข**	**ค**	**ง**	**จ**
1	( )	( )	( )	( )	( )		**16**	( )	( )	( )	( )	( )
2	( )	( )	( )	( )	( )		**17**	( )	( )	( )	( )	( )
3	( )	( )	( )	( )	( )		**18**	( )	( )	( )	( )	( )
4	( )	( )	( )	( )	( )		**19**	( )	( )	( )	( )	( )
5	( )	( )	( )	( )	( )		**20**	( )	( )	( )	( )	( )
6	( )	( )	( )	( )	( )		**21**	( )	( )	( )	( )	( )
7	( )	( )	( )	( )	( )		**22**	( )	( )	( )	( )	( )
8	( )	( )	( )	( )	( )		**23**	( )	( )	( )	( )	( )
9	( )	( )	( )	( )	( )		**24**	( )	( )	( )	( )	( )
10	( )	( )	( )	( )	( )		**25**	( )	( )	( )	( )	( )
11	( )	( )	( )	( )	( )		**26**	( )	( )	( )	( )	( )
12	( )	( )	( )	( )	( )		**27**	( )	( )	( )	( )	( )
13	( )	( )	( )	( )	( )		**28**	( )	( )	( )	( )	( )
14	( )	( )	( )	( )	( )		**29**	( )	( )	( )	( )	( )
15	( )	( )	( )	( )	( )		**30**	( )	( )	( )	( )	( )

Appendix B

Paper-based design and Example of How does it works

In Appendix B, firstly we introduced the composition details of GOLeM's paper-based design in section B.1. This paper-based design consists of components as displayed in Figure B.1 from A to I. More details of these A to I components are explained in B.1.1 to B.1.9.

Secondly in section B.2, the illustration of how this GOLeM's paper-based design works is given as an example. This section shows communication dialogue that group members made during the group-test. Moreover focusing on the way that system updates the group learner model relies on what the group perform – both group-test and communication.

Finally the summary of the results and comments on the design are explained in section B.3. These are concerned with how the majority group of learners performs and what they want to see from the later version of the GOLeM.

B.1 Composition details of the paper-based design

As seen in Figure B.1, there are varieties of documents that are produced as a paper-based tool for participants to do the test as a group of two. This tool consists of components **A-I.** The detail of these components will be orderly introduced starting from **A** and finishing with **I**.

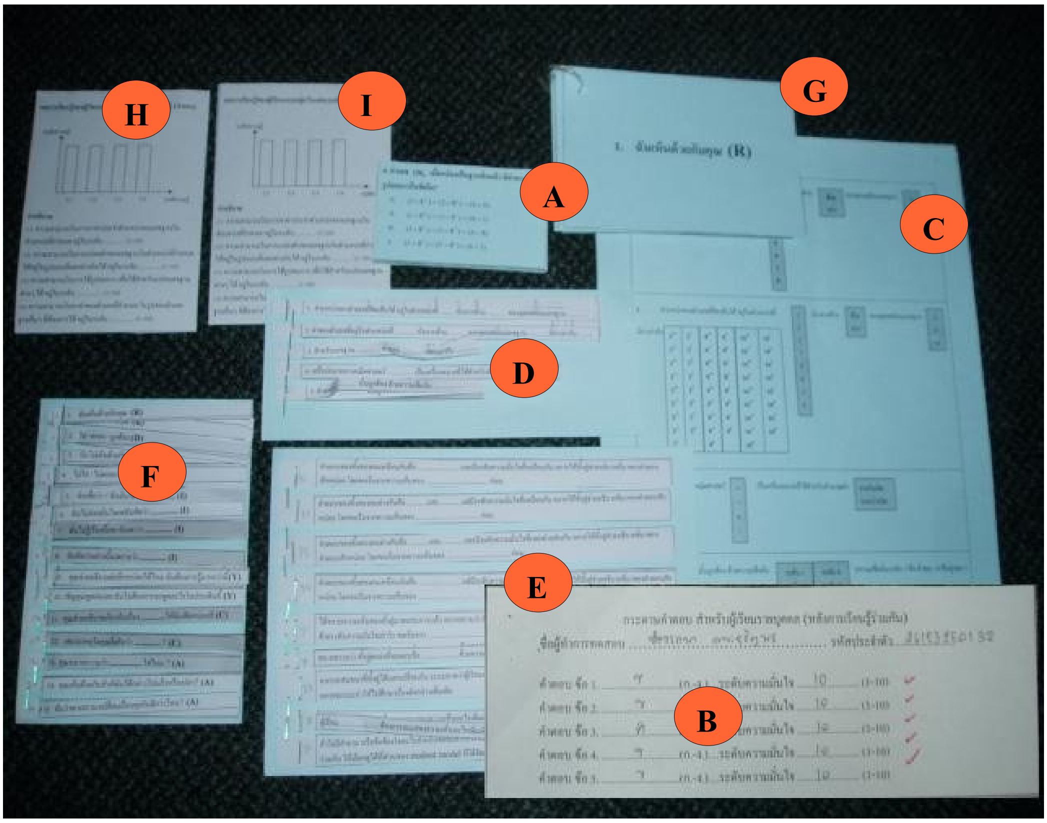


Figure B.1. The paper-based design of GOLeM

B.1.1 The detail of component A

This component contains five questions which are provided in this learning environment as pre-test, group-test and post-test. Detail of these five questions is displayed below.

1. ตัวเลขในตำแหน่งที่ขีดเส้นใต้ของ $\underline{1}11_8$ เมื่อแปลงเป็นฐานสิบแล้ว มีค่าเท่ากับเท่าไร?

   ก. 32
   ข. 64
   ค. 100
   ง. 512

2. ตัวเลขในตำแหน่งที่ขีดเส้นใต้ของ $\underline{1}01_8$ เมื่อแปลงเป็นฐานสิบแล้ว มีค่าเท่ากับเท่าไร?

   ก. 1×10^2
   ข. 1×8^2
   ค. 1×10^2
   ง. 1×8^3

3. ตัวเลขในตำแหน่งที่ขีดเส้นใต้ของ $\underline{7}02_8$ เมื่อแปลงเป็นฐานสิบแล้ว มีค่าเท่ากับเท่าไร?

ก. $7 \times 10 \times 10$
ข. $7 + (8 \times 8)$
ค. $7 \times (8 \times 8)$
ง. 7×8

4. ตัวเลข $\underline{156_8}$ เมื่อแปลงเป็นฐานสิบแล้ว มีค่าตรงกับรูปสมการในข้อใด?

ก. $(1 \times 8^2) + (5 \times 8^1) + (6 \times 0)$
ข. $(1 \times 8^2) + (5 \times 8^1) + (6 \times 1)$
ค. $(1 \times 8^3) + (5 \times 8^2) + (6 \times 8)$
ง. $(1 + 8^2) \times (5 + 8^1) \times (6 + 1)$

5. ตัวเลข 75_8 เมื่อแปลงเป็นฐานสิบแล้ว มีค่าเท่ากับเท่าใด?

ก. 56
ข. 61
ค. 75
ง. 96

B.1.2 The detail of component B

This component contains three forms of answer sheets which are provided to participants for pre-test, group-test, and post-test. Detail of these forms is displayed in section B.1.2.1 to B.1.2.3.

B.1.2.1 Answer sheet for pre-test

กระดาษคำตอบ สำหรับผู้เรียนรายบุคคล (ก่อนการเรียนรู้ร่วมกัน)

ชื่อผู้ทำการทดสอบ …….………………......……………….................

คำตอบ ข้อ 1. ....(ก.-ง.)....ระดับความมั่นใจ .... (1-10)
คำตอบ ข้อ 2. ....(ก.-ง.)....ระดับความมั่นใจ .... (1-10)
คำตอบ ข้อ 3. ....(ก.-ง.)....ระดับความมั่นใจ .... (1-10)
คำตอบ ข้อ 4. ....(ก.-ง.)....ระดับความมั่นใจ .... (1-10)
คำตอบ ข้อ 5. ....(ก.-ง.)....ระดับความมั่นใจ .... (1-10)

B.1.2.2 Answer sheet for group-test

กระดาษคำตอบ สำหรับผู้ที่เรียนรู้ร่วมกัน

ชื่อผู้ทำการทดสอบ ....

ชื่อผู้ทำการทดสอบ ....

คำตอบ ข้อ 1. ....(ก.-ง.)....ระดับความมั่นใจ .... (1-10)

คำตอบ ข้อ 2. ....(ก.-ง.)....ระดับความมั่นใจ .... (1-10)

คำตอบ ข้อ 3. ....(ก.-ง.)....ระดับความมั่นใจ .... (1-10)

คำตอบ ข้อ 4. ....(ก.-ง.)....ระดับความมั่นใจ .... (1-10)

คำตอบ ข้อ 5. ....(ก.-ง.)....ระดับความมั่นใจ .... (1-10)

B.1.2.3 Answer sheet for post-test

กระดาษคำตอบ สำหรับผู้เรียนรายบุคคล (หลังการเรียนรู้ร่วมกัน)

ชื่อผู้ทำการทดสอบ ....

คำตอบ ข้อ 1. ....(ก.-ง.)....ระดับความมั่นใจ .... (1-10)

คำตอบ ข้อ 2. ....(ก.-ง.)....ระดับความมั่นใจ .... (1-10)

คำตอบ ข้อ 3. ....(ก.-ง.)....ระดับความมั่นใจ .... (1-10)

คำตอบ ข้อ 4. ....(ก.-ง.)....ระดับความมั่นใจ .... (1-10)

คำตอบ ข้อ 5. ....(ก.-ง.)....ระดับความมั่นใจ .... (1-10)

B.1.3 The detail of component C

This component contains specific information of number-conversion used to complete the sentence which has utterances that contain '...'. Detail of these sentences are displayed in Table B.1

Table B.1. Detail of using these five *utterances* with *sentence openers* that contain '...'

1. ตำแหน่งของตัวเลขที่ขีดเส้นใต้ อยู่ในตำแหน่งที่ [1 2 3 4 5 6 7 8] นับจากด้าน [ซ้าย ขวา] ของจุดทศนิยมเลขฐาน [2 8 16]
2. ตำแหน่งของตัวเลขที่ขีดเส้นใต้ อยู่ในตำแหน่งที่ [1 2 3 4 5 6 7 8] นับจากด้าน [ซ้าย ขวา] ของจุดทศนิยมเลขฐาน [2 8 16] มีค่าเท่ากับ [2^{-8} 2^{-7} 2^{-6} 2^{-5} 2^{-4} 2^{-3} 2^{-2} 2^{-1} 2^{0}] [2^{1} 2^{2} 2^{3} 2^{4} 2^{5} 2^{6} 2^{7} 2^{8}] [8^{-8} 8^{-7} 8^{-6} 8^{-5} 8^{-4} 8^{-3} 8^{-2} 8^{-1} 8^{0}] [8^{1} 8^{2} 8^{3} 8^{4} 8^{5} 8^{6} 8^{7} 8^{8}] [16^{-8} 16^{-7} 16^{-6} 16^{-5} 16^{-4} 16^{-3} 16^{-2} 16^{-1} 16^{0}] [16^{1} 16^{2} 16^{3} 16^{4} 16^{5} 16^{6} 16^{7} 16^{8}]
4. เครื่องหมายทางคณิตศาสตร์ [+ - x /] เป็นเครื่องหมายที่ใช้สำหรับคำนวณค่า [ภายในบิต ระหว่างบิต]
5. คำตอบ [ก. ข. ค. ง.] นั้นถูกต้อง ด้วยความเชื่อมั่น [ระดับ 1 ระดับ 2 ... ระดับ 9 ระดับ 10] (ความเชื่อมั่นระดับ 1 คือ ต่ำสุด, 10 คือสูงสุด)

B.1.4 The detail of component D

This component contains information of incomplete sentences or *utterances.* There are 5 *utterances* introduced here used as complement to complete the sentence. Detail of these sentences are displayed in Table B.2

Table B.2. Five *utterances* provided in paper-based version of GOLeM

Utterances 1	ตำแหน่งของตัวเลขที่ขีดเส้นใต้ อยู่ในตำแหน่งที่ ..... นับจากด้าน .... ของจุดทศนิยมเลขฐาน ....
Utterances 2	ค่าของตัวเลขที่อยู่ในตำแหน่งที่ ....นับจากด้าน.............ของจุดทศนิยมเลขฐาน........... มีค่าเท่ากับ ....
Utterances 3	สำหรับเลขฐาน .... ค่าของ ....มีค่าเท่ากับ ....
Utterances 4	เครื่องหมายทางคณิตศาสตร์ .... เป็นเครื่องหมายที่ใช้สำหรับคำนวณค่า ....
Utterances 5	คำตอบ .... นั้นถูกต้อง ด้วยความเชื่อมั่น ....

B.1.5 The detail of component E

This component contains sentences used by the system to intervene the conversation if necessary. Detail of these sentences is displayed subsection B.1.5.1 to B.1.5.9.

B.1.5.1 If learners have both the same answers and degree of confidence, the system will intervene with the sentence below

คำตอบของทั้งสองคนเหมือนกันคือ .... และมีระดับความมั่นใจที่เหมือนกัน อยากให้ทั้งคู่ช่วยอธิบายที่มาของคำตอบสักหน่อย โดยขอเริ่มจากความเห็นของ .... ก่อน

B.1.5.2 If learners have different answers but the same degree of confidence, the system will intervene with the sentence below

คำตอบของทั้งสองคนต่างกันคือ ....และ............. แต่มีระดับความมั่นใจที่เหมือนกัน อยากให้ทั้งคู่ช่วยอธิบายที่มาของคำตอบสักหน่อย โดยขอเริ่มจากความเห็นของ .... ก่อน

B.1.5.3 If learners have both different answers and degree of confidence, the system will intervene with the sentence below

คำตอบของทั้งสองคนต่างกันคือ ....และ............. และมีระดับความมั่นใจที่แตกต่างเช่นกัน อยากให้ทั้งคู่ช่วยอธิบายที่มาของคำตอบสักหน่อย โดยขอเริ่มจากความเห็นของ .... ก่อน

B.1.5.4 If learners have the same answers but different degree of confidence, the system will intervene with the sentence below

คำตอบของทั้งสองคนเหมือนกันคือ .... แต่มีระดับความมั่นใจที่แตกต่างกัน อยากให้ทั้งคู่ช่วยอธิบายที่มาของคำตอบสักหน่อย โดยขอเริ่มจากความเห็นของ .... ก่อน

B.1.5.5 If learners cannot come up with the group answer after having a long conversation, the system will intervene with the sentence below

ได้ทราบความเห็นของทั้งคู่มาพอสมควรแล้ว อยากทราบว่า ถ้าต้องเลือกเพียงคำตอบเดียวสำหรับกลุ่มจะตกลงเลือกตอบในข้อใด ด้วยระดับความมั่นใจเท่าไร ขอเริ่มจาก .... ก่อน

B.1.5.6 If the group come up with the final answer, the system will confirm their the answer with the sentence below

หมายความว่า ทั้งคู่ตกลงที่จะตอบข้อ .... ด้วยความมั่นใจระดับ........................ ใช่หรือไม่

B.1.5.7 If the system finds out those group members might have misconception about particular concepts of '*number-conversion*', it will suggest with the sentence below

จากบทสนทนาที่ทั้งคู่ได้แลกเปลี่ยนกัน ระบบคาดว่าผู้เรียนอาจสับสนเกี่ยวกับ................. ....ดังนั้น จึงอยากจะแนะนำให้ไปศึกษาเรื่องดังกล่าวเพิ่มเติม

B.1.5.8 The system asks the particular members whether they have the anything to ask or not with this sentence

ผู้เรียน....................... ต้องการจะแสดงความเห็นอะไรเพิ่มเติมหรือเปล่า

B.1.5.9 If learners have nothing to ask, the system will encourage them to continue doing the group-test with this sentence

ถ้าไม่มีคำถาม หรือข้อข้องใจอะไรสำหรับข้อนี้แล้ว เราก็ไปทำข้อต่อไปกันเลย ถ้าทั้งคู่อยากจะทราบความสามารถในการเรียนรู้แบบร่วมกัน ให้เลือกดูได้ที่ส่วนของ student model ที่ได้จัดเตรียมไว้ให้

B.1.6 The detail of component F and G

The component F contains 15 *sentence openers* which are used to start the sentence. The rules of how to use *sentence openers* are introduced in component G. Detail of these components F and G are displayed in Table B.3.

Table B.3: The details of sentence-openers and rules of using

Details of *sentence openers*	**Rules of using each *sentence-opener***
1. ฉันเห็นด้วยกับคุณ (R)	ตัวเลือกที่สอดคล้องกับประโยคด้านหน้า (1) 5. ฉันเห็นด้วยกับคุณ (R) 6. ฉันไม่ค่อยมั่นใจแต่ฉันคิดว่า .... (I) 7. ฉันไม่รู้เรื่องนี้เลย ฉันเดาว่า ....(I) 11. คุณช่วยอธิบายเกี่ยวกับเรื่อง...............ให้ฉันฟังหน่อยสิ (C) 13. คุณหมายความว่า.................. ใช่ไหม ? (A) 15. ฉันว่าพวกเรามาเปลี่ยนเรื่องคุย กันดีกว่าไหม? (A)
2. ใช่ / ตกลง / ถูกต้อง (R)	ตัวเลือกที่สอดคล้องกับประโยคด้านหน้า (2) 1. ฉันเห็นด้วยกับคุณ (R) 5. ฉันเห็นด้วยกับคุณ (R) 6. ฉันไม่ค่อยมั่นใจแต่ฉันคิดว่า .... (I) 7. ฉันไม่รู้เรื่องนี้เลย ฉันเดาว่า ....(I) 8. ฉันคิดว่าอย่างนั้นเพราะว่า .... (I) 11. คุณช่วยอธิบายเกี่ยวกับเรื่อง...............ให้ฉันฟังหน่อยสิ (C) 15. ฉันว่าพวกเรามาเปลี่ยนเรื่องคุย กันดีกว่าไหม? (A)
3. ฉันไม่เห็นด้วยกับคุณ (D)	ตัวเลือกที่สอดคล้องกับประโยคด้านหน้า (3) 9. คุณช่วยอธิบายต่ออีกหน่อยได้ไหมฉันต้องการรู้มากกว่านี้(Y) 12. เพราะเหตุใดคุณจึงคิดว่า .... ? (C)
4. ไม่ใช่ / ไม่ตกลง / ไม่ถูกต้อง (D)	ตัวเลือกที่สอดคล้องกับประโยคด้านหน้า (4) 5. ฉันเห็นด้วยกับคุณ (R) 6. ฉันไม่ค่อยมั่นใจแต่ฉันคิดว่า .... (I) 7. ฉันไม่รู้เรื่องนี้เลย ฉันเดาว่า ....(I) 8. ฉันคิดว่าอย่างนั้นเพราะว่า .... (I) 9. คุณช่วยอธิบายต่ออีกหน่อยได้ไหมฉันต้องการรู้มากกว่านี้(Y) 10. เชิญคุณพูดต่อเลยฉันไม่ต้องการจะพูดอะไรในประเด็นนี้ (Y) 11. คุณช่วยอธิบายเกี่ยวกับเรื่อง...............ให้ฉันฟังหน่อยสิ (C) 12. เพราะเหตุใดคุณจึงคิดว่า .... ? (C) 13. คุณหมายความว่า.................. ใช่ไหม ? (A) 15. ฉันว่าพวกเรามาเปลี่ยนเรื่องคุย กันดีกว่าไหม? (A)

Table B.3: The details of sentence-openers and rules of using (cont.)

Details of *sentence openers*	Rules of using each *sentence-opener*
5. ฉันเห็นด้วยกับคุณ (R) **6. ฉันไม่ค่อยมั่นใจแต่ฉันคิดว่า .... (I)** **7. ฉันไม่รู้เรื่องนี้เลย ฉันเดาว่า ....(I)** **8. ฉันคิดว่าอย่างนั้นเพราะว่า .... (I)**	ตัวเลือกที่สอดคล้องกับประโยคด้านหน้า (5,6,7,8) 1. ฉันเห็นด้วยกับคุณ (R) 3. ฉันไม่เห็นด้วยกับคุณ (D) 9. คุณช่วยอธิบายต่ออีกหน่อยได้ไหมฉันต้องการรู้มากกว่านี้(Y) 10. เชิญคุณพูดต่อเลยฉันไม่ต้องการจะพูดอะไรในประเด็นนี้ (Y) 11. คุณช่วยอธิบายเกี่ยวกับเรื่อง...............ให้ฉันฟังหน่อยสิ (C) 13. คุณหมายความว่า.................. ใช่ไหม ? (A)
9. คุณช่วยอธิบายต่ออีกหน่อยได้ไหม ฉันต้องการรู้มากกว่านี้(Y)	ตัวเลือกที่สอดคล้องกับประโยคด้านหน้า (9) 5. ฉันเห็นด้วยกับคุณ (R) 6. ฉันไม่ค่อยมั่นใจแต่ฉันคิดว่า .... (I) 7. ฉันไม่รู้เรื่องนี้เลย ฉันเดาว่า ....(I)
10. เชิญคุณพูดต่อเลย ฉันไม่ต้องการจะพูดอะไรในประเด็นนี้ (Y)	ตัวเลือกที่สอดคล้องกับประโยคด้านหน้า (10) 14. คุณเห็นด้วยกับสิ่งที่ฉันได้กล่าวไปแล้วหรือเปล่า? (A) 15. ฉันว่าพวกเรามาเปลี่ยนเรื่องคุย กันดีกว่าไหม? (A)
11. คุณช่วยอธิบายเกี่ยวกับเรื่อง......ให้ฉันฟังหน่อยสิ (C)	ตัวเลือกที่สอดคล้องกับประโยคด้านหน้า (11) 5. ฉันเห็นด้วยกับคุณ (R) 6. ฉันไม่ค่อยมั่นใจแต่ฉันคิดว่า .... (I) 7. ฉันไม่รู้เรื่องนี้เลย ฉันเดาว่า ....(I)
12. เพราะเหตุใดคุณจึงคิดว่า ..... ? (C)	ตัวเลือกที่สอดคล้องกับประโยคด้านหน้า (12) 8. ฉันคิดว่าอย่างนั้นเพราะว่า .... (I)
13. คุณหมายความว่า.....ใช่ไหม ? (A)	ตัวเลือกที่สอดคล้องกับประโยคด้านหน้า (13) 2. ใช่ / ตกลง / ถูกต้อง (R) 4. ไม่ใช่ / ไม่ตกลง / ไม่ถูกต้อง (D)
14. คุณเห็นด้วยกับสิ่งที่ฉันได้กล่าวไปแล้วหรือเปล่า? (A)	ตัวเลือกที่สอดคล้องกับประโยคด้านหน้า (14) 2. ใช่ / ตกลง / ถูกต้อง (R) 4. ไม่ใช่ / ไม่ตกลง / ไม่ถูกต้อง (D)
15. ฉันว่าพวกเรามาเปลี่ยนเรื่องคุยกันดีกว่าไหม? (A)	ตัวเลือกที่สอดคล้องกับประโยคด้านหน้า (15) 2. ใช่ / ตกลง / ถูกต้อง (R) 4. ไม่ใช่ / ไม่ตกลง / ไม่ถูกต้อง (D)

B.1.7 The detail of component H and I

The components H and I are used to represent information of the group performance in terms of IdealGLM and GLM. These components will be illustrated in an example of section 5.2 in Chapter 5.

Appendix C

Flowchart of 'GOLeM'

In Appendix C, we represent the processes of how this GOLeM works into twelve steps. The details of processes in Step 1, 2 and 3 are displayed in Figure C.1. For Step 4, 5 and 6 the explanation of processes is displayed in Figure C.2. Figure C.3 represents the detail of process in Step 7. Figure C.4 represents the detail of processes in Step 8, 9 and 10. Figure C.5 represents the detail of processes in Step 11 and 12. The description of each step is displayed in Table C.1

Table C.1. The descriptions of twelve steps of processes in GOLeM

Step Name	Description
Step 1	Check validation of user who 'Login' to the system
Step 2	The system check availability of learner's pair
Step 3	The system matches learner's group performance to the specific type of question and later provides to learner.
Step 4	A learner answers each question as a pre-test and states degree of confidence (do until finished four question)
Step 5	A learner chooses whether 'to see' or 'not to see' the group performance provided by the system.
Step 6	A learner continues to study as a group in the provided 'Group Learning Area'
Step 7	The system provides 'the turn' for each learner in a specific time and allows them to use utterances to compose the sentence to communicate to each other until the final solution has been made.
Step 8	The system calculates the score from each 'communicative interaction' made by learners and updates in the database for 'Student Model'
Step 9	A learner answers each question as a group-test and states degree of confidence (do until finished four question)
Step 10	A learner chooses whether 'to see' or 'not to see' the group performance provided by the system.
Step 11	A learner answers each question as a post-test and states degree of confidence (do until finished four question)
Step 12	A learner chooses whether 'to see' or 'not to see' the group performance provided by the system.

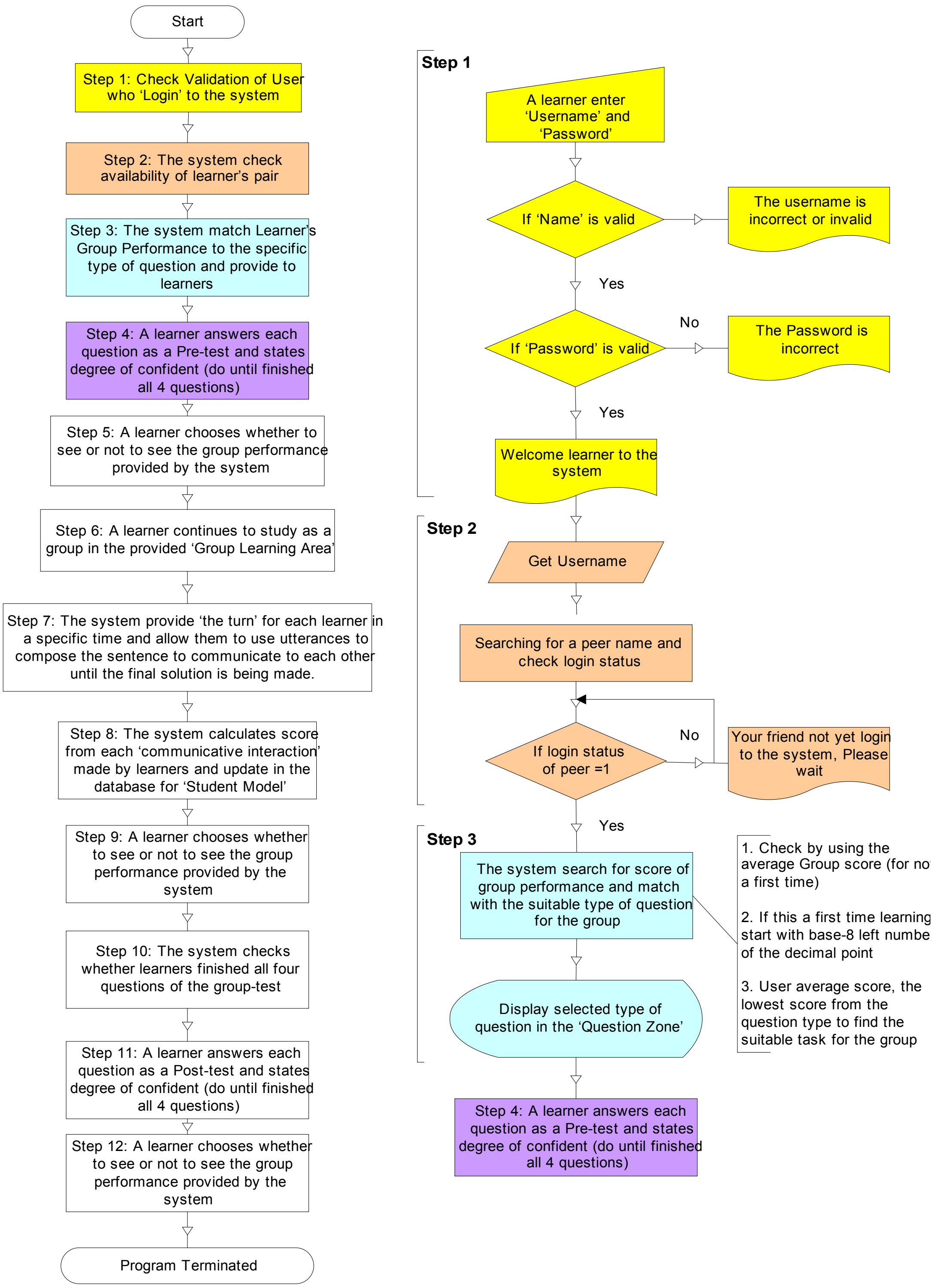


Figure C.1. The flowchart for Step 1 to 3

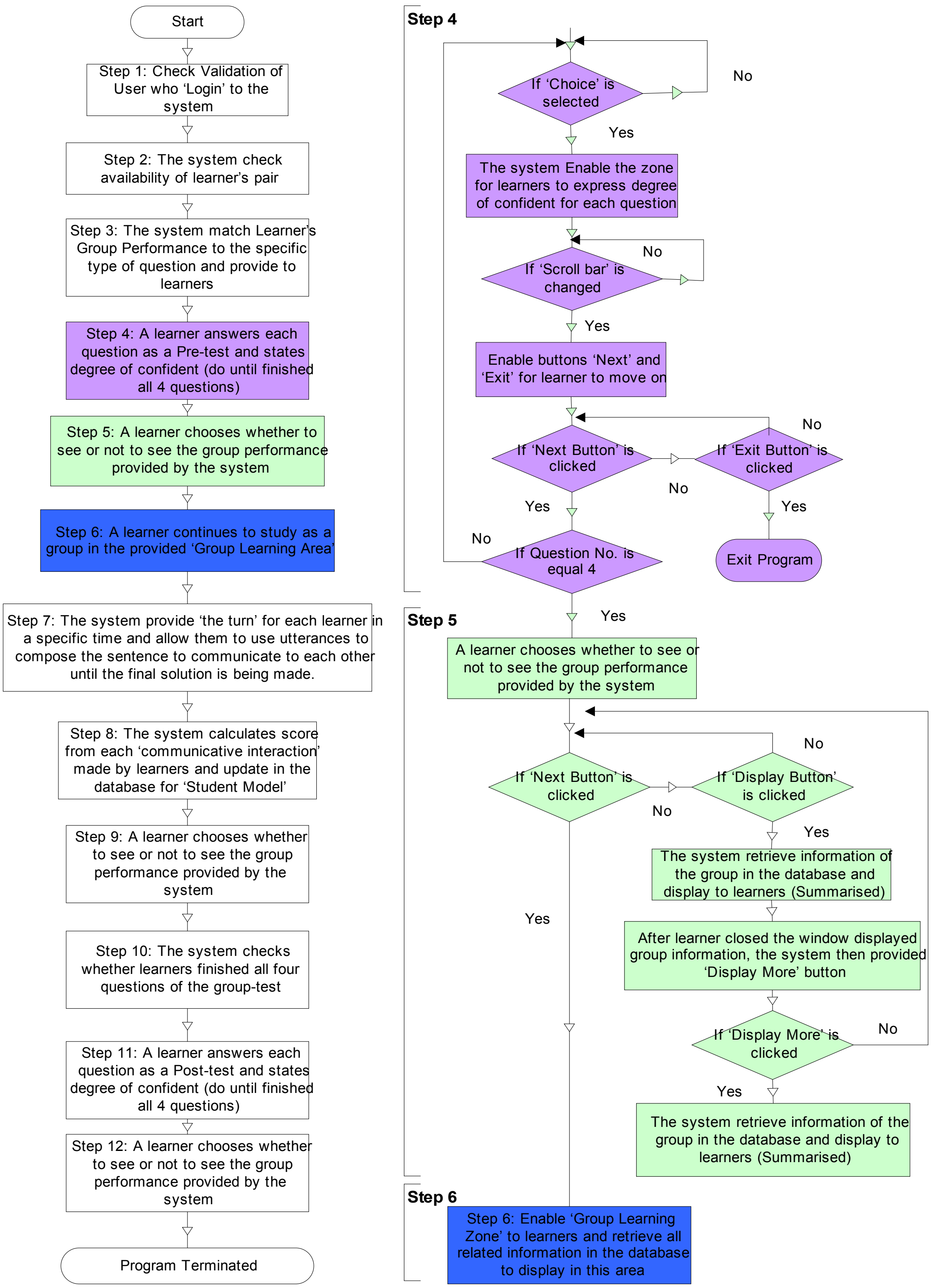


Figure C.2. The flowchart for Step 4 to 5

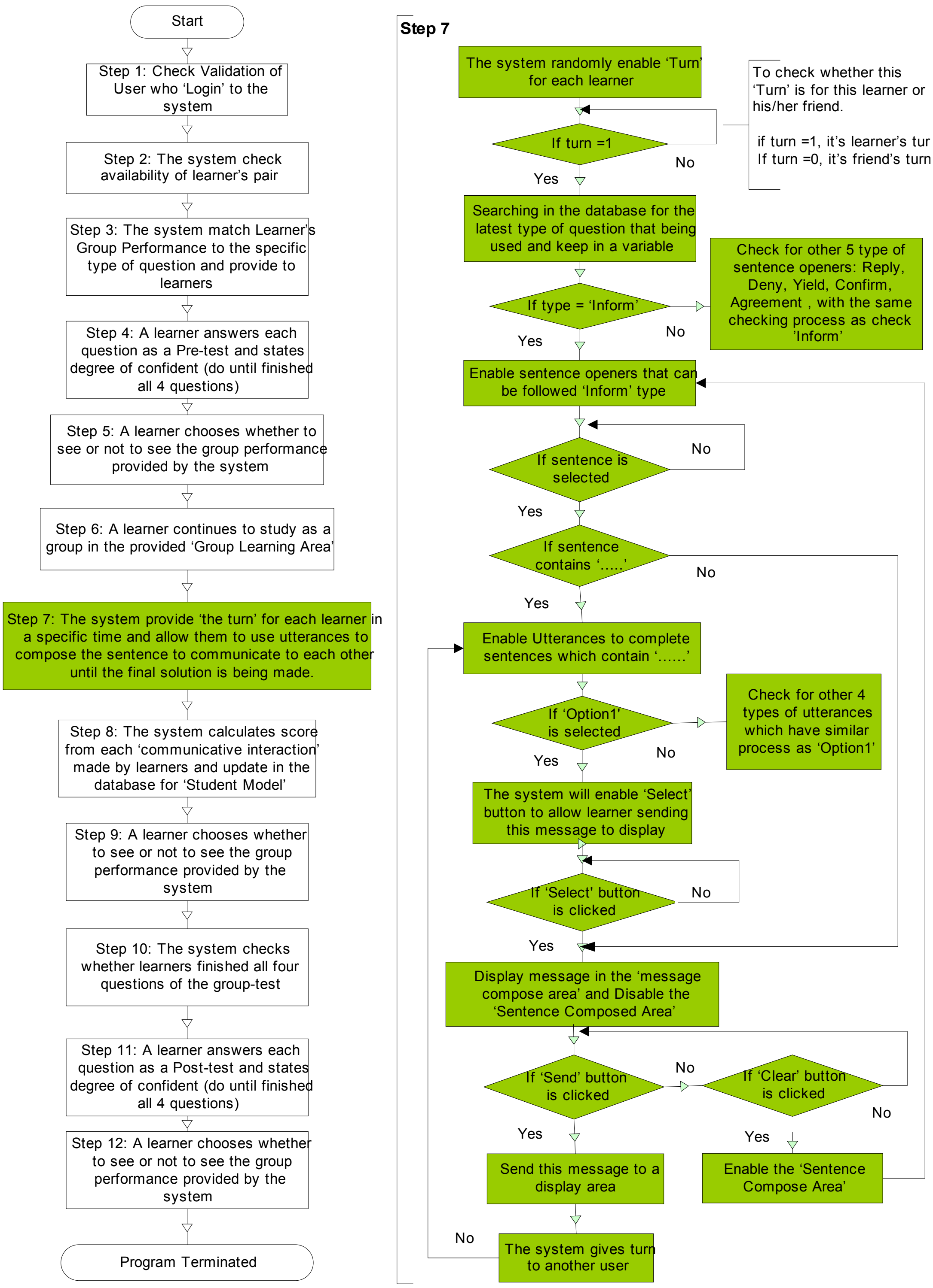


Figure C.3. The flowchart for Step 7

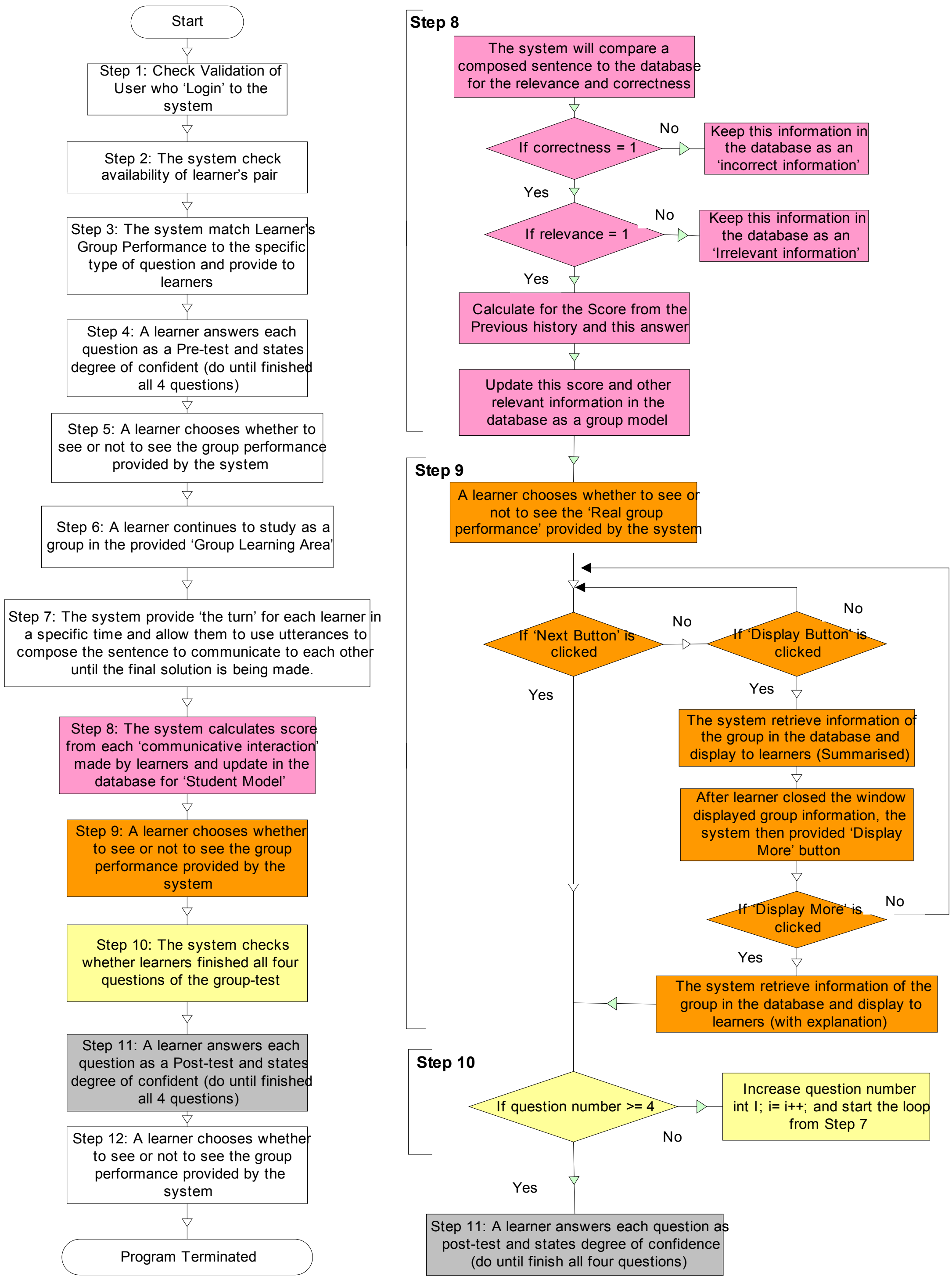


Figure C.4. The flowchart for Step 8 to 10

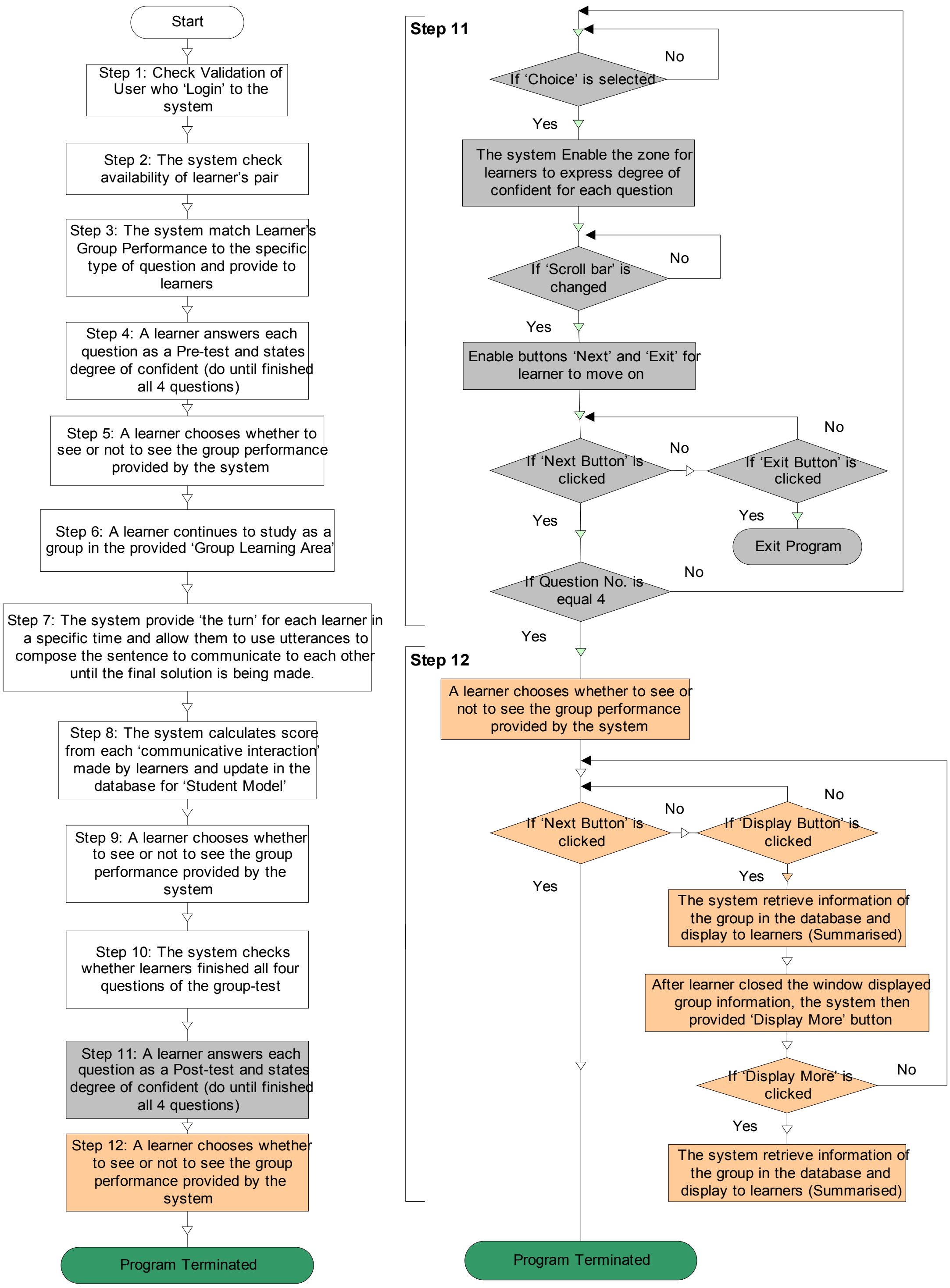


Figure C.5. The flowchart for Step 11 and 12

Appendix D

The User Manual of Using GOLeM

In Appendix D, the instruction of how to use GOLeM is explained in four steps: *Step1, Step2, Step3* and *Step 4* (See Figure D.1and D.10). In order to see whether there is any impact of seeing the *GLM* and *IdealGLM* on an individual's knowledge improvement, we then set two learning environments: *Envi1*and *Envi2*. Only *Envi1* allows learner to see their learning performance as *GLM* and Ideal *GLM*.

First the fully detail of how GOLeM applies to *Envi1* is explained, followed by the detail of *Envi2* which includes only details that defer from *Envi1*.

In ordert to use the GOLeM, first of all, you run the program that is provided as an icon on the screen. After that you will see the window screen as display in Figure D.1. Then follow though Step 1 – Step 4, step by step.

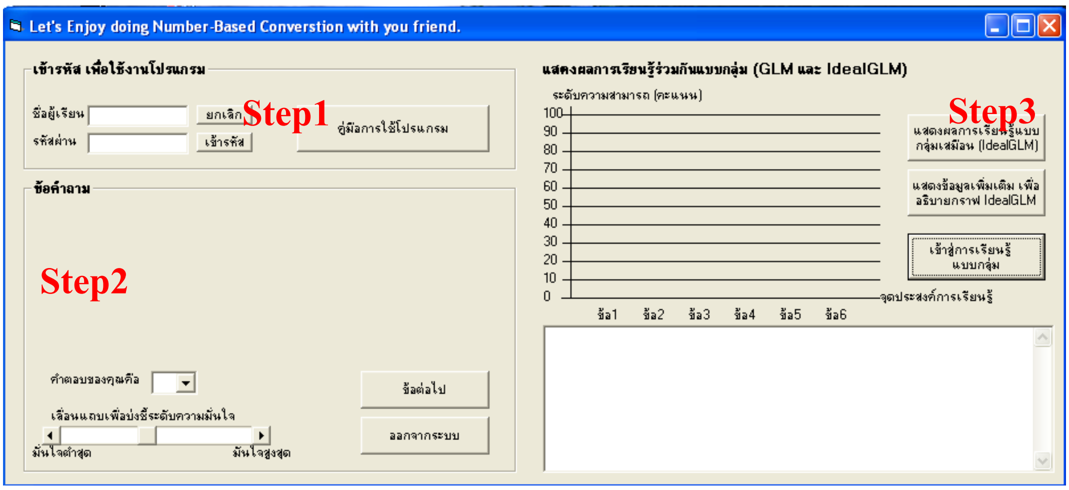


Figure D.1. The User Interface of GOLeM from the start

D.1 Login to the System (Step1)

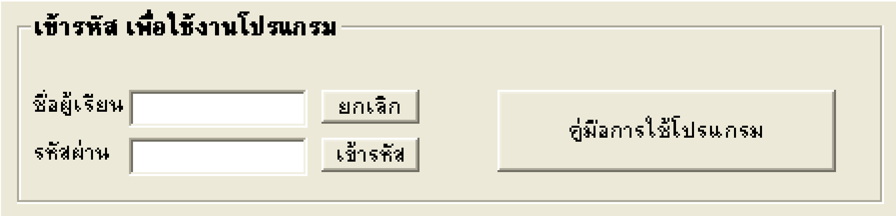


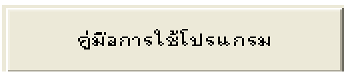
Figure D.2. Login Area

In Figure D.2, there is a '*Login Area*' which is used to check permission of the user before allowing accessing a particular area of learning. In order to login to the system, please follow step D.1.1 to D.1.4.

D.1.1 Type your provided *username* in the textbox of 'ชื่อผู้เรียน' and *password* in the textbox of 'รหัสผ่าน'.

D.1.2 If you would like to clear information of *username* and *password* that you already typed in, you can press button  to clear textboxes.

D.1.3 If you would like to login to the system after already entering both *username* and *password*, you can press button  to login.

D.1.4 If you would like to learn more about how this program works, you can press button  for a playing instruction.

D.2: Doing an Individual Pre-test (Step 2)

When you login to the system, the set of questions will be sent to you and your friend according to your previous knowledge. A set of question consists of four question types which respectively apply to six concepts. The questions will be provided automatically after you have logged in (See Figure D.3). To answer these four questions, you should follow step D.2.1 to D.2.6

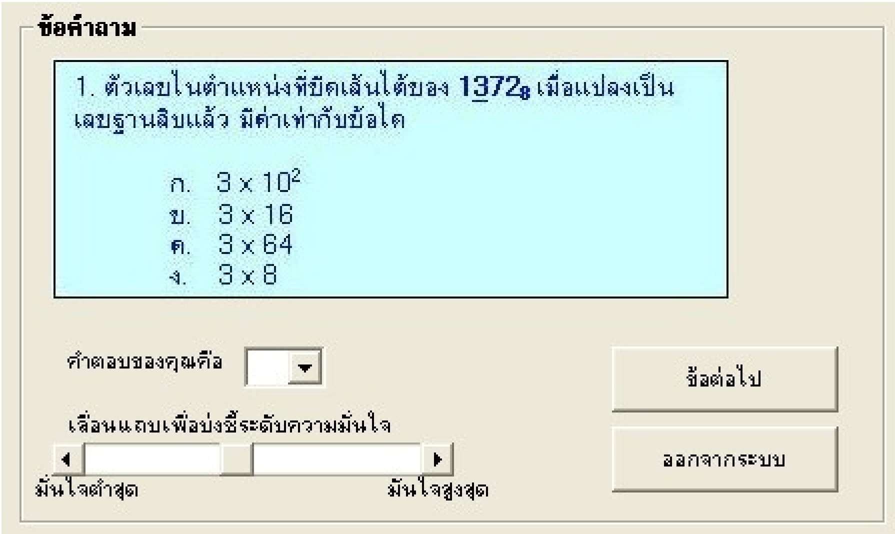
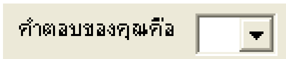


Figure D.3. Question Area

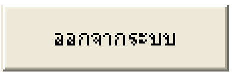
D.2.1 State your answer in the combo box 

D.2.2 Scale your degree of confidence for each particular question on this scale bar 

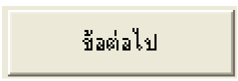
(from most left (lowest = level 1) to most right (highest = level 10) degree of confidence)

D.2.3 If you have finished the question and would like to continue to the next question, you can press the button 

. Then the system will provide you the next question.

D.2.4 If you would like to end what already has been done and exit the program, you can press the button 

to leave.

D.2.5 If you complete all questions, the button caption will be changed from 'Next question' button 

to 'Next Step' button 

D.2.6 The system will check whether your friend has already finished the individual task before providing you with an opportunity to see an *IdealGLM*. If your friend already finished a task, the pop-up as seen in Figure D.4 is displayed.

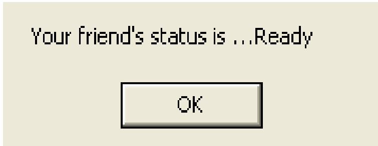


Figure D.4. Ready status

D.3: Display the Group Performance (Step 3)

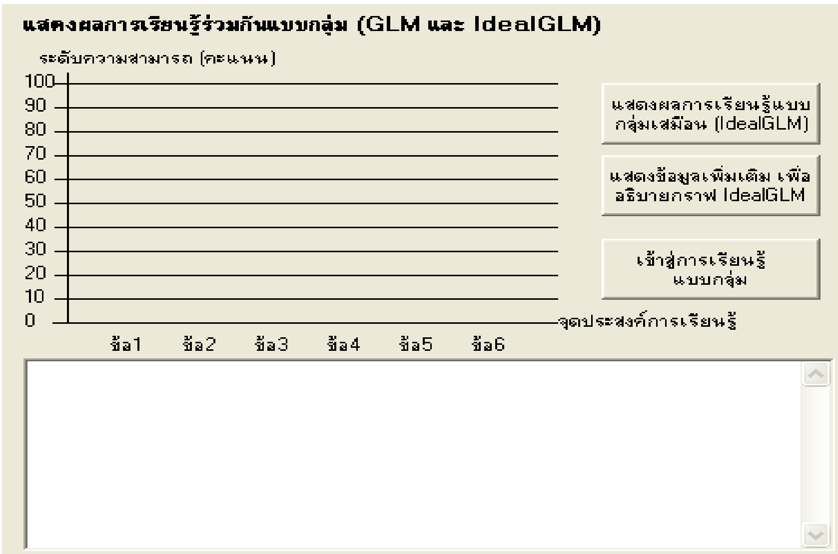
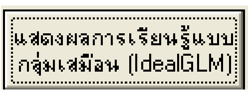


Figure D.5. Display Group Performance Area

After you press the '*OK*' button of Figure D.4, then the focus of the system is moved to the area of '*Display Group Performance*' which is displayed in Figure D.5. In this area you can press the button either to see the *IdealGLM* or *GLM* depending on the task that you perform, you can see *IdealGLM* after you already perform the pre-test or post-test. The *GLM* is available after performing each question of the group-test. In order to see the *IdealGLM*, please follow step D.3.1 to D.3.3.

D.3.1 If the button 

is pressed, the system will provide information of *IdealGLM* which is defined as an expectation of the group performance from individual performances. Information of the *IdealGLM* will be displayed as *bar-chart.* Each bar stands for performance of each concept (See Figure D.6).

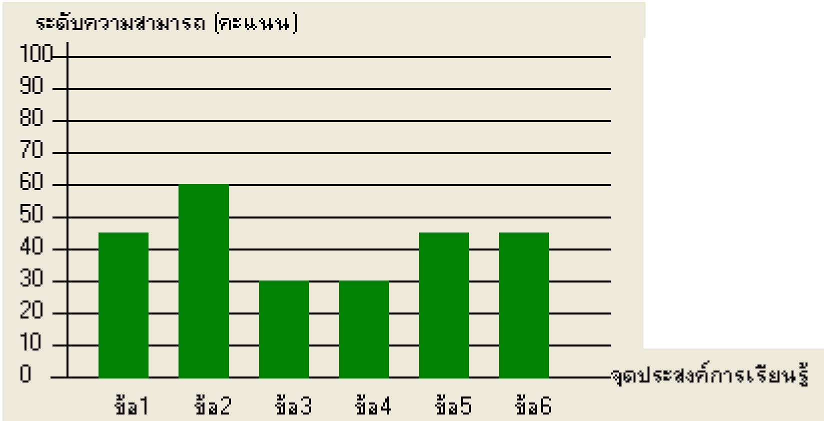


Figure D.6. The displayed of *IdealGLM* as a *bar-chart*

D.3.2 If you would like to have more explanation about the graph of *IdealGLM* above, you can press button 

. Explanation of each graph will be displayed as an image below. While using the program, you can use the scroll bar to see all information.

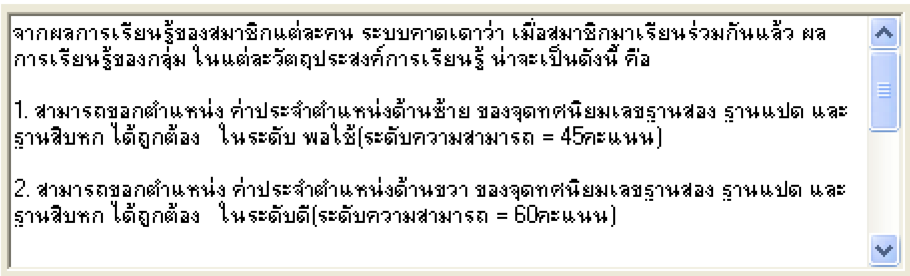
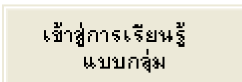
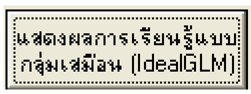
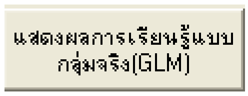


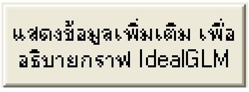
Figure D.7. The displayed of *IdealGLM* in detail

D.3.3 When you press the button 

to continue learning as a group. The caption that is displayed on button 

(display learning performance as *IdealGLM*) is changed to 

(display the learning

performance as *GLM*), and 

(display more explanation of the *IdealGLM*'s graph) will be changed to 

(display more explanation of the *GLM*'s graph). After that the system will provide the questionnaire to ask about performance of yourself and your group as display in Figure D.8.

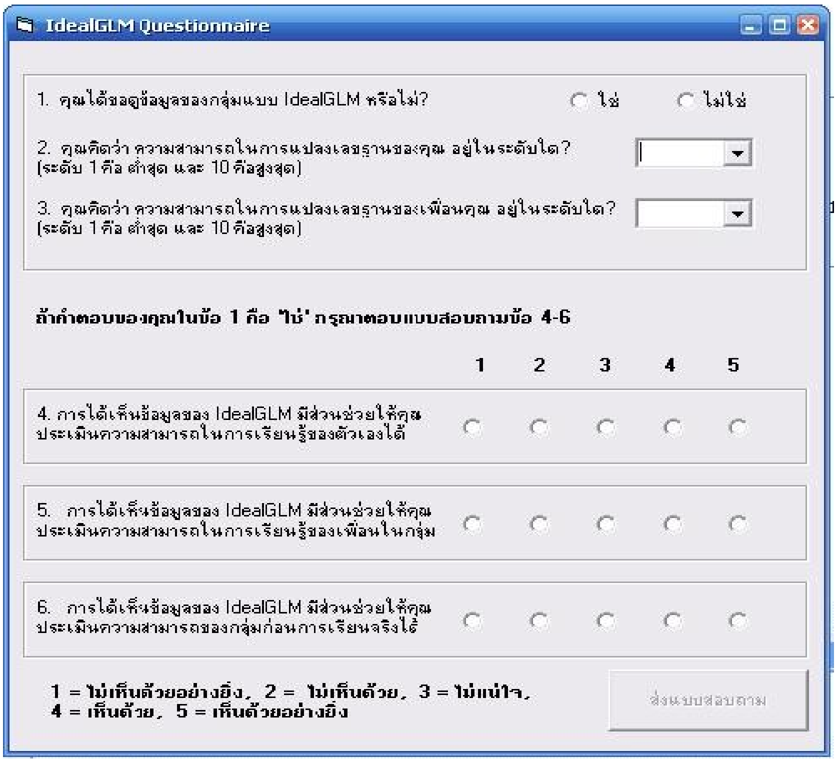


Figure D.8. The questionnaire asking asking about seeing *GLM* and *IdealGLM*

D.3.4 After finished filling the questionnaire (See Figure D.8), press the submit button and the window of the group task which contain chat program (See Figure D.9). The relevant question will be provided in the Question area (See Figure D.3) for the group-test.

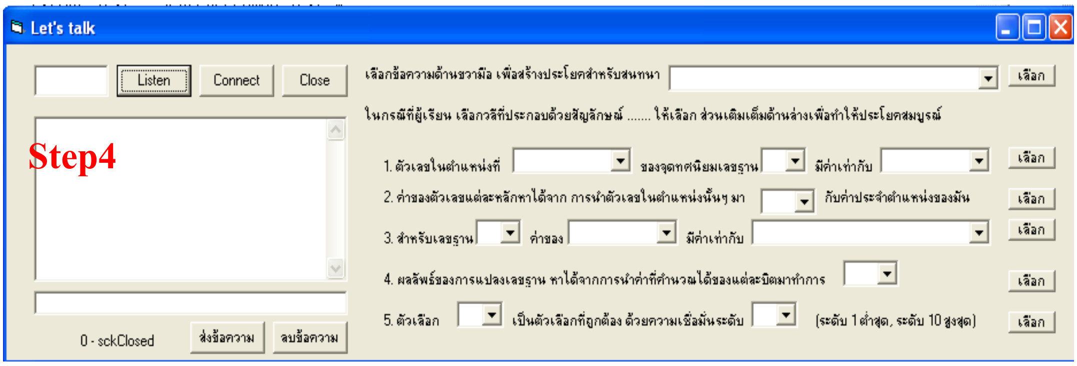


Figure D.9. The displayed of provided chat program with *sentence openers*

D.4: Group task and Chat with friends (Step 4)

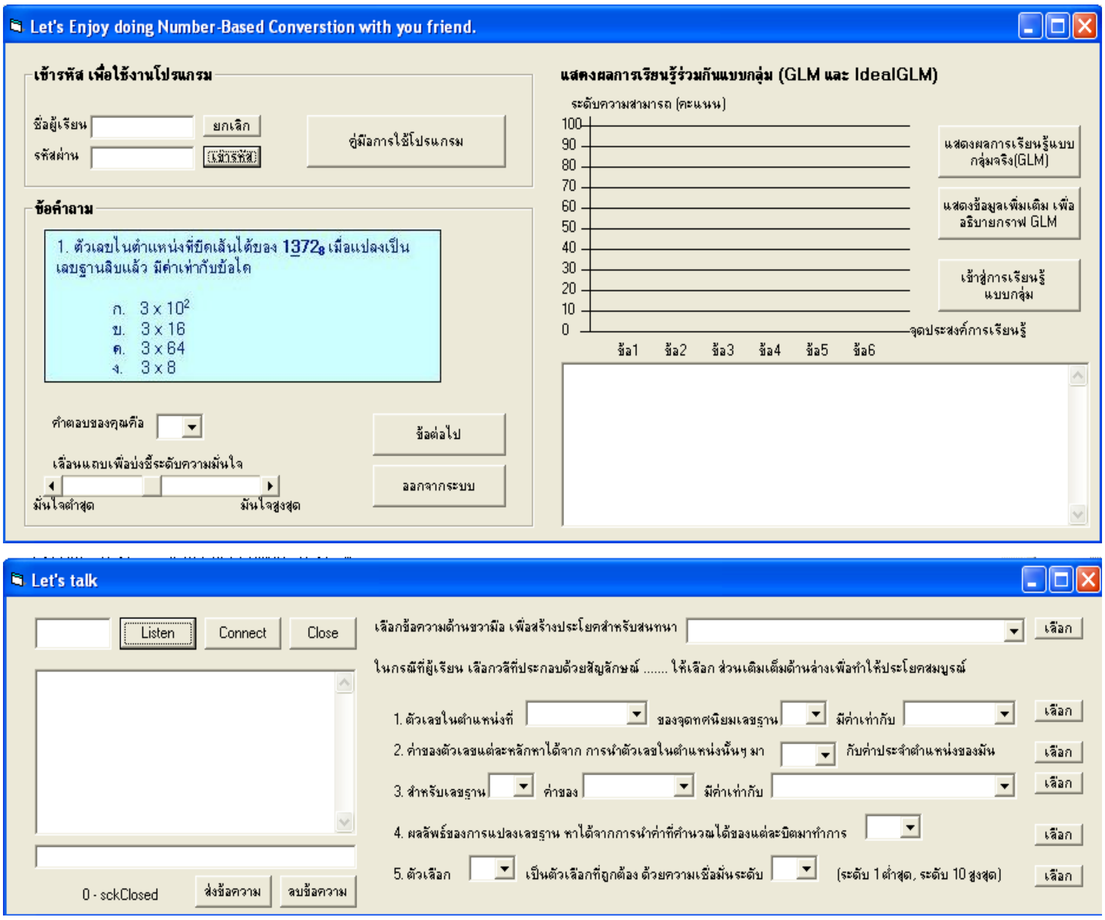


Figure D.10. The displayed for learning with friend for a group-test

In Step4, only '*Chat Area'* will be enabled for you to interact. The system will start the conversation from what each member answers through the individual task. The system then assigns the turn to one of the group members to start the conversation. At each time, only one group member can compose one sentence and provide the relevant sentences to the other member for the next move.

D.4.1 From the '*Chat Area*', start the chat connection by assigning one member to press on '*Listen*' button of Figure D.11 and the other member press on '*Connect'* button.

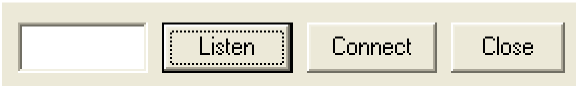


Figure D.11. Chat Connection Buttons

D.4.2 If the connection is established, the one who is assigned the turn will select the sentence from the provided 14 *sentence openers* to communicate with a friend. After selecting the sentence in the combo box (See Figure D.12), you then press the button  to continue.

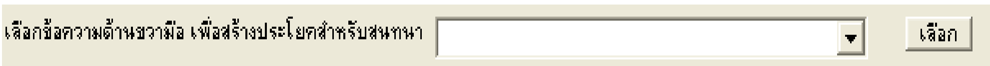


Figure D.12. A List of *sentence openers*

1. ฉันเห็นด้วยกับคุณ (I agree with you)
2. ใช่ / ตกลง (Yes/ OK)
3. ฉันไม่เห็นด้วยกับคุณ (I don't agree with you)
4. ไม่ใช่ / ไม่ตกลง (No)
5. ฉันมั่นใจว่า..... (I believe that…)
6. ฉันไม่ค่อยมั่นใจ แต่ฉันคิดว่า.....(I am not sure, but I think that…)
7. ฉันไม่รู้เรื่องนี้เลย แต่ฉันเดาว่า.....(I don't know about this, but I guess that…)
8. ฉันคิดว่าอย่างนั้นเพราะว่า..... (I think that because…)
9. คุณช่วยอธิบายต่ออีกหน่อยได้ไหม ฉันต้องการรู้มากกว่านี้ (Please you could explain more, I would like to know)
10. เชิญคุณพูดต่อเถอะ ฉันไม่ต้องการจะพูดอะไรในประเด็นนี้ (I don't want to talk about this at all, please go on)
11. คุณช่วยอธิบายเกี่ยวกับเรื่อง.....ให้ฉันฟังหน่อยสิ (Please explain me about ….)
12. เพราะเหตุใดคุณจึงคิดว่า..... (Why do you think that…)
13. คุณหมายความว่า.....ใช่หรือไม่? (Do you think that…, don't you?)
14. ฉันว่าพวกเรามาเปลี่ยนเรื่องคุยกันดีไหม? (Shall we change the topic?)

D.4.3 If *sentence openers* that you choose from Figure D.12 contain '…', you will be asked to complete these sentences with 5 options of utterances (*utterance1 – utterance5*; See Figure D.13) which we will call as complements. After completing your sentence, please press เลือก to continue.

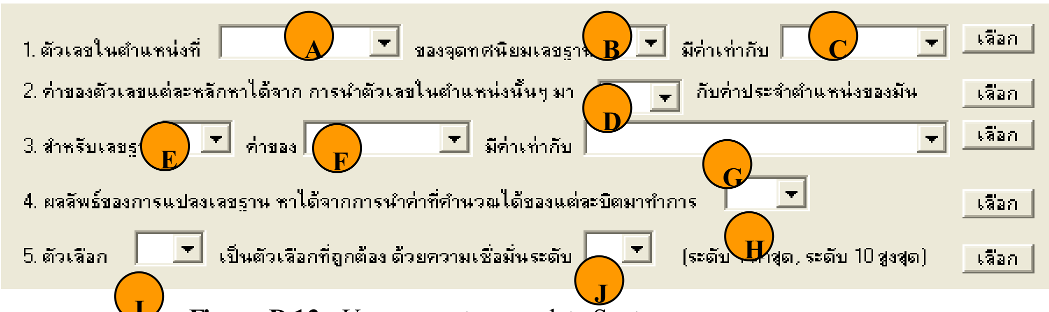


Figure D.13. *Utterances* to complete Sentence openers

D.4.3.1 As display in Figure D.13, if *utterance1* is selected, there are 3 spaces that you have to fill in. The detail of what you can fill in space A, B and C are displayed in Table D.1.

Table D.1. Details of what can be filled in space A, B and C of *utterance1*

A	B	C		
1 นับไปทางซ้าย	2	2 ยกกำลัง -8	8 ยกกำลัง -8	16 ยกกำลัง -8
2 นับไปทางซ้าย	8	2 ยกกำลัง -7	8 ยกกำลัง -7	16 ยกกำลัง -7
3 นับไปทางซ้าย	16	2 ยกกำลัง -6	8 ยกกำลัง -6	16 ยกกำลัง -6
4 นับไปทางซ้าย		2 ยกกำลัง -5	8 ยกกำลัง -5	16 ยกกำลัง -5
5 นับไปทางซ้าย		2 ยกกำลัง -4	8 ยกกำลัง -4	16 ยกกำลัง -4
6 นับไปทางซ้าย		2 ยกกำลัง -3	8 ยกกำลัง -3	16 ยกกำลัง -3
7 นับไปทางซ้าย		2 ยกกำลัง -2	8 ยกกำลัง -2	16 ยกกำลัง -2
8 นับไปทางซ้าย		2 ยกกำลัง -1	8 ยกกำลัง -1	16 ยกกำลัง -1
1 นับไปทางขวา		2 ยกกำลัง 0	8 ยกกำลัง 0	16 ยกกำลัง 0
2 นับไปทางขวา		2 ยกกำลัง 1	8 ยกกำลัง 1	16 ยกกำลัง 1
3 นับไปทางขวา		2 ยกกำลัง 2	8 ยกกำลัง 2	16 ยกกำลัง 2
4 นับไปทางขวา		2 ยกกำลัง 3	8 ยกกำลัง 3	16 ยกกำลัง 3
5 นับไปทางขวา		2 ยกกำลัง 4	8 ยกกำลัง 4	16 ยกกำลัง 4
6 นับไปทางขวา		2 ยกกำลัง 5	8 ยกกำลัง 5	16 ยกกำลัง 5
7 นับไปทางขวา		2 ยกกำลัง 6	8 ยกกำลัง 6	16 ยกกำลัง 6
8 นับไปทางขวา		2 ยกกำลัง 7	8 ยกกำลัง 7	16 ยกกำลัง 7
		2 ยกกำลัง 8	8 ยกกำลัง 8	16 ยกกำลัง 8

D.4.3.2 As display in Figure D.13, if *utterance2* is selected, there is one space that you have to fill in. The detail of what you can fill in space D are displayed in Table D.2.

Table D.2. Details of what can be filled in space D and H of *utterance2* and *utterance4*

D and H
บวก (+) ลบ (-) คูณ (x) หาร (/)

D.4.3.3 As display in Figure D.13, if *utterance3* is selected, there are 3 spaces that you have to fill in. The detail of what you can fill in space E, F and G are displayed in Table D.3 and D.4.

Table D.3. Details of what can be filled in space E and F of *utterance3*

E	F					
2	2 ยกกำลัง -8	2 ยกกำลัง -8	2 ยกกำลัง 0	8 ยกกำลัง 0	16 ยกกำลัง -8	16 ยกกำลัง 0
8	2 ยกกำลัง -7	2 ยกกำลัง -7	2 ยกกำลัง 1	8 ยกกำลัง 1	16 ยกกำลัง -7	16 ยกกำลัง 1
16	2 ยกกำลัง -6	2 ยกกำลัง -6	2 ยกกำลัง 2	8 ยกกำลัง 2	16 ยกกำลัง -6	16 ยกกำลัง 2
	2 ยกกำลัง -5	2 ยกกำลัง -5	2 ยกกำลัง 3	8 ยกกำลัง 3	16 ยกกำลัง -5	16 ยกกำลัง 3
	2 ยกกำลัง -4	2 ยกกำลัง -4	2 ยกกำลัง 4	8 ยกกำลัง 4	16 ยกกำลัง -4	16 ยกกำลัง 4
	2 ยกกำลัง -3	2 ยกกำลัง -3	2 ยกกำลัง 5	8 ยกกำลัง 5	16 ยกกำลัง -3	16 ยกกำลัง 5
	2 ยกกำลัง -2	2 ยกกำลัง -2	2 ยกกำลัง 6	8 ยกกำลัง 6	16 ยกกำลัง -2	16 ยกกำลัง 6
	2 ยกกำลัง -1	2 ยกกำลัง -1	2 ยกกำลัง 7	8 ยกกำลัง 7	16 ยกกำลัง -1	16 ยกกำลัง 7
			2 ยกกำลัง 8	8 ยกกำลัง 8		16 ยกกำลัง 8

D.4.3.4 As display in Figure D.13, if *utterance4* is selected, there is one space that you have to fill in. The detail of what you can fill in space H are displayed in Table D.2.

D.4.3.5 As display in Figure D.13, if *utterance5* is selected, there is two spaces that you have to fill in. The detail of what you can fill in space I and J are displayed in Table D.5.

Table D.4. Details of what can be filled in space G of *utterance3*

G		
2	8x3	16x5
2x2	8x4	16x6
2x3	8x5	16x7
2x4	8x6	16x8
2x5	8x7	-----------------------------------
2x6	8x8	นำ 16 สองตัวมาคูณกัน
2x7	-----------------------------------	นำ 16 สามตัวมาคูณกัน
2x8	นำ 8 สองตัวมาคูณกัน	นำ 16 สี่ตัวมาคูณกัน
-----------------------------------	นำ 8 สามตัวมาคูณกัน	นำ 16 ห้าตัวมาคูณกัน
นำ 2 สองตัวมาคูณกัน	นำ 8 สี่ตัวมาคูณกัน	นำ 16 หกตัวมาคูณกัน
นำ 2 สามตัวมาคูณกัน	นำ 8 ห้าตัวมาคูณกัน	นำ 16 เจ็ดตัวมาคูณกัน
นำ 2 สี่ตัวมาคูณกัน	นำ 8 หกตัวมาคูณกัน	นำ 16 แปดตัวมาคูณกัน
นำ 2 ห้าตัวมาคูณกัน	นำ 8 เจ็ดตัวมาคูณกัน	------------------------------
นำ 2 หกตัวมาคูณกัน	นำ 8 แปดตัวมาคูณกัน	1/16
นำ 2 เจ็ดตัวมาคูณกัน	------------------------------	นำ (1/16) สองตัวมาคูณกัน
นำ 2 แปดตัวมาคูณกัน	1/8	นำ (1/16) สามตัวมาคูณกัน
------------------------------	นำ (1/8) สองตัวมาคูณกัน	นำ (1/16) สี่ตัวมาคูณกัน
1/2	นำ (1/8) สามตัวมาคูณกัน	นำ (1/16) ห้าตัวมาคูณกัน
นำ (1/2) สองตัวมาคูณกัน	นำ (1/8) สี่ตัวมาคูณกัน	นำ (1/16) หกตัวมาคูณกัน
นำ (1/2) สามตัวมาคูณกัน	นำ (1/8) ห้าตัวมาคูณกัน	นำ (1/16) เจ็ดตัวมาคูณกัน
นำ (1/2) สี่ตัวมาคูณกัน	นำ (1/8) หกตัวมาคูณกัน	นำ (1/16) แปดตัวมาคูณกัน
นำ (1/2) ห้าตัวมาคูณกัน	นำ (1/8) เจ็ดตัวมาคูณกัน	------------------------------
นำ (1/2) หกตัวมาคูณกัน	นำ (1/8) แปดตัวมาคูณกัน	นำ (1/16) สองตัวมาบวกกัน
นำ (1/2) เจ็ดตัวมาคูณกัน	------------------------------	นำ (1/16) สามตัวมาบวกกัน
นำ (1/2) แปดตัวมาคูณกัน	นำ (1/8) สองตัวมาบวกกัน	นำ (1/16) สี่ตัวมาบวกกัน
------------------------------	นำ (1/8) สามตัวมาบวกกัน	นำ (1/16) ห้าตัวมาบวกกัน
นำ (1/2) สองตัวมาบวกกัน	นำ (1/8) สี่ตัวมาบวกกัน	นำ (1/16) หกตัวมาบวกกัน
นำ (1/2) สามตัวมาบวกกัน	นำ (1/8) ห้าตัวมาบวกกัน	นำ (1/16) เจ็ดตัวมาบวกกัน
นำ (1/2) สี่ตัวมาบวกกัน	นำ (1/8) หกตัวมาบวกกัน	นำ (1/16) แปดตัวมาบวกกัน
นำ (1/2) ห้าตัวมาบวกกัน	นำ (1/8) เจ็ดตัวมาบวกกัน	---------------------------------
นำ (1/2) หกตัวมาบวกกัน	นำ (1/8) แปดตัวมาบวกกัน	0
นำ (1/2) เจ็ดตัวมาบวกกัน	-----------------------------------	1
นำ (1/2) แปดตัวมาบวกกัน	16x1	-1
-----------------------------------	16x2	-2
8x1	16x3	-8
8x2	16x4	-16

Table D.5. Details of what can be filled in space I and J of *utterance5*

I	J	
ก (A)	1	6
ข (B)	2	7
ค (C)	3	8
ง (D)	4	9
	5	10

D.4.4 The sentence that you composed will be sent to the compose text area. You can choose either to send that message to your friend by pressing ส่งข้อความ or delete the message and compose the new one by pressing ลบข้อความ.

D.4.5 The dialogue will be terminated for each question only when group members agree with the answer and degree of confidence that the other one proposed. In other words, when one member proposed sentence which contains *utterance5* and another one choose to agree on that sentence then the system will provide the *GLM* and prepare to provide a next question.

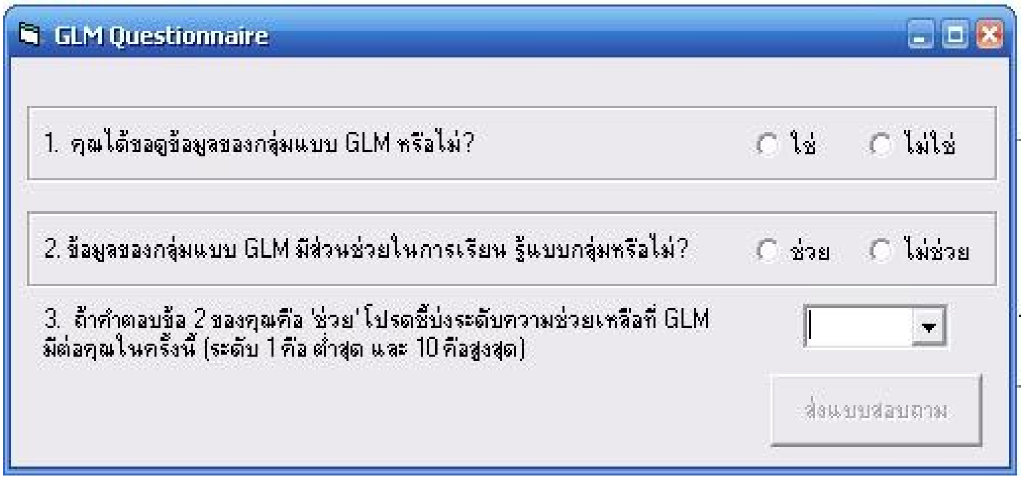


Figure D.14. The questionnaires asking for the perceive of *GLM*

After participants do the group-test, they do the similar test individually as a post-test. Then the system is terminated. For learner who participate in *Envi2* rather than *Envi1*, the system will automatically skip Step 3 and D.4.5 for the part dealing with *IdealGLM* and *GLM*.

Appendix E

Summary of the Testing Results

In Appendix E, we provide further information of summary of the testing results. The results of how learners perform in five questions of paper-based test are displayed in section E.1. The description of table's headings are defined in Table E.1. The results of how learners perform in four questions of computer-based test compare between Envi1 and Envi2 are displayed in section E.2. This section firstly provide description of table's headings are defined in Table E.2 and followed by details of computer-based results. In section E.3, the details of dialogue pattern of 21 cases that the group members contribute to each other during the group-test are provided.

E.1 Summary of the 'paper-based' results.

Table E.1. The descriptions of paper-based results' table heading.

Title	Descriptions
Question number	The question number (1-5)
Pair number	A number that is used to specify groups of learners (pair 1-6)
Correction	The correction of each question item as a group result
Score	The value to show how well the group performs for each particular question item. (from 0 to 10)
Agreement on group answer	The value to show that the final result of each group comes from what they totally agree(A) or not agree but only just want to finish the question (D).
Knowledge contribution	To show whether there is any knowledge contributed while members of the group talk to each other via the provided chat area. (Y for Yes, and N for No)
No. of knowledges	Number of knowledge that was contributed for each question item while learning as a group of two.
No. of misconception	Number of misconception that were contributed for each question item while learning as a group of two.
Similarity of answer (group vs. individual)	The value to show that before learning as a group, each member answers the same result or not.
Similarity of individual answers	Compare the final result to the answer that each member has before doing as a group, is it still in one of the answers?
Details of contributed knowledge	Details of what learners contribute as knowledge

Table E.2. Paper-based results of *Question1*

Question number	Pair number	Correction (√ or ×)	Score	Agreement on group answer	Knowledge contribution (Y, N)	No. Of knowledge	No. Of misconception	Similarity of answer(group vs. individual)	Similarity of individual answer	Details of contributed knowledge
1	1	×	1	D	Y	1	2	Diff	No	**(5)** I believe that … **(2)** The value of number in the **3rd-** position from **the left side** of the **base8** decimal point is equal **8²**.
	2	√	10	A	Y	2	1	Diff	Yes	**(5)** I believe that … **(2)** The value of number in the **3rd-** position from **the left side** of the **base8** decimal point is equal **8²**. **(3)** I don't agree with you that **(2)** The value of number in the **3rd** position from **the left side** of the **base8** decimal point is equal **8³**.
	3	√	6	A	N	0	1	Same	Yes	-
	4	√	8	A	Y	2	0	Diff	Yes	(**6**) I am not sure but I think… **(1)** The number at the underlined position is in the **3rd** position from **the left side** of the **base8** decimal point. **(5)** I belief that…**(2)** The value of number in the **3rd-** position from **the left side** of the **base8** decimal point is equal **8²**.
	5	√	10	A	Y	2	0	Diff	Yes	**(5)** I belief that…**(2)** The value of number in the **3rd-** position from **the left side** of the **base8** decimal point is equal **8²**. **(5)** I belief that… **(4)** Operator **x** is being used for calculating value **within each bit**.
	6	√	1	D	N	0	0	Diff	No	-

Table E.3. Paper-based results of *Question2*

Question number	Pair number	Correction (√ or ×)	Score	Agreement on group answer	Knowledge contribution (Y, N)	No. Of knowledge	No. Of misconception	Similarity of answer(group vs. individual)	Similarity of individual answer	Details of contributed knowledge
2	1	√	9	A	Y	1	0	Same	Yes	**(5)** I belief that…**(2)** The value of number in the **3^{rd}** position from **the left side** of the **base8** decimal point is equal **8^2**.
	2	√	8	A	Y	1	0	Same	Yes	**(8)** I think that because … **(2)** The value of number in the **3^{rd}** position from **the left side** of the **base8** decimal point is equal **8^2**?
	3	×	1	D	Y	2	2	Diff	Yes	**(7)** I don't know about this but I guess that… **(1)** The number at the underlined position is in the **3^{rd}** position from **the left side** of the **base8** decimal point. (**6)** I am not sure but I think… **(3)** For **base8** number, the value of **8^3** is equal **8x8x8**.
	4	√	6	A	Y	1	0	Diff	Yes	(**6)** I am not sure but I think… **(2)** The value of number in the **3^{rd}** position from **the left side** of the **base8** decimal point is equal **8^2**.
	5	√	10	A	Y	2	0	Same	Yes	**(5)** I believe that … **(1)** The number at the underlined position is in the **3^{rd}** position **(5)** I believe that … **(2)** The value of number in the **3^{rd}** position from **the left side** of the **base8** decimal point is equal **8^2**
	6	√	10	A	Y	2	0	diff	Yes	(**6)** I am not sure but I think… **(2)** The value of number in the **3^{rd}** position from **the left side** of the **base8** decimal point is equal **8^2**. **(8)** I think that because … **(1)** The number at the underlined position is in the **3^{rd}** position from **the left side** of the **base8** decimal point.

Table E.4. Paper-based results of *Question3*

Question number	Pair number	Correction (√ or ×)	Score	Agreement on group answer	Knowledge contribution (Y, N)	No. Of knowledge	No. Of misconception	Similarity of answer(group vs. individual)	Similarity of individual answer	Details of contributed knowledge
3	1	√	10	A	Y	1	0	Same	Yes	**(8)** I think that because ….**(1)** The number at the underlined position is in the **3rd** position from **the left side** of the **base8** decimal point?
	2	√	9	A	Y	3	0	Same	No	**(11)** Could you please explain me about … **(1)** The number at the underlined position is in the **3rd** position from **the left side** of the **base8** decimal point? **(8)** I think that because … **(3)** For **base8** number, the value of 8^2 is equal **8x8**. **(5)** I belief that… **(4)** Operator **x** is being used for calculating value **within each bit**.
	3	×	1	D	Y	2	3	Diff	No	(**6)** I am not sure but I think… **(3)** For **base8** number, the value of 8^0 is equal **1**. (**6)** I am not sure but I think… **(3)** For **base8** number, the value of 8^3 is equal **8x8x8**.
	4	√	7	A	Y	1	0	Diff	No	(**6)** I am not sure but I think… **2)** The value of number in the **3rd** position from **the left side** of the **base8** decimal point is equal 8^2
	5	√	10	A	N	0	0	Same	Yes	-
	6	√	10	A	Y	2	0	Diff	Yes	(**5)** I believe that… **(2)** The value of number in the **3rd** position from **the left side** of the **base8** decimal point is equal 8^2. **(8)** I think that because … **(1)** The number at the underlined position is in the **3rd** position from **the left side** of the **base8** decimal point.

Table E.5. Paper-based results of *Question4* and *Question5*

Question number	Pair number	Correction (√ or ×)	Score	Agreement on group answer	Knowledge contribution (Y, N)	No. Of knowledge	No. Of misconception	Similarity of answer(group vs. individual)	Similarity of individual answer	Details of contributed knowledge
4	1	√	10	A	Y	1	0	Same	Yes	**(5)** I believe that … **(3)** For **base8** number, the value of **8^{0}** is equal **1**.
	2	√	8	A	N	0	0	Same	Yes	-
	3	×	1	A	Y	1	1	Diff	Yes	**(6)** I am not sure but I think… **(1)** The number at the underlined position is in the **1st** position from **the left side** of the **base8** decimal point.
	4	√	7	A	Y	2	0	Diff	Yes	**(5)** I belief that… **(3)** For **base8** number, the value of **8^{2}** is equal **8x8**. **(6)** I am not sure but I think…**(3)** For **base8** number, the value of **8^{0}** is equal **1**.
	5	√	10	A	Y	1	0	Diff	Yes	**(5)** I believe that … **(2)** The value of number in the **3rd** position from **the left side** of the **base8** decimal point is equal **8^{2}**
	6	×	0	A	N	0	0	Diff	Yes	-
5	1	√	10	D	N	0	1	Diff	Yes	-
	2	√	10	A	Y	4	1	Diff	Yes	**(5)** I believe that **(3)** For **base8** number, the value of **8^{1}** is equal **8**. **(5)** I believe that **(3)** For **base8** number, the value of **8^{0}** is equal **1**. **(5)** I belief that… **(4)** Operator **x** is being used for calculating value **within each bit**. **(5)** I belief that… **(4)** Operator **+** is being used for calculating value **between each bit**.
	3	×	1	A	Y	1	1	Same	Yes	**(8)** I think that because … **(3)** For **base8** number, the value of **8^{-1}** is equal **1/8**.
	4	√	10	A	Y	3	1	Diff	Yes	**(7)** I don't know about this but I guess…**(3)** For **base8** number, the value of **8^{1}** is equal **8**. **(5)** I belief that… **(4)** Operator **x** is being used for calculating value **within each bit**. **(5)** I belief that… **(4)** Operator **+** is being used for calculating value **between each bit**.
	5	√	10	A	Y	2	0	Same	Yes	**(5)** I belief that…**(3)** For **base8** number, the value of **8^{0}** is equal **1**. **(5)** I belief that…**(3)** For **base8** number, the value of **8^{1}** is equal **8**.
	6	√	10	A	Y	1	0	Diff	Yes	**(8)** I think that because … **(3)** For **base8** number, the value of **8^{0}** is equal **1**.

E.2.1 Computer-based results of Question1

Table E.6. Computer-based results of *Question1*

Group	Conversation Pattern	Contribution	Pre-Min	Pre-Max	Result x-y	Conf x-y	Final result	Group Type	Correction	Score	NoOf_C	NoOf_Ic	ZPD	Diff
A1	5,1	No	7	10	S	D	S	S-S-C	C	10	1	0	I	3
A2	5,3,-,1	No	0	7	S	D	S	S-S-C	C	8	1	0	A	1,8
A3	5,1	No	6	10	S	D	S	S-S-C	C	10	1	0	I	4
A4	5,1	No	10	10	S	S	S	S-S-C	C	10	1	0	I	0**
A5	5,1	No	0	10	D	D	S	D-S-C	C	10	1	0	I	10
A6	5,1	No	10	10	S	S	S	S-S-C	C	10	1	0	I	0**
A7	5,1	No	5	10	S	D	S	S-S-C	C	10	1	0	I	5
A8	5,1	No	10	10	S	S	S	S-S-C	C	10	1	0	I	0**
B1	5,1,7,10,1,10,7,14,2,5,1	Yes	0	0	S	D	S	S-S-Ic	IC	0	0	5	I	0*
B2	5,1,5,1,5,5,1	Yes	8	10	S	D	S	S-S-C	C	7	3	1	B	-1
B3	5,1	No	9	10	S	D	S	S-S-C	C	9	1	0	I	1
B4	5,1	No	0	9	D	D	D	D-D-Ic	IC	0	0	1	I	0*
B5	5,1	No	7	8	S	D	S	S-S-C	C	8	1	0	I	1
B6	5,1,9,-,10,6,5,1	Yes	7	10	S	D	S	S-S-C	C	9	2	1	I	2
C1	6,5,5,1	Yes	0	0	S	D	D	S-D-Ic	IC	0	1	2	I	0*
C2	5,1	No	5	10	S	D	S	S-S-C	C	10	1	0	I	5
C3	7,3,9,5,1,5,1,5,1	Yes	0	4	D	D	S	D-S-C	C	5	4	1	A	1,5
C4	5,3,9,6,3,10,5,1	Yes	0	0	D	D	S	D-S-Ic	IC	0	0	3	I	0*
D1	5,1,5,1	No	10	10	S	S	S	S-S-C	C	10	1	0	I	0**
D2	5,3,10,5,3,9,5,1	Yes	6	10	S	D	S	S-S-C	C	8	2	1	I	2
D3	5,1	No	7	8	S	D	S	S-S-C	C	8	1	0	I	1
D4	5,1	No	7	8	S	D	S	S-S-C	C	8	1	0	I	1
E1	5,1	No	8	10	S	D	S	S-S-C	C	9	1	0	I	1
E2	5,1	No	0	10	D	D	S	D-S-C	C	10	1	0	I	10
E3	5,1	No	7	8	S	D	S	S-S-C	C	8	1	0	I	1
E4	5,1	No	7	7	S	S	S	S-S-C	C	8	1	0	A	1
F1	5,1	No	5	9	S	D	S	S-S-C	C	5	1	0	I	0
F2	5,1	No	7	8	S	D	S	S-S-C	C	7	1	0	I	0
F3	5,1	No	0	4	D	D	S	D-S-C	C	5	1	0	A	1,5
F4	5,9,5,9,5,1	Yes	0	7	D	D	S	D-S-C	C	8	1	0	A	1,8

<u>Note</u>

0* means there is no difference between 'Score' and 'Pre-Min' because both learners cannot answer the test correctly for both pre-test and group-test.

0** means there is no difference between 'Score' and 'Pre-Min' because both learners have highest score as individual in pre-test and group-test.

E.2.2 Computer-based results of Question2

Table E.7. Computer-based results of *Question2*

Group	Conversation Pattern	Contribution	pre-min	pre-max	result x-y	conf x-y	final result	Group Type	Correction	Score	NoOf_C	NoOf_Ic	ZPD	Diff
A1	5,1	No	7	10	S	D	S	S-S-C	C	10	1	0	I	3
A2	5,1	No	9	9	S	S	S	S-S-C	C	8	1	0	B	1
A3	5,1	No	10	10	S	S	S	S-S-C	C	10	1	0	I	0**
A4	5,1	No	10	10	S	S	S	S-S-C	C	10	1	0	I	0**
A5	5,1	No	7	10	S	D	S	D-S-C	C	10	1	0	I	3
A6	5,1	No	10	10	S	S	S	S-S-C	C	10	1	0	I	0**
A7	5,1	No	5	10	S	D	S	S-S-C	C	10	1	0	I	5
A8	5,1	No	9	10	S	D	S	S-S-C	C	10	1	0	I	1
B1	7,1,5,1,7,1,7,1,7,1,5,1	Yes	0	4	D	D	S	D-S-C	C	4	0	2	I	4
B2	5,1	No	8	10	S	D	S	S-S-C	C	10	1	0	I	2
B3	5,1	No	9	10	S	D	S	S-S-C	C	9	1	0	I	0
B4	5,1	No	9	10	S	D	S	S-S-C	C	8	1	0	B	-1
B5	0,7,1,5,1	Yes	8	9	D	D	S	S-S-C	C	8	1	0	I	0
B6	5,3,5,1	Yes	0	10	S	D	S	D-S-C	C	10	1	0	I	10
C1	5,3,10,5,5,1	Yes	8	10	S	D	S	S-S-C	C	10	1	0	I	2
C2	5,1	No	5	10	S	D	S	S-S-C	C	10	1	0	I	5
C3	5,1	No	2	5	S	D	S	S-S-C	C	7	1	0	A	2,5
C4	5,1	No	0	0	S	S	S	S-S-Ic	IC	0	0	1	I	0*
D1	5,1	No	0	10	D	S	S	S-S-C	C	10	1	0	I	10
D2	5,1	No	6	10	S	D	S	S-S-C	C	8	1	0	I	2
D3	5,1	No	7	7	S	S	S	S-S-C	C	8	1	0	A	1
D4	5,1	No	7	7	S	S	S	S-S-C	C	8	1	0	A	1
E1	5,1	No	9	10	S	D	S	S-S-C	C	9	1	0	I	9
E2	5,1	No	0	10	D	D	S	D-S-C	C	10	1	0	I	10
E3	5,1	No	7	8	S	D	S	S-S-C	C	8	1	0	I	1
E4	5,1	No	7	7	S	S	S	S-S-C	C	8	1	0	A	1
F1	5,1	No	9	10	S	D	S	S-S-C	C	10	1	0	I	1
F2	5,1	No	6	8	S	D	S	S-S-C	C	5	1	0	B	-1
F3	7,3,9,5,1	Yes	0	0	S	D	S	S-S-Ic	IC	0	0	2	I	0*
F4	5,1	No	0	0	S	D	S	S-S-Ic	IC	0	0	1	I	0*

Note

0* means there is no difference between 'Score' and 'Pre-Min' because both learners cannot answer the test correctly for both pre-test and group-test.

0** means there is no difference between 'Score' and 'Pre-Min' because both learners have highest score as individual in pre-test and group-test.

E.2.3 Computer-based results of Question3

Table E.8. Computer-based results of *Question3*

Group	Conversation Pattern	Contribution	pre-min	pre-max	result x-y	conf x-y	final result	Group Type	Correction	Score	NoOf_C	NoOf_Ic	ZPD	Diff
A1	5,1	No	0	8	D	D	S	D-S-C	C	9	1	0	A	1,9
A2	5,1	No	7	8	S	D	S	S-S-C	C	7	1	0	I	0
A3	5,1	No	10	10	S	S	S	S-S-C	C	10	1	0	I	0**
A4	5,1	No	10	10	S	S	S	S-S-C	C	10	1	0	I	0**
A5	5,1	No	7	10	S	D	S	S-S-C	C	10	1	0	I	3
A6	5,1	No	10	10	S	S	S	S-S-C	C	10	1	0	I	0**
A7	5,1	No	7	8	S	D	S	S-S-C	C	7	1	0	I	0
A8	5,1	No	9	9	S	D	D	S-D-Ic	IC	0	0	1	B	(-9)
B1	9,6,13,2,5,1,5,1,5,1	Yes	0	0	S	D	S	S-S-Ic	IC	0	3	2	I	0*
B2	5,1	No	8	10	S	D	S	S-S-C	C	10	1	0	I	2
B3	5,1	No	9	10	S	D	S	S-S-C	C	9	1	0	I	0
B4	5,1	No	0	9	D	D	S	D-S-C	C	8	1	0	I	8
B5	5,1	No	8	10	S	D	D	S-D-Ic	IC	0	0	1	B	(-8)
B6	5,1	No	6	8	S	D	S	S-S-C	C	10	1	0	A	2,4
C1	6,5,5,1	Yes	0	0	S	D	D	S-D-Ic	IC	0	1	2	I	0*
C2	5,1	No	5	10	S	D	S	S-S-C	C	10	1	0	I	5
C3	7,3,9,5,1,5,1,5,1	Yes	0	4	D	D	S	D-S-C	C	5	4	1	A	1,5
C4	5,3,9,6,3,10,5,1	Yes	0	0	D	D	S	D-S-Ic	IC	0	0	3	I	0*
D1	5,1,5,1	No	10	10	S	S	S	S-S-C	C	10	1	0	I	0**
D2	5,3,10,5,3,9,5,1	Yes	6	10	S	D	S	S-S-C	C	8	2	1	I	2
D3	5,1	No	7	8	S	D	S	S-S-C	C	8	1	0	I	1
D4	5,1	No	7	8	S	D	S	S-S-C	C	8	1	0	I	1
E1	5,1	No	8	10	S	D	S	S-S-C	C	9	1	0	I	1
E2	5,1	No	0	10	D	D	S	D-S-C	C	10	1	0	I	10
E3	5,1	No	7	8	S	D	S	S-S-C	C	8	1	0	I	1
E4	5,1	No	7	7	S	S	S	S-S-C	C	8	1	0	A	1
F1	5,1	No	5	9	S	D	S	S-S-C	C	5	1	0	I	0
F2	5,1	No	7	8	S	D	S	S-S-C	C	7	1	0	I	0
F3	5,1	No	0	4	D	D	S	D-S-C	C	5	1	0	A	1,5
F4	5,9,5,9,5,1	Yes	0	7	D	D	S	D-S-C	C	8	1	0	A	1,8

Note

0* means there is no difference between 'Score' and 'Pre-Min' because both learners cannot answer the test correctly for both pre-test and group-test.

0** means there is no difference between 'Score' and 'Pre-Min' because both learners have highest score as individual in pre-test and group-test.

E.2.4 Computer-based results of Question4

Table E.9. Computer-based results of *Question4*

Group	Conversation Pattern	Contribution	pre-min	pre-max	result x-y	conf x-y	final result	Group Type	Correction	Score	NoOf_C	NoOf_Ic	ZPD	Diff
A1	5,1	No	9	10	D	D	S	S-S-C	C	9	1	0	I	1
A2	5,1	No	10	10	S	S	S	S-S-C	C	10	1	0	I	0**
A3	5,1	No	10	10	S	S	S	S-S-C	C	10	1	0	I	0**
A4	5,1	No	10	10	S	S	S	S-S-C	C	10	1	0	I	0**
A5	5,1	No	7	10	S	D	S	S-S-C	C	10	1	0	I	3
A6	5,1	No	10	10	S	S	S	S-S-C	C	10	1	0	I	0**
A7	5,1	No	8	10	S	S	S	S-S-C	C	10	1	0	I	2
A8	5,1	No	9	10	S	D	S	S-S-C	C	10	1	0	I	1
B1	6,-,13,2,6,1,11,5,1,5,3,10,5,1	Yes	0	0	S	D	S	S-S-C	IC	0	3	3	I	0*
B2	5,1	No	8	10	S	D	S	S-S-C	C	10	1	0	I	2
B3	5,1	No	9	10	S	D	S	S-S-C	C	9	1	0	I	0
B4	5,1	No	0	9	D	D	S	D-S-C	C	8	1	0	I	8
B5	5,1	No	8	10	S	D	S	S-S-C	C	8	1	0	I	0
B6	5,1	No	6	10	S	D	S	S-S-C	C	10	1	0	I	4
C1	5,1	No	5	8	S	D	S	S-S-C	C	10	1	0	A	2,5
C2	5,1	No	8	10	S	D	S	S-S-C	C	10	1	0	I	2
C3	5,1	No	4	7	S	D	S	S-S-C	C	6	1	0	A	2
C4	5,1	No	0	0	S	S	S	S-D-C	C	5	1	0	I	5
D1	5,1	No	5	10	S	D	D	S-S-C	C	10	1	0	I	5
D2	5,1	No	6	10	S	D	S	S-S-C	C	8	1	0	I	2
D3	5,1	No	7	7	S	S	S	S-S-C	C	8	1	0	A	1
D4	5,1	No	7	7	S	S	S	S-S-C	C	8	1	0	A	1
E1	5,1	No	9	10	S	D	D	S-D-Ic	IC	10	0	1	B	(-9)*
E2	5,1	No	0	10	D	D	S	D-S-Ic	IC	10	0	1	I	0*
E3	5,1	No	7	8	S	D	S	S-S-C	C	8	1	0	I	1
E4	5,1	No	0	8	D	D	S	D-S-C	C	8	1	0	I	8
F1	5,1	No	9	9	S	S	S	S-S-C	C	9	1	0	I	0
F2	5,1	No	0	7	D	S	S	D-S-C	C	8	1	0	A	1,8
F3	5,7,5,9,5,9,5,9,5,1	Yes	0	6	D	D	S	D-S-C	C	7	5	1	A	1,7
F4	5,1	No	4	7	S	D	S	S-S-C	C	8	1	0	A	1,4

<u>**Note**</u>

0* means there is no difference between 'Score' and 'Pre-Min' because both learners cannot answer the test correctly for both pre-test and group-test.

0** means there is no difference between 'Score' and 'Pre-Min' because both learners have highest score as individual in pre-test and group-test.

E.3 Dialogue pattern from the 'group-test'

According to information of 120 dialogue patterns in E.2.1 to E.2.4, we use the matter of 'contribution' as a measure to categorise these dialogues into two groups. The first group is for dialogues that members of the group state nothing but their answer and degree of confidence. The detail of this pattern is explained in section E.3.1.

The second group is for dialogues that group member contribute more than the answer and degree of confidence. There are 21 cases of dialogue patterns that group member contribute something during the group-test. These cases are explained later in E.3.2.1 to E.3.2.21 of section E.2.2.

E.3.1 Contribute nothing but their answers

The detail of answers and degree of confidence in this question for learner5 and learner6 are: *learner5* choose to answer choice *C* with degree of confidence *10* while learner6 choose choice *C* with degree of confidence *10*. Please give reasons of your answer by composing sentences with the provided utterances (start with learner6)

Learner6 said: (5) I believe that..... (5)Choice C is the correct answer with degree of confidence 10.
Learner5 said: (1) I agree with you.

E.3.2 Contribute something rather than their answers

E.3.2.1 Group B1: Question1

The detail of answers and degree of confidence in this question for learner1 and learner2 are: *learner1* choose to answer choice *A* with degree of confidence *2* while *learner2* choose choice *A* with degree of confidence *4*. Please give reasons of your answer by composing sentences with the provided utterances (start with learner2)

Learner2 said: (5) I believe that... (1) The number on the 2^{nd} left of decimal point of base-8 number is equal 2^{-1}.
Learner1 said: (1) I agree with you.
Learner2 said: (7) I don’t know about this but I guess that...(2) the value of number on each bit can be calculated by multiplied that particular number to the value of that bit.

Learner1 said: (10)Please go on, I don't want to talk about this any more
Learner2 said: (7) I don't know about this but I guess that...(3) for base-2, the value of 2^{-6} is equal 2x2.
Learner1 said: (10)Please go on, I don't want to talk about this any more
Learner2 said: (7) I don't know about this but I guess that...(4) the result of number conversion can be calculated by adding the value of each bit together.
Learner1 said: (14) Shall we change the topic?
Learner2 said: (2) Yes/Ok
Learner1 said: (5) I believe that... (5)Choice A is the correct answer with degree of confidence 1.
Learner2 said: (1)I agree with you.

E.3.2.2 Group B1: Question2

The detail of answers and degree of confidence in this question for learner1 and learner2 are: *learner1* choose to answer choice *A* with degree of confidence *2* while *learner2* choose choice *C* with degree of confidence *4*. Please give reasons of your answer by composing sentences with the provided utterances (start with learner2)

Learner1 said: (5) I believe that... (1) The number on the 1st left of decimal point of base8 number is equal 2^8.
Learner2 said: (1) I agree with you.
Learner1 said: (5) I believe that... (2) the value of number on each bit can be calculated by multiplied that particular number to the value of that bit.
Learner2 said: (1) I agree with you.
Learner1 said: (7) I don't know about this but I guess that... (3) for base8, the value of 8^2 is equal 8x8.
Learner2 said: (1) I agree with you.
Learner1 said: (7) I don't know about this but I guess that... (4) the result of number conversion can be calculated by adding the value of each bit together.
Learner2 said: (1) I agree with you.
Learner1 said: (7) I don't know about this but I guess that... (5)Choice C is the correct answer with degree of confidence 4.
Learner2 said: (1) I agree with you.
Learner1 said: (5) I believe that... (5)Choice C is the correct answer with degree of confidence 4.
Learner2 said: (1) I agree with you.

E.3.2.3 Group B1: Question3

The detail of answers and degree of confidence in this question for learner1 and learner2 are: *learner1* choose to answer choice *A* with degree of confidence *2* while *learner2* choose choice *A* with degree of confidence *4*. Please give reasons of your answer by composing sentences with the provided utterances (start with learner2)

Learner1 said: (11) Please explain more about... (1) The number on the 1st left of decimal point of base8 number is equal 2^8.

Learner2 said: (6) I am not sure but I think that... (1) The number on the 1st left of decimal point of base8 number is equal 2^{-1}.
Learner1 said: (13) Do you mean that... (2) the value of number on each bit can be calculated by multiplied that particular number to the value of that bit?
Learner2 said: (2)Yes/OK
Learner1 said: (5) I believe that... (3) for base8, the value of 8^2 is equal 8x8.
Learner2 said: (1) I agree with you.
Learner1 said: (5) I believe that... (4) the result of number conversion can be calculated by adding the value of each bit together.
Learner2 said: (1) I agree with you.
Learner1 said: (5) I believe that... (5)Choice C is the correct answer with degree of confidence 4.
Learner2 said: (1) I agree with you.

E.3.2.4 Group B1: Question4

The detail of answers and degree of confidence in this question for learner1 and learner2 are: *learner1* choose to answer choice *A* with degree of confidence *2* while *learner2* choose choice *A* with degree of confidence *4*. Please give reasons of your answer by composing sentences with the provided utterances (start with learner2)

Learner1 said: (6) I am not sure but I think that... (1) The number on the 1nd left of decimal point of base8 number is equal 8^{-2}.
Learner2 said: -
Learner1 said: (13) Do you mean that... (2) the value of number on each bit can be calculated by multiplied that particular number to the value of that bit?
Learner2 said: (2)Yes/OK
Learner1 said: (6) I am not sure but I think that... (3) for base8, the value of 8^2 is equal 8x8.
Learner2 said: (1) I agree with you.
Learner1 said: (11) Please explain more about... (4) the result of number conversion can be calculated by adding the value of each bit together.
Learner2 said: (5) I believe that... (4) the result of number conversion can be calculated by adding the value of each bit together.
Learner1 said: (1) I agree with you.
Learner2 said: (5) I believe that... (5)Choice A is the correct answer with degree of confidence 5.
Learner1 said: (3) I do not agree with you.
Learner2 said: (10) Please go on, I don't want to talk about this any more
Learner1 said: (5) I believe that... (5)Choice A is the correct answer with degree of confidence 3.
Learner2 said: (1) I agree with you.

E.3.2.5 Group B2: Question1

The detail of answers and degree of confidence in this question for learner15 and learner16 are: *learner15* choose to answer choice *C* with degree of confidence *10* while *learner16* choose choice *C* with degree of confidence *8*. Please give reasons of your answer by composing sentences with the provided utterances (start with learner2)

Learner16 said: (5) I believe that... (1) The number on the 2^{nd} left of decimal point of base8 number is equal 2^{-2}.
Learner15 said: (1) I agree with you.
Learner16 said: (5) I believe that... (2) the value of number on each bit can be calculated by multiplied that particular number to the value of that bit.
Learner15 said: (1) I agree with you.
Learner16 said: (5) I believe that... (3) for base8, the value of 8^1 is equal 8x1.
Learner15 said: (5) I believe that... (5)Choice C is the correct answer with degree of confidence 4.
Learner16 said: (1) I agree with you.

E.3.2.6 Group B5: Question2

The detail of answers and degree of confidence in this question for learner35 and learner36 are: *learner3*5 choose to answer choice *C* with degree of confidence *7* while *learner36* choose choice *C* with degree of confidence *9*. Please give reasons of your answer by composing sentences with the provided utterances (start with learner2)

Learner36 said: -
Learner35 said: (7) I don't know but I guess that... (5)Choice C is the correct answer with degree of confidence 8.
Learner36 said: (1) I agree with you.
Learner35 said: (5) I believe that... (5)Choice C is the correct answer with degree of confidence 8.
Learner36 said: (1) I agree with you.

E.3.2.7 Group B6: Question1

The detail of answers and degree of confidence in this question for learner3 and learner4 are: *learner3* choose to answer choice *C* with degree of confidence *10* while *learner4* choose choice *C* with degree of confidence *7*. Please give reasons of your answer by composing sentences with the provided utterances (start with learner4)

Learner4 said: (6) I am not sure but I think that... (5)Choice B is the correct answer with degree of confidence 5.
Learner3 said: (3) I do not agree with you.
Learner4 said: (9)Please tell me more about this.
Learner3 said: -
Learner4 said: (10) Please go on, I don't want to talk about this any more
Learner3 said: (6) I am not sure but I think that... (1) The number on the 3^{rd} left of decimal point of base8 number is equal 8^2.
Learner4 said: (5) I believe that... (5)Choice C is the correct answer with degree of confidence 10.
Learner3 said: (1) I agree with you.

E.3.2.8 Group C1: Question1

The detail of answers and degree of confidence in this question for learner9 and learner10 are: *learner9* choose to answer choice *A* with degree of confidence *8* while *learner10* choose choice *A* with degree of confidence *5*. Please give reasons of your answer by composing sentences with the provided utterances (start with learner10)

Learner10 said: (6) I am not sure but I think that... (5)Choice A is the correct answer with degree of confidence 6.
Learner9 said: (5) I believe that... (4) the result of number conversion can be calculated by adding the value of each bit together.
Learner10 said: (5) I believe that... (5)Choice C is the correct answer with degree of confidence 10.
Learner9 said: (1) I agree with you.

E.3.2.9 Group C1: Question2

The detail of answers and degree of confidence in this question for learner9 and learner10 are: *learner9* choose to answer choice *C* with degree of confidence *8* while *learner10* choose choice *C* with degree of confidence *10*. Please give reasons of your answer by composing sentences with the provided utterances (start with learner10)

Learner10 said: (5) I believe that... (5) Choice B is the correct answer with degree of confidence 10.
Learner9 said: (3) I do not agree with you.
Learner10 said: (10) Please go on, I don’t want to talk about this any more
Learner9 said: (5) I believe that... (5)Choice C is the correct answer with degree of confidence 10.
Learner10 said: (5) I believe that... (5)Choice C is the correct answer with degree of confidence 10.
Learner9 said: (1) I agree with you.

E.3.2.10 Group C3: Question1

The detail of answers and degree of confidence in this question for learner5 and learner6 are: *learner5* choose to answer choice *C* with degree of confidence *4* while *learner6* choose choice *B* with degree of confidence *3*. Please give reasons of your answer by composing sentences with the provided utterances (start with learner6)

Learner6 said: (7) I don’t know but I guess... (5)Choice B is the correct answer with degree of confidence 3.
Learner5 said: (3) I do not agree with you.
Learner6 said: (9) Please tell me more about this
Learner5 said: (5) I believe that... (1) The number on the 3rd left of decimal point of base2 number is equal 2^2.
Learner6 said: (1) I agree with you.
Learner5 said: (5) I believe that... (3) for base2, the value of 2^2 is equal 2x2.

Learner6 said: (1) I agree with you.
Learner5 said: (5) I believe that... (5)Choice C is the correct answer with degree of confidence 5.
Learner6 said: (1) I agree with you.

E.3.2.11 Group C3: Question3

The detail of answers and degree of confidence in this question for learner5 and learner6 are: *learner5* choose to answer choice *B* with degree of confidence *7* while *learner6* choose choice *A* with degree of confidence *3*. Please give reasons of your answer by composing sentences with the provided utterances (start with learner5)

Learner5 said: (5) I believe that... (5)Choice B is the correct answer with degree of confidence 6.
Learner6 said: (3) I do not agree with you.
Learner5 said: (9) Please tell me more about this
Learner6 said: (5) I believe that... (3) for base8, the value of 8^{-1} is equal 8x1.
Learner5 said: (3) I do not agree with you.
Learner6 said: (9) Please tell me more about this
Learner5 said: (5) I believe that..... (3) for base8, the value of 8^{-1} is equal 1/8.
Learner6 said: (10) Please go on, I don't want to talk about this any more
Learner5 said: (5) I believe that..... (5)Choice B is the correct answer with degree of confidence 6.
Learner6 said: (1) I agree with you.

E.3.2.12 Group C4: Question1

The detail of answers and degree of confidence in this question for learner23 and learner24 are: *learner23* choose to answer choice *A* with degree of confidence *2* while *learner24* choose choice *B* with degree of confidence *3*. Please give reasons of your answer by composing sentences with the provided utterances (start with learner24)

Learner24 said: (5) I believe that... (1) The number on the 3rd left of decimal point of base2 number is equal 2^2.
Learner23 said: (3) I do not agree with you.
Learner24 said: (9) Please tell me more about this
Learner23 said: (6) I am not sure but I think that... (3) for base8, the value of 8^2 is equal 8x2.
Learner24 said: (3) I do not agree with you.
Learner23 said: (10) Please go on, I don't want to talk about this anymore
Learner24 said: (5) I believe that... (5)Choice B is the correct answer with degree of confidence 5.
Learner23 said: (1) I agree with you.

E.3.2.13 Group D1: Question3

The detail of answers and degree of confidence in this question for learner21 and learner22 are: *learner21* choose to answer choice *B* with degree of confidence *5* while *learner22* choose choice *B* with degree of confidence *10*. Please give reasons of your answer by composing sentences with the provided utterances (start with learner22)

Learner46 said: (5) I believe that... (5)Choice B is the correct answer with degree of confidence 10.
Learner45 said: (3) I do not agree with you.
Learner46 said: (9) Please tell me more about this
Learner45 said: (5) I believe that... (5)Choice B is the correct answer with degree of confidence 10.
Learner46 said: (1) I agree with you.

E.3.2.14 Group D2: Question1

The detail of answers and degree of confidence in this question for learner35 and learner36 are: *learner35* choose to answer choice *C* with degree of confidence *10* while *learner36* choose choice *C* with degree of confidence *6*. Please give reasons of your answer by composing sentences with the provided utterances (start with learner36)

Learner36 said: (5) I believe that... (1) The number on the 1st left of decimal point of base2 number is equal 2^{-8}.
Learner35 said: (3) I do not agree with you.
Learner36 said: (10) Please go on, I don't want to talk about this anymore
Learner35 said: (5) I believe that... (3) for base8, the value of 8^2 is equal 8x8.
Learner36 said: (3) I do not agree with you.
Learner35 said: (9) Please tell me more about this
Learner35 said: (5) I believe that... (5)Choice C is the correct answer with degree of confidence 8.
Learner36 said: (1) I agree with you.

E.3.2.15 Group E2: Question3

The detail of answers and degree of confidence in this question for learner43 and learner44 are: *learner43* choose to answer choice *C* with degree of confidence *5* while *learner44* choose choice *A* with degree of confidence *1*. Please give reasons of your answer by composing sentences with the provided utterances (start with learner43)

Learner43 said: (5) I believe that... (5)Choice C is the correct answer with degree of confidence 10.
Learner44 said: (6) I am not sure but I think that... (5)Choice A is the correct answer with degree of confidence 1.
Learner43 said: (5) I believe that... (5)Choice C is the correct answer with degree of confidence 10.
Learner44 said: (1) I agree with you.

E.3.2.16 Group E3: Question3

The detail of answers and degree of confidence in this question for learner45 and learner46 are: *learner45* choose to answer choice *C* with degree of confidence *8* while *learner46* choose choice *B* with degree of confidence *7*. Please give reasons of your answer by composing sentences with the provided utterances (start with learner46)

Learner46 said: (5) I believe that... (5)Choice B is the correct answer with degree of confidence 7.
Learner45 said: (3) I do not agree with you.
Learner46 said: (9) Please tell me more about this
Learner45 said: (5) I believe that... (5)Choice C is the correct answer with degree of confidence 8.
Learner46 said: (5) I believe that... (1) The number on the 1^{st} right of decimal point of base8 number is equal 8^{-1}.
Learner45 said: (1) I agree with you.
Learner46 said: (5) I believe that... (3) for base8, the value of 8^{-1} is equal 1/8.
Learner45 said: (1) I agree with you.
Learner46 said: (5) I believe that... (2) the value of number on each bit can be calculated by multiplied that particular number to the value of that bit.
Learner45 said: (1) I agree with you.
Learner46 said: (5) I believe that... (5)Choice B is the correct answer with degree of confidence 8.
Learner45 said: (1) I agree with you.

E.3.2.17 Group E4: Question3

The detail of answers and degree of confidence in this question for learner1 and learner2 are: *learner1* choose to answer choice *B* with degree of confidence *7* while *learner2* choose choice *A* with degree of confidence *4*. Please give reasons of your answer by composing sentences with the provided utterances (start with learner2)

Learner2 said: (6) I am not sure but I think that... (5)Choice A is the correct answer with degree of confidence 4.
Learner1 said: (9) Please tell me more about this
Learner2 said: (6) I am not sure but I think that... (1) The number on the 1^{st} right of decimal point of base8 number is equal 8^{-1}.
Learner1 said: (9) Please tell me more about this
Learner2 said: (6) I am not sure but I think that... (2) the value of number on each bit can be calculated by multiplied that particular number to the value of that bit.
Learner1 said: (9) Please tell me more about this
Learner2 said: (5) I believe that... (5)Choice A is the correct answer with degree of confidence 5.
Learner1 said: (1) I agree with you.

E.3.2.18 Group F3: Question2

The detail of answers and degree of confidence in this question for learner11 and learner12 are: *learner11* choose to answer choice *B* with degree of confidence *3* while *learner12* choose choice *B* with degree of confidence *2*. Please give reasons of your answer by composing sentences with the provided utterances (start with learner12)

Learner12 said: (7) I don't know but I guess that... (5) Choice B is the correct answer with degree of confidence 2.
Learner11 said: (3) I do not agree with you.
Learner12 said: (9) Please tell me more about this
Learner11 said: (5) I believe that... (5)Choice B is the correct answer with degree of confidence 4.
Learner12 said: (1) I agree with you.

E.3.2.19 Group F3: Question4

The detail of answers and degree of confidence in this question for learner11 and learner12 are: *learner11* choose to answer choice *B* with degree of confidence *6* while *learner12* choose choice *C* with degree of confidence *2*. Please give reasons of your answer by composing sentences with the provided utterances (start with learner11)

Learner11 said: (5) I believe that... (5)Choice B is the correct answer with degree of confidence 6.
Learner12 said: (7) I don't know but I guess that... (5) Choice C is the correct answer with degree of confidence 2.
Learner11 said: (5) I believe that... (2) the value of number on each bit can be calculated by multiplied that particular number to the value of that bit.
Learner12 said: (9) Please tell me more about this
Learner11 said: (5) I believe that... (4) the result of number conversion can be calculated by adding the value of each bit together.
Learner12 said: (9) Please tell me more about this
Learner11 said: (5) I believe that... (1) The number on the 1^{st} right of decimal point of base8 number is equal 8^{-1}.
Learner12 said: (9) Please tell me more about this
Learner11 said: (5) I believe that... (5)Choice B is the correct answer with degree of confidence 7.
Learner12 said: (1) I agree with you.

E.3.2.20 Group F4: Question1

The detail of answers and degree of confidence in this question for learner13 and learner14 are: *learner13* choose to answer choice *A* with degree of confidence *5* while *learner14* choose choice *C* with degree of confidence *7*. Please give reasons of your answer by composing sentences with the provided utterances (start with learner14)

Learner14 said: (5) I believe that... (1) The number on the 3rd left of decimal point of base8 number is equal 8^2.
Learner13 said: (9) Please tell me more about this
Learner14 said: (5) I believe that... (3) for base8, the value of 8^2 is equal 8x8.
Learner13 said: (9) Please tell me more about this
Learner14 said: (5) I believe that... (5)Choice C is the correct answer with degree of confidence 8.
Learner13 said: (1) I agree with you.

E.3.2.21 Group F4: Question3

The detail of answers and degree of confidence in this question for learner13 and learner14 are: *learner13* choose to answer choice *B* with degree of confidence *7* while *learner14* choose choice *A* with degree of confidence *3*. Please give reasons of your answer by composing sentences with the provided utterances (start with learner14)

Learner14 said: (7) I don't know but I guess that... (5)Choice A is the correct answer with degree of confidence 3.
Learner13 said: (3) I do not agree with you.
Learner14 said: (9) Please tell me more about this
Learner13 said: (5) I believe that.. (2) the value of number on each bit can be calculated by multiplied that particular number to the value of that bit.
Learner14 said: (9) Please tell me more about this

Learner13 said: (5) I believe that... (3) for base8, the value of 8^{-1} is equal 1/8.
Learner14 said: (9) Please tell me more about this
Learner13 said: (5) I believe that... (5)Choice B is the correct answer with degree of confidence 8.
Learner14 said: (1) I agree with you.

Appendix F

Relevance and Correctness of the Answers

In Appendix F, we refer to the six learning concepts of '*number-conversion'* that have already been stated in Chapter 4. In order to measure whether learners' answers or what they contribute during the group-test is relevant and correct, the information presented here in section F.1 to F.6 is used as rules to measure the correctness of the answer. We assume that apart from what is stated in F.1 to F.6, the learner might have misconceptions concerning the particulars of '*number-conversion*'.

F.1 Concept1

This concept aims at measuring whether *learners can use the value of each bit position on the left of the decimal point to calculate for a specific number*. There are three different based numbers, which are base-2, base-8 and base-16 that we are concerned about. Details of what we define as correctness are expressed in F.1.1 for base-2, F.1.2 for base-8 and F.1.3 for base-16.

F.1.1 Concept1 for base-2

This concept aims at measuring whether *learners can use the value of each bit position to the left of the decimal point to calculate for a base-2 number*. We assume that learners might know about concept1 if they state either of statements below

Number on the 1st left of the decimal point of base-2 number is equal 2 powered by 0.
Number on the 2nd left of the decimal point of base-2 number is equal 2 powered by1.
Number on the 3rd left of the decimal point of base-2 number is equal 2 powered by 2.
Number on the 4th left of the decimal point of base-2 number is equal 2 powered by 3.
Number on the 5th left of the decimal point of base-2 number is equal 2 powered by 4.
Number on the 6th left of the decimal point of base-2 number is equal 2 powered by 5.
Number on the 7th left of the decimal point of base-2 number is equal 2 powered by 6.
Number on the 8th left of the decimal point of base-2 number is equal 2 powered by 7.

F.1.2 Concept1 for base-8

This concept aims at measuring whether *learners can use the value of each bit position to the left of the decimal point to calculate for a base-8 number*. We assume that learners might know about concept1 if they state either of statements below

Number on the 1st left of the decimal point of base-8 number is equal 8 powered by 0.
Number on the 2nd left of the decimal point of base-8 number is equal 8 powered by1.
Number on the 3rd left of the decimal point of base-8 number is equal 8 powered by 2.
Number on the 4th left of the decimal point of base-8 number is equal 8 powered by 3.
Number on the 5th left of the decimal point of base-8 number is equal 8 powered by 4.
Number on the 6th left of the decimal point of base-8 number is equal 8 powered by 5.
Number on the 7th left of the decimal point of base-8 number is equal 8 powered by 6.
Number on the 8th left of the decimal point of base-8 number is equal 8 powered by 7.

F.1.3 Concept1 for base-16

This concept aims at measuring whether *learners can use the value of each bit position to the left of the decimal point to calculate for a base-16 number*. We assume that learners might know about concept1 if they state either of statements below

Number on the 1st left of the decimal point of base-16 number is equal 16 powered by 0.
Number on the 2nd left of the decimal point of base-16 number is equal 16 powered by1.
Number on the 3rd left of the decimal point of base-16 number is equal 16 powered by 2.
Number on the 4th left of the decimal point of base-16 number is equal 16 powered by 3.
Number on the 5th left of the decimal point of base-16 number is equal 16 powered by 4.
Number on the 6th left of the decimal point of base-16 number is equal 16 powered by 5.
Number on the 7th left of the decimal point of base-16 number is equal 16 powered by 6.
Number on the 8th left of the decimal point of base-16 number is equal 16 powered by 7.

F.2 Concept2

This concept aims at measuring whether *learners can use the value of each bit position to the right of the decimal point to calculate for a specific number*. There are three different based number, which are base-2, base-8 and base-16 that we are concerned about. Details of what we define as correctness are expressed in F.2.1 for base-2, F.2.2 for base-8 and F.2.3 for base-16.

F.2.1 Concept2 for base-2

This concept aims at measuring whether *learners can use the value of each bit position to the right of the decimal point to calculate for a base-2 number*. We assume that learners might know about concept1 if they state either of statements below

Number on the 1st right of the decimal point of base-2 number is equal 2 powered by -1.
Number on the 2nd right of the decimal point of base-2 number is equal 2 powered by-2.
Number on the 3rd right of the decimal point of base-2 number is equal 2 powered by -3.
Number on the 4th right of the decimal point of base-2 number is equal 2 powered by -4.
Number on the 5th right of the decimal point of base-2 number is equal 2 powered by -5.
Number on the 6th right of the decimal point of base-2 number is equal 2 powered by -6.
Number on the 7th right of the decimal point of base-2 number is equal 2 powered by -7.
Number on the 8th right of the decimal point of base-2 number is equal 2 powered by -8.

F.2.2 Concept2 for base-8

This concept aims at measuring whether *learners can use the value of each bit position to the right of the decimal point to calculate for a base-8 number*. We assume that learners might know about concept1 if they state either of statements below

Number on the 1st right of the decimal point of base-8 number is equal 8 powered by -1.
Number on the 2nd right of the decimal point of base-8 number is equal 8 powered by-2.
Number on the 3rd right of the decimal point of base-8 number is equal 8 powered by -3.
Number on the 4th right of the decimal point of base-8 number is equal 8 powered by -4.
Number on the 5th right of the decimal point of base-8 number is equal 8 powered by -5.
Number on the 6th right of the decimal point of base-8 number is equal 8 powered by -6.
Number on the 7th right of the decimal point of base-8 number is equal 8 powered by -7.
Number on the 8th right of the decimal point of base-8 number is equal 8 powered by -8.

F.2.3 Concept2 base-16

This concept aims at measuring whether *learners can use the value of each bit position to the right of the decimal point to calculate for a base-16 number*. We assume that learners might know about concept1 if they state either of statements below

Number on the 1st right of the decimal point of base-16 number is equal 16 powered by -1.
Number on the 2nd right of the decimal point of base-16 number is equal 16 powered by -2.
Number on the 3rd right of the decimal point of base-16 number is equal 16 powered by -3.
Number on the 4th right of the decimal point of base-16 number is equal 16 powered by -4.
Number on the 5th right of the decimal point of base-16 number is equal 16 powered by -5.
Number on the 6th right of the decimal point of base-16 number is equal 16 powered by -6.
Number on the 7th right of the decimal point of base-16 number is equal 16 powered by -7.
Number on the 8th right of the decimal point of base-16 number is equal 16 powered by -8.

F.3 Concept3

This concept aims at measuring whether *learners can use the arithmetic operator to calculate for the value between each bit*. We assume that learners might know about concept4 if they state that *'the value of each bit can be calculated by using arithmetic operator x to do between the specific number and value of bit position'.*

F.4 Concept4

This concept aims at measuring whether *learners can use the arithmetic operator to calculate for the value between each bit*. We assume that learners might know about concept4 if they state that *'the value of each specific number can be calculated by using arithmetic operator "+" to do value between each bit'.*

F.5 Concept5

This concept aims at measuring whether *learners can transform the given number, which is to the left of the decimal point into other forms.*' There are three different based number, which are base-2, base-8 and base-16 that we are concerned about. Details of what we define as correctness are expressed in F.5.1 for base-2, F.5.2 for base-8 and F.5.3 for base-16.

F.5.1 Concept5 for base-2

This concept aims at measuring whether *learners can transform the given number, which is to the left of the decimal point into other forms of base-2 number.* We assume that learners might know about concept1 if they state either of statements below

For base-2 number, the value of 2 powered by 0 is equal 1.
For base-2 number, the value of 2 powered by 1 is equal 2.
For base-2 number, the value of 2 powered by 2 is equal 2+2.
For base-2 number, the value of 2 powered by 2 is equal 2x2.
For base-2 number, the value of 2 powered by 3 is equal 2x2x2.
For base-2 number, the value of 2 powered by 4 is equal 2x2x2x2.
For base-2 number, the value of 2 powered by 5 is equal 2x2x2x2x2.
For base-2 number, the value of 2 powered by 6 is equal 2x2x2x2x2x2.
For base-2 number, the value of 2 powered by 7 is equal 2x2x2x2x2x2x2.

F.5.2 Concept5 for base-8

This concept aims at measuring whether learners can transform the given number, which is to the left of the decimal point into other forms of base-8 number. We assume that learners might know about concept1 if they state either of statements below

For base-8 number, the value of 8 powered by 0 is equal 1.
For base-8 number, the value of 8 powered by 1 is equal 8.
For base-8 number, the value of 8 powered by 2 is equal 8x8.
For base-8 number, the value of 8 powered by 3 is equal 8x8x8.
For base-8 number, the value of 8 powered by 4 is equal 8x8x8x8.
For base-8 number, the value of 8 powered by 5 is equal 8x8x8x8x8.
For base-8 number, the value of 8 powered by 6 is equal 8x8x8x8x8x8.
For base-8 number, the value of 8 powered by 7 is equal 8x8x8x8x8x8x8.

F.5.3 Concept5 for base-16

This concept aims at measuring whether *learners can transform the given number, which is to the left of the decimal point into other forms of base-16 number*. We assume that learners might know about concept1 if they state either of statements below

For base-16 number, the value of 16 powered by 0 is equal 1.
For base-16 number, the value of 16 powered by 1 is equal 16.
For base-16 number, the value of 16 powered by 2 is equal 16x16.
For base-16 number, the value of 16 powered by 3 is equal 16x16x16.
For base-16 number, the value of 16 powered by 4 is equal 16x16x16x16.
For base-16 number, the value of 16 powered by 5 is equal 16x16x16x16x16.
For base-16 number, the value of 16 powered by 6 is equal 16x16x16x16x16x16.
For base-16 number, the value of 16 powered by 7 is equal 16x16x16x16x16x16x16.

F.6 Concept6

This concept aims at measuring whether *learners can transform the given number, which is to the right of the decimal point into other forms*. There are three different based number, which are base-2, base-8 and base-16 that we are concerned about. Details of what we define as correctness are expressed in F.6.1 for base-2, F.6.2 for base-8 and F.6.3 for base-16.

F.6.1 Concept6 for base-2

This concept aims at measuring whether *learners can transform the given number, which is to the right of the decimal point into other forms of base-2 number*. We assume that learners might know about concept1 if they state either of statements below

For base-2 number, the value of 2 powered by -1 is equal 1/2.
For base-2 number, the value of 2 powered by -2 is equal (1/2)x(1/2).
For base-2 number, the value of 2 powered by -3 is equal (1/2)x(1/2)x(1/2)..
For base-2 number, the value of 2 powered by -4 is equal (1/2)x(1/2)x(1/2)x(1/2).
For base-2 number, the value of 2 powered by -5 is equal (1/2)x(1/2)x(1/2)x(1/2)x(1/2).
For base-2 number, the value of 2 powered by -6 is equal
(1/2)x(1/2)x(1/2)x(1/2)x(1/2) x(1/2).

For base-2 number, the value of 2 powered by -7 is equal
(1/2)x(1/2)x(1/2)x(1/2)x(1/2) x(1/2)x(1/2).
For base-2 number, the value of 2 powered by -8 is equal
(1/2)x(1/2)x(1/2)x(1/2)x(1/2) x(1/2)x(1/2)x(1/2).

F.6.2 Concept6 for base-8

This concept aims at measuring whether *learners can transform the given number, which is to the right of the decimal point into other forms of base-8 number*. We assume that learners might know about concept1 if they state either of statements below

For base-8 number, the value of 8 powered by -1 is equal 1/8.
For base-8 number, the value of 8 powered by -2 is equal (1/8)x(1/8).
For base-8 number, the value of 8 powered by -3 is equal (1/8)x(1/8)x(1/8)..
For base-8 number, the value of 8 powered by -4 is equal (1/8)x(1/8)x(1/8)x(1/8).
For base-8 number, the value of 8 powered by -5 is equal (1/8)x(1/8)x(1/8)x(1/8)x(1/8).
For base-8 number, the value of 8 powered by -6 is equal
(1/8)x(1/8)x(1/8)x(1/8)x(1/8)x(1/8).
For base-8 number, the value of 8 powered by -7 is equal
(1/8)x(1/8)x(1/8)x(1/8)x(1/8)x(1/8)x(1/8).
For base-8 number, the value of 8 powered by -8 is equal
(1/8)x(1/8)x(1/8)x(1/8)x(1/8)x(1/8)x(1/8)x(1/8).

F.6.3 Concept6 for base-16

This concept aims at measuring whether l*earners can transform the given number, which is to the right of the decimal point into other forms of base-16 number*. We assume that learners might know about concept1 if they state either of statements below

For base-16 number, the value of 16 powered by -1 is equal 1/16.
For base-16 number, the value of 16 powered by -2 is equal (1/16)x(1/16).
For base-16 number, the value of 16 powered by -3 is equal (1/16)x(1/16)x(1/16)..
For base-16 number, the value of 16 powered by -4 is equal
(1/16)x(1/16)x(1/16)x(1/16).
For base-16 number, the value of 16 powered by -5 is equal
(1/16)x(1/16)x(1/16)x(1/16)x(1/16).
For base-16 number, the value of 16 powered by -6 is equal
(1/16)x(1/16)x(1/16)x(1/16)x(1/16)x(1/16).
For base-16 number, the value of 16 powered by -7 is equal
(1/16)x(1/16)x(1/16)x(1/16)x(1/16)x(1/16)x(1/16).
For base-16 number, the value of 16 powered by -16 is equal
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Enhancing Metacognitive Skills through the use of a Group Open Learner Model based on the Zone of Proximal Development

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Abstract: Collaborative Learning is seen as a good way to encourage peers to learn and to teach each other whereas Open Learner Modelling can help learners to enhance their metacognitive skills and their understanding using high-level indicators to monitor, and represent, the state of their learning. In this work we aim to develop a learning environment that encourages students to obtain an advantage from both Collaborative Learning and Open Learner Modelling. We then seek to determine the benefits of Collaborative Learning with a scrutable Group Learner Model[1] by examining the learning gains when compared with the case in which no Group Learner Model is available.

1. Introduction

Collaborative Learning is seen as a good way to encourage peers to learn and to teach each other whereas Open Learner Modelling can help learners to improve their performance and their understanding using high-level indicators to monitor, and represent, the state of their learning. This research seeks to apply both concepts of Collaborative Learning and Open Learner Modelling.

Why collaborative learning? Following Vygotsky who argued that learning had a strong social dimension. We believe that learners can often better improve their knowledge while learning with peers than learning individually. In this work, we exploit the notion of Vygotsky's Zone of Proximal Development, defined as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" [2, p.86].

An Open Learner Model is often considered to be an aid to reflection. Bull defines an Open Learner Model (OLM) as a student model which is designed to help learners understand what they have learned more effectively[3]. This kind of model allows the learner to inspect, and sometimes challenge, beliefs recorded in the user model which encourages the learner to think more deeply or extensively about their understanding.

Group Open Learner Model emerges from the merging of a ‘Group Model’ and an ‘Open Learner Model’. An ‘Open Learner Model’ is simply thought of as an aid to reflection while a ‘Group Model’ is a more complex concept. While there are many works that use a group model, there are few that can define the OLM in a way that differentiates clearly between the emerging properties of the group and the properties of the individuals involved. For our work, we especially need to define what exactly the group model is, how it works, and precisely what the model includes. From Paiva [4], a group model is considered as ‘a way of capturing the aspects that identify a group as a whole’ and it may include group beliefs, group actions, group goals, group misconceptions, differences between individual and group conflicts.

Less has been done with Group Open Learner Models (GOLMs) though Zapata-Rivera and Greer[5] found that students could be very confused when seeking to understand their GOLM. However, this GOLM was developed by a group of students working together with a single instance of Zapata-Rivera's ViSMod system. The issue of the GOLM is taken up again later.

2. Research Problems

During past decades, many tools and methodologies have been designed to support Collaborative Learning interaction. The focus of this research topic is shifted from 'studying group characteristics and product', which contain many unpredictable factors, to 'studying group process' in the nineties. Jermann, Soller et al [6] introduced the idea of the 'Collaboration Management Cycle', which consists of four phases: Collect interaction data, Construct a model of interaction, Compare the current state of interaction to the desired state and Advise/Guide the interaction. This cycle provides a conceptual framework for managing collaborative interaction. In their view, all the four phases above are covered by three computer-based support options: Mirroring tools, Metacognitive tools and Guiding Systems.

When someone learns a topic, either on their own or with a friend, they may need to know how well they performed on that particular task. In the classroom, the teacher may give some information such as a score or some suggestion about performance on the task[1]. An Open Learner Model is considered to be an aid to reflection insofar as it can convey - directly or indirectly[2] - such information, and provokes the learner to think about the truth or falsity of the information conveyed, and in doing this, reflects upon a number of issues including perhaps that of how their learning is progressing.

An Open Learner Model is seen as the model that reflects back to the learner information that lets them know how well they are performing particular tasks or how well they understand some concept. From the information provided, learners then become aware of their knowledge and decide what should do next. The generally held belief amongst researchers is that it is possible to improve learners’ knowledge by showing them their learner model [7-9]. To investigate this belief, concepts of ‘Theory of Mind’ and ‘Meta-Cognition’ are considered as crucial factors to understand how OLMs help improve knowledge (skills).

2.1 Theory of Mind, Metacognition and Metacognitive Skills

One definition of ‘Theory of Mind’ is as ‘a specific cognitive ability to understand others as intentional agents to interpret their mind in terms of theoretical concept of intentional states such as beliefs and desires’[10]. In short, theory of mind is ‘an awareness and understanding of mental processes’. For example when a learner performs a specific task and the system reflects back the score or some other information, the way that learner try to

[1] This might be done in absolute or relative terms e.g. you got 7/10 or you did better than the average.
[2] By indirect, we mean that the information may not be explicit but can be inferred from the information provided.

understand what the system reflects back is what the system believes about a learner's knowledge and skills.

One form of 'Metacognition' is often simply defined as 'thinking about thinking'[11]. However defining Metacognition is not simple because there is still much debate over what metacognition means for a couple of decades. Defining by Wilson[12, p.14], "Metacognition is the knowledge and awareness one has of their own thinking processes and strategies and the ability to evaluate and regulate one's own thinking processes".

According to Flavell [13] metacognition consists of both metacognitive knowledge and metacognitive experience or regulation. Metacognitive knowledge is briefly stated to acquire knowledge about cognitive process and how to use knowledge to control the cognitive process. Flavell divided metacognitive knowledge into three categories: knowledge of person variables, task variables and strategy variables. Knowledge of person variables contains information about how well a particular person learned and processed information while knowledge about task variables considers the nature of the task to provide a suitable environment for the most productive results (e.g. reading a physics book is harder to understand than reading a novel so more time should be provided for this physics task). Knowledge strategy variables are concerned with when and where appropriate strategies are being applied.

Metacognitive experience involves the uses of Metacognitive regulation to control cognitive activities to ensure that the cognitive goal has been met. For example, after reading a lesson asking oneself what one has got from the lesson. If the question cannot be answered, then go back to the lesson again and at the same time determine what else can be done to ensure that that lesson has been understood.

Schraw [14, p.121] has develop a regulatory checklists that student can use to monitor their own metacognitive control. There are three groups of checklists: Developing a plan of action, Monitoring the plan (being aware of everything that has been done by oneself), and Evaluating the plan. The following is an initial adaptation of Schraw's checklists for the group learning[3].

1. Checklists for developing a plan of action (Before performing a task)
    - How much my peer does know?
    - How much our prior knowledge?
    - How can I get my peer to help me?
    - What should we do first?
    - How much time is needed to complete this task?

2. Checklists for Monitoring a plan of action (During performing a task)
    - How are we doing?
    - Can I make a group contribution?
    - How should we proceed?
    - What do we need to do if either you or I don't understand?

3. Checklists for Evaluating a plan of action (After performing a task)
    - How well did we do?
    - Did we do more or less well than what we had expected?
    - What could I have done differently?
    - Did we learn more?
    - How well I have helped peer to learn better?

[3] These checklists suggest a way of evaluating metacognitive activity

If learners have such a Metacognitive experience, we assume that they will have self-awareness of what they know and what they do not know, and what they should do to complete the given task. In Collaborative Learning, there is a need not only to understand themselves but also to understand others which motivates our concern to include notions of Theory of Mind. Thus knowing how the group is doing and reflecting upon the Group Open Learner Model, the learner also needs to understand themselves so that they can determine their weak and strong points. At the same time, they may need to take into account the knowledge of their peers and the potential for their peers to help them.

2.2. Collaborative Learning and Zone of Proximal Development

Collaborative Learning is interpreted here in two distinct ways - the way that learners help each other in a group and the way that a teacher or a learning system helps the student to gain a better understanding. Teaching collaboratively helps learners to learn skills and ideas initially in their ZPD which is why "collaborative teaching" is important. Murray and Arroyo [15] implemented a learner model to support the concept of ZPD – their work illustrated that the student who masters material collaboratively today can master it individually tomorrow.

Related to the idea of ZPD is that everyone may be in a different state of learning in a group. Hence with a user model, either a personal or a group model, it is possible to individualise the level of knowledge to provide a suitable degree of reflection. However for developing more efficient collaborative learning, empirical studies have changed the focus from 'establishing parameters' to trying to understand the role which such variables play in mediating interaction [16].

There are many systems that are used for Collaborative Learning, some of which refer to the concept of ZPD, some reflect back the learner model to an individual student and a very few use a GOLM but how many of them contain both concepts of reflecting back group knowledge and explicit use of the notion of the ZPD? Six systems have been selected as representative of the state of the art; these are compared.

Table1: The comparison of systems to represent concept of ZPD, individual and group learner model

System's name	**References**	**Did they use the ZPD concept explicitly[4]?**	**Did they reflect back to individual learner?**	**Did they reflect back the group learner model?**
ViSMod[5]	[5]	No	Yes	No
ECOLAB	[7]	Yes	Yes	No
ICLS	[17]	No	Yes	Yes
PairSM	[18]	Yes	Yes	No
STyLE-OLM	[9]	No	Yes	No
Mr.Collins	[19]	No	Yes	No

2.3 Group Learner Model

Group Open Learner Model emerges from the merging of a 'Group Model' and an 'Open Learner Model'. Paiva [4] described two scenarios which represent her notion of a group

[4] We mean that internally there is a model of the learner which represents ZPD in some direct ways.

[5] Another version of ViSMod describes some works with a Group Model but not the kind that we are interested in.

model. The first scenario is to combine multiple individual models for the possible peer group (this notion is presented by Hoppe[20]). The second scenario is about learners who interact with the collaborative environment for which all of these properties should be considered: a shared-task space, a communication space, authorisation to see the communication, a domain model and an individual-task space.

According to Table 1, ViSMod, STyLE-OLM and Mr.Collins are systems that reflect back only to individual learners whereas PairSM and Ecolab use both the concept of ZPD and reflect back the model to each learner. ICLS reflects back both individual and Group Learner Models. However none of the systems above uses all of the concepts - namely, ZPD and reflecting back the individual and group models. In this paper, the ideas of the system that utilises both the concept of ZPD and reflecting back the Group Learner Model are illustrated. The first question is why we want to utilise a Group Model and the second is how are we going to generate a Group Model?

2.3.1 How are we going to generate a Group Model?

Most people see the Group Model as some kind of addition of individual models. Hoppe[20] combined multiple individual learner models with the aim of forming more effective peer groups though Paiva [4] looked for something potentially better by combining the concept of a group model with an individual learner model to construct a basic framework for models in collaborative situations. However PairSM, a model that applied a simple picture and a set theory equation to illustrate the Group Learner Model, seems to be interesting because it considers a Group Learner Model together with the notion of the ZPD even though the group model comes from a simple combination of the individual learner models. The explanation above can express a Group Model as an equation $SM\text{-}S1S2 = SM1 \cup SM2 \cup SM\ S1\&S2$,which SM represents the knowledge of an individual learner, and SM S1&S2 represents knowledge that the two can display only when working together. The group model in this work will borrow ideas from both Paiva and PairSM to generate the group model for Collaborative Learning with considering to ZPD concept.

2.3.2 How are we going to represent the model?

There are many possible ways such as text and graphical form that we could represent the learner model. STyLE-OLM [9]uses a diagrammatic form of conceptual graph to represent the learner model and the text form for an interaction model. Moreover users can swap between learning mode and interaction mode to see what they have done in the past. ViSMod [5] uses different colours and link sizes and nodes to indicate the level of knowledge for particular learners for each concept. This should help learners quickly distinguish how well they perform for each concept. In our work, we will use a text form to represent the interaction model, while a graphical form will be used to indicate the level of knowledge for both group and individual learners.

2.3.3 How are we going to manage the interaction?

STyLE-OLM, and ICLS use different means of tagging individual moves in the interaction. STyLE-OLM uses the notion of a dialogue game for interactive communication between a learner and the system, while the open learner model concept allows student to inspect and negotiate their own model. Mr.Collins aims at improving learning through promoting reflection by giving a chance to both students and a system to defend their beliefs using the difference of confidence in beliefs between the learner and the system. Whether learners can challenge and negotiate models through menu, changing models ultimately depends on the rules programmed into the system.

ICLS (Intelligent Collaborative Learning System) provides a good example of the use of sentence openers. This emphasises the role of communicative interaction. The ICLS system classifies groups of sentence openers, helping the group know how well they perform. In our work, we borrow the idea of dialogue game and sentence opener for the communication interaction and the level of confidence for their beliefs to generate the learner model. In our research we focus on a Group Open Learner Model for Collaborative Learning. The group model will borrow ideas from Paiva and Bull's PairSM to generate the group model while taking the notion of the ZPD into account. Dialogue game and sentence openers will be used for communication interaction whereas it is planned to use a pie-chart and text as mirroring tools to represent the learner's beliefs and knowledge.

3. Evaluation

It is currently envisaged that two conditions for learning with a peer are compared: 'can see the group model' and 'cannot see the group model' using a bar-chart and some explanation to represent the information of each sub-concept that the group performs. The hypothesis is that learning with a peer and seeing the information reflected back as a group model will help the learner get a higher score than not seeing the group model.

The learner model - either group or individual - contains elements as a member of set for each sub-concepts. There are two major types of information that are represented in the learner model: ‘Experience’ and ‘Inexperience’ value. In this system, the‘Experience’ value contains one of these three values: ‘K’ as Known that a sub-concept is used correctly, ‘M’ as MayKnown for a sub-concept is sometimes used correctly, and ‘N’ as Notknown for a sub-concept is used incorrectly.Values represent in each elements of sub-concept show the performance of using sub-concepts for previous tasks of particular learners. While the ‘Inexperience’ value for a sub-concept represents the situation that the learner has not tried to perform a task involving that concept before (as far as the system knows).

There are two types of group models: GLM (Group Learner Model) and Ideal GLM (Ideal Group Learner Model -see Figure 1).

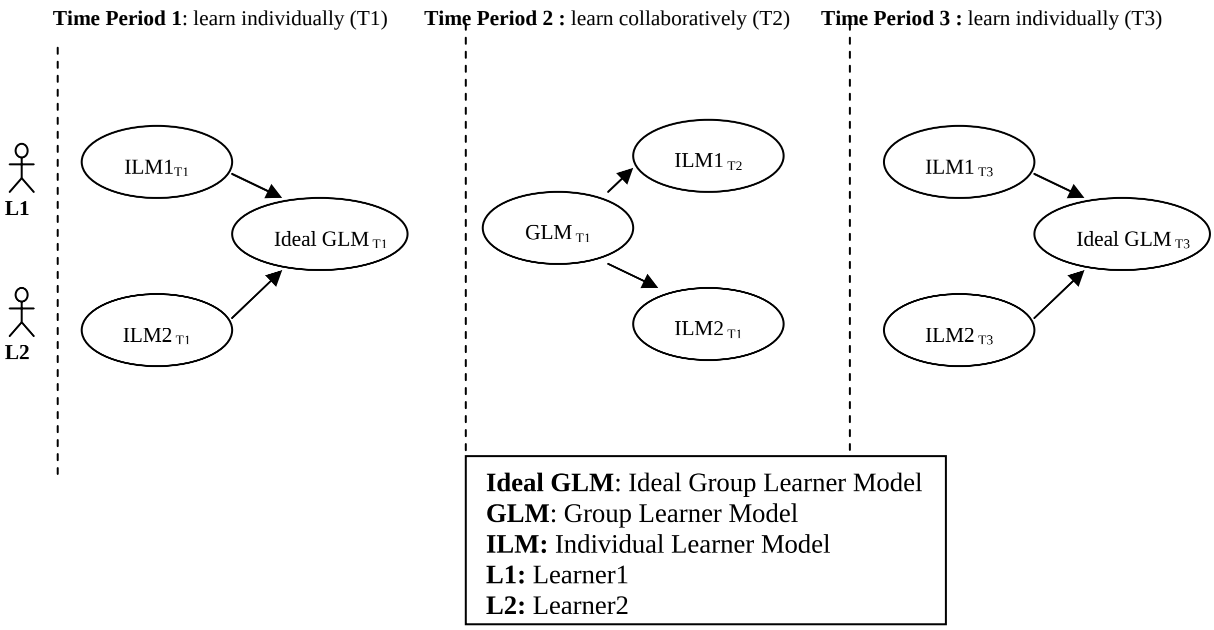

Figure 1: A Group Model diagram

- *GLM*: the group model that reflects the collective effort made by learner1 (L1) and learner2 (L2) when they collaboratively solve the group task.

- *Ideal GLM*: the group model which is constructed from the individual learner models (ILM1 and ILM2).

To fulfil that aim, we have decided to use two students learning together[6]. Each student can choose their peer as they wish from the list that the system provides. Before starting to learn with a peer, the learner registers with the system and takes a pretest. The learner's information is kept individually for use in the future.

As seen in Figure 1, there are two learners L1 and L2 who have decided to learner together. Firstly they perform the task individually during Time Period 1 and submit their answer to the system at the end or the period. After that results of learning are checked, scored, they are reflected back to learners as an Ideal GLM. The Ideal GLM is expected to promote self assessment, self-awareness (at least). Thus encouraging Metacognition, learners would be supposted to assess both their own knowledge and their peers' knowledge by the provided information.

The Ideal GLM uses a model merging algorithm to derive a group model which is ideal in the sense that the merging of models is intended to show the potential of the group (assuming no learning takes place). In a group model, we present the values that calculate from the difference between the Ideal GLM and GLM in terms of bar-charts with some explanatory information. If learners see these details and perform better than learners who cannot see this information, we may be able to conclude that a group model[7] is effective for collaborative learning.

During Time Period 2, learner are provided with the environment for the group task which allows interaction with both peer and the system by using a provided template for generating the dialogue. These dialogues rely on the concept of a dialogue move so that the system can categorise what learners try to say to each other, and will be used to determine what learners understand of that particular task. Each dialogue move that learners use will contribute a score which affects the assessment for each concept of the group model. The approach will rely technically on the use of fuzzy logic.

After finished a task, the system will reflect back the information of the group performance using GLM. At this stage, the result of an individual model ($LM1_{T1}$ and $LM2_{T1}$) from T1, which represent the actual knowledge of particular learners will be compared to the result of GLM_{T2} from T2. Differences of results are expected to be a potential performance of these learner and are kept in $LM1_{T2}$ and $LM2_{T2}$.

A simplified version of the ZPD is an ability of doing something that you cannot do you on your own but with others. The ability that learner can do something without any help sometimes is known as 'actual performance'. Whilst 'potential performance' represents the ability that with some helps, ones can complete tasks. In order to turn a potential performance into an actual performance, learners should repeat similar tasks individually as seen in Time Period 3 (Figure 1) after doing them collaboratively in Time Period 2. This time the information of each individual learner at each specific times is used to compare and calculate showing that learner can improve their knowledge and performance by collaboratively learning using this system. However no one can guarantee that particular learners will always succeed on the similar task again when doing it individually.

A prototype will be built to demonstrate the working of the model and it is expected to use fuzzy logic for dealing with the uncertainty in such a model. After the model has

[6] i.e. the pair will be regarded as a group, a simplifying assumption that we will seek to lift later.

[7] Note that this is a strong statement - the learners will *not* be shown their individual model. We are currently constructing a theoretical account of how this may work.

been developed further, the approach above will be implemented, tested and revised prior to developing the model used for the final study with learners. A repeated measure design within subject will be used to compare the result of learning to show that collaborative learning with the Group Open Learner Model is better than without the Group Open Learner Model.

4. Conclusion

Collaborative learning is a good way to encourage peers to learn and to teach each other whereas Open Learner Modelling gives learners an opportunity to inspect or sometimes challenge[8] their user model to make it more accurate and to learn from this process. The work described here aims to encourage students to obtain an advantage from both collaborative learning and the use of an Open Learner Model to try to prove that the result of collaborative learning using a Group Open Learner Model helps them get a higher score than when unable to inspect the group model. Since we also want to determine whether such an experience also contributes to the enhancement of the learners' metacognitive skills, we are currently considering how to extend the experimental design. After this work is done, further work will concentrate on 'In what ways is a Group Learner Model better than an individual Learner Model?'

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Enhancing Collaborative Learning through the use of a Group Model based on the Zone of Proximal Development

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Collaborative Learning is seen as a good way to encourage peers to learn and to teach each other whereas Open Learner Modelling can help learners to improve their performance and their understanding using high-level indicators to monitor, and represent, the state of their learning. This research seeks to apply both concepts of Collaborative Learning and Open Learner Modelling. Less has been done with Group Open Learner Models (GOLMs) though the idea has potential [1].

The group model will borrow ideas from both Paiva's work [2] and PairSM [3] to generate the group model taking the ZPD concept into account. In this work we would like to know whether the inspection of the GOLM improves learning. To answer that question, the value from the difference between the Ideal GLM[2] and GLM[3] is compared. If learners see a pie-chart and perform better than learners who cannot see the group model, we may be able to conclude that a group model is effective for collaborative learning.

A prototype will be built to demonstrate the working of the model and it is expected to use fuzzy logic for dealing with the uncertainty in such a model. After the model has been developed further, the approach above will be implemented, tested and revised prior to developing the model used for the final study with learners.

The work in this thesis aims to encourage students to obtain an advantage from both collaborative learning and the use of an Open Learner Model to try to prove that the result of collaborative learning with a group model capitalise Open Learner Model allows the learner to get a higher score than when unable to inspect the group model. Now we are in the process of simplifying the group model taking the ZPD into account and using fuzzy logic as a technique to generate values representing group knowledge After the hypothesis described above is tested, the next question for this work is ‘In what ways is a Group Learner Model better than an Individual Learner Model?’

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[1] The PhD student is under the supervision of Dr.Paul Brna.

[2] Ideal GLM is a model of the group that is generated from the performance of individual learners

[3] the group model that reflect when learner1 and learner2 collaboratively perform to solve the group task.

The Impact of a Group Open Learner Model on Learning in a Computer-Based Collaborative Learning Environment

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1. Introduction

Collaborative Learning is often seen as a good way to encourage peers to learn and teach each other while Open Learner Modelling is seen as helping learners improve their knowledge by representing the state of their learning[1]. This research seeks to apply both concepts of Collaborative Learning and Open Learner Modelling in a computer-based learning environment in order to see whether there is any difference between seeing and not seeing the group model.

We consider Collaborative Learning in terms of Vygotsky's Zone of Proximal Development which is defined as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" [2, p.86].

When someone learns something, whether on their own or with a friend, they may need to know how well they performed on that particular task. In the classroom, the teacher may give some information such as a score or some suggestion about their performance on the task. An Open Learner Model is considered to be an aid to reflection. Bull defines an Open Learner Model (OLM) as a student model which is designed to help learners understand what they have learned more effectively [3]. This kind of model allows the learner to inspect, and sometimes challenge, beliefs recorded in the user model in order to change them[4].

Less has been done with Group Open Learner Models (GOLMs) though there is some work with them. Zapata-Rivera and Greer [5] found that students could be very confused when seeking to understand their GOLM. However, this GOLM was developed by a group of students working together with a single instance of ViSMod. The issue of the GOLM is taken up again later.

2. Research Problems

Collaborative Learning is interpreted here in two distinct ways - the way that learners help each other in a group and the way that a teacher or a learning system helps the student to gain a better understanding. Teaching collaboratively helps learners to learn skills and ideas initially in their ZPD which is why "collaborative teaching" is important.

There are many systems that are used for Collaborative Learning, some of which refer to the concept of communicative interaction, some reflect back the learner model to an individual

[1] The author is a PhD student under the supervision of Prof Paul Brna.

student and a very few use a GOLM – but how many of them contain both the notion of reflecting back group knowledge and a concern for what learners say to each other? Five systems have been selected and compared as representative of the state of the art.

Table 1: The comparison of systems to represent communicative interaction, individual and group leaner model concepts

System's name	References	Did the system examine the content of learners' conversation?	Did the system reflect back the Learner Model to the learner?	Did the system reflect back the Group Learner Model?
ViSMod[2]	[5]	No	Yes	No
ICLS	[6]	Yes	Yes	Yes
PairSM	[7]	Yes	Yes	No
STyLE-OLM	[8]	No	Yes	No
Mr.Collins	[9]	No	Yes	No

According to Table 1, all of these five systems reflect back information to individual learners, and two of them are concerned with what learners say to each other. However apart from these two systems, only ICLS is concerned with what learners talk about and reflect on – both in relation to an individual and group model. Nevertheless the concentration of ICLS on the communicative interaction module is quite different to the system I am designing which will focus on updating the model from the knowledge exchanged rather than classify groups of sentence openers, to help the group know how well they cooperate. In order to do this, a dialogue game[10, 11] has been designed as a first approach to defining the communicative interaction possible in the system.

In our research we focus on a Group Open Learner Model in Collaborative Learning. The group model borrows ideas from both Paiva's work [12] and PairSM [7] to generate the group model while a dialogue game and a set of sentence opener will be used for communication interaction. Each role and move of the game has been defined and applied in the domain of 'Number-based conversion'. To confirm my belief that this domain is suitable, I produced a multiple choice test and asked experts to do the test. The result from 10 experts who graduated and work in the area of computing reveals that some of them still make mistakes even though they have previously learned this particular topic.

3. Evaluation

It is currently envisaged that two conditions for learning with a peer will be compared: can see the group model and cannot see the group model using a bar-chart to represent the group model. The main hypothesis is that learning with a peer and seeing the group model will help the learner get a higher score than not seeing the group model.

There are two types of group models: GLM (Group Learner Model) and IdealGLM (Ideal Group Learner Model) – see Figure1.

[2] Another version of ViSMod [5] describes some works with a group model but not the kind that we are interested in.

- *GLM*: the group model that reflects what happens when learner1 (L1) and learner2 (L2) work collaboratively to solve the group task.
- *IdealGLM*: the group model which is generated from merging the performance of each learner (ILM1 and ILM2).

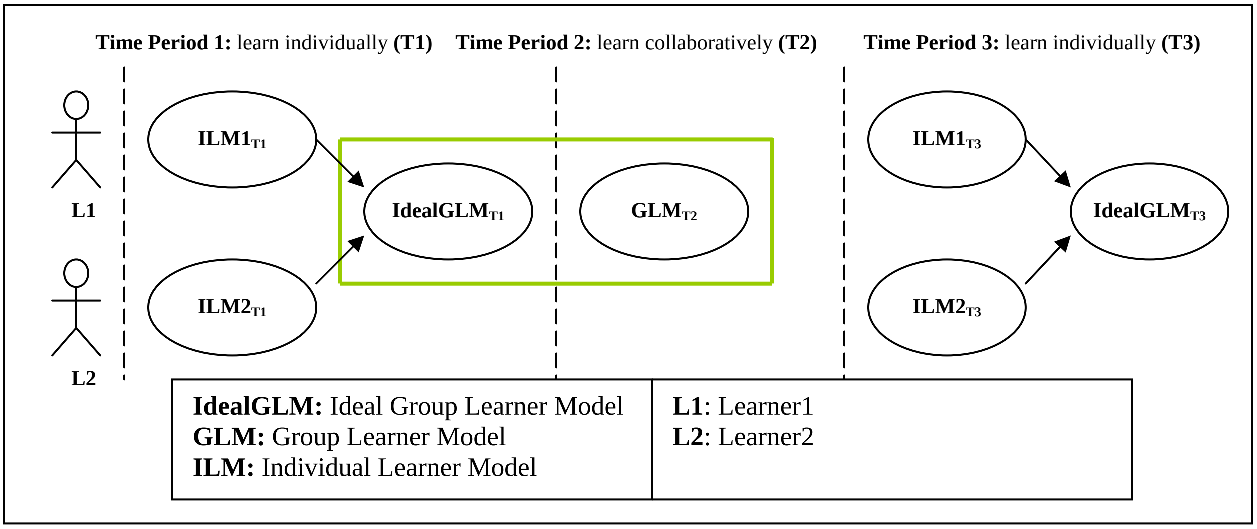

Figure 1: A Group Model diagram

In the system, both individual and group models are calculated over three periods of time (time period1 (T1), time period2 (T2), and time period3 (T3))

T1: learners perform the provided task and submit their answers to the system. The information of how well learners perform is kept in individual learner models (ILM_{T1}). The system will estimate the model of $IdealGLM_{T1}$ which will be used as the expected performance of both learners when they perform the group task in T2.

T2: the system keeps and updates information about group learning in GLM_{T2}. At this point, learners are allowed to talk with their peer using the provided communicative interaction area which combines a dialogue game together with fuzzy logic techniques to update the group model. At the end of this period, information about GLM_{T2} and $IdealGLM_{T1}$ are compared by the system to ask 'Is there any improvement of knowledge in this group learning?'

T3: the process of this period is to confirm that individual learners can benefit from collaborative learning using a Group Open Learner Model by comparing information about ILM_{T1} with ILM_{T3}.

Whenever learners communicate with their peer, either about the task or through the communication interface, the system will evaluate each move that learners make and update each relevant parameter of ILM and GLM. At the particular time that the system allows learners to see their own performance, it will provide information about GLM and IdealGLM in the form of a bar chart with textual descriptions to explain how well their group performs. The values in GLM and IdealGLM are compared to see the difference between seeing and not seeing the group model which may help us evaluate to extent to which a group model is effective for collaborative learning.

4. Conclusion

This work aims to encourage students to obtain an advantage from both collaborative learning and the use of an Open Learner Model in a computer-based learning environment in order to see if the result of collaborative learning with the ability to inspect a group model allows the learner to get a higher score than when unable to inspect the group model.

Learning improvements which have been demonstrated for many collaborative learning systems [6, 7, 9] and for Open Learner Models [1, 5, 8, 9] gives us reason to belief that our system, which combines these two approaches, will show similar improvements.

After this hypothesis is tested, further questions for this work include 'is there any significant correlation between patterns of dialogue moves and the improvement of knowledge for each group?' and 'how general is this approach?' We could also look at the difference between learners to see and not to see ILM_{T2} together with GLM_{T2} in order to see whether we need an ILM_{T2} in this system or if only a GLM_{T2} is adequate and 'what theoretical reasons might there be for a GLM to be more effective than an ILM for individual learning?'

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