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Development of an ICT Integration Framework and Implementation Model Based on the Delphi Approach

Kurt Junshean P. Espinosa
Department of Computer Science
University of the Philippines Cebu
Lahug, Cebu City, Philippines
Tel: +63 32 233 8203
kpespinosa@up.edu.ph

Jaime D.L. Caro
Department of Computer Science
University of the Philippines Diliman
Diliman, Quezon City, Philippines
Tel: +63 2 981 8500 loc 3255
jdlcaro@dcs.upd.edu.ph

ABSTRACT
This paper presents a framework for ICT integration based on the Delphi approach. The goal is to construct an assessment and a monitoring framework that can be used by schools in the process of ICT integration. We asked 26 experts from the academe, industry, and government to anonymously participate in a "Delphi Conference" or real-time web-based Delphi with two aims: 1) determine the relative importance of the five (5) main indicators as established by UNESCO 2003 (Delphi I), 2) to determine the scale of importance of each sub-indicators along the stages of ICT integration (Delphi II). Delphi I consisted of three (3) rounds while Delphi II had two (2) rounds. Average Measure Intra-class Correlation Coefficients (ICC) was computed for each round (ICCs) using the two-way random ANOVA model and with absolute agreement as individual rater variability type. A consensus emerged at Round 2 of Delphi I with ICC=0.7 and at Round 2 of Delphi II with ICC=0.8. Using the results, the framework was constructed and as an implementation model, it pilot tested in one division participated by a total of twelve (12) schools covering both elementary and high school levels and public and private schools. Each school was ranked according to its ICT integration score and patterns were analyzed. The highest-ranking school scored 46.99%. The division scored only 32.75% of the ideal. Concrete development pathway for the top school was crafted. It is recommended that a national survey be conducted using the framework.

Categories and Subject Descriptors
H.1.2 [**Information Systems**]: User/Machine Systems - *Human factors, human information processing*

H.5.3 [**Information Interfaces and Presentation**]: Group and Organization Interfaces - *collaborative computing, computer-supported cooperative work, evaluation/methodology, web-based interaction*

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General Terms
Algorithms, Measurement, Reliability, Experimentation, Human Factors

Keywords
Collective Intelligence, Group Decision Making, Delphi Technique

1. INTRODUCTION

ICT integration is a response to an emerging shift of global economy from industry-based to knowledge-based [6, 1]. There is a need then that the future workforce is prepared to be globally competitive in a knowledge-based economy by increasing their skills and capacity [12]. Many government efforts and private initiatives tried to address ICT integration in the school level by carving out policies and strategies, providing computers and Internet access, giving trainings to teachers, or by adopting an ICT-based curriculum [16, 4]. However, it appears that ICT integration is still a challenge that remains to be addressed [11, 14]. This study uses the UNESCO 2003[13] performance matrix in evaluating the impact of ICT use in education to create an ICT integration framework that will be used to evaluate and assist ICT integration in schools.

We make use of the UNESCO 2003 indicators and identify three stages of ICT integration (adopted from UNESCO 2008), which are: ICT Literacy-Driven, ICT Knowledge Application-Driven, and ICT Knowledge Creation-Driven. This completes the framework needed to specify development pathways to guide and assist each school through the different stages and various contexts of the ICT integration process as recommended by [16].

2. ICT INTEGRATION FRAMEWORKS

One existing tool that can help assess ICT integration is the CEO STaR Chart[2], which "is a guide, not a definitive measure, of a school's effectiveness in integrating technology into the teaching and learning process." It identifies and defines four school profiles ranging from the school with "Early Technology" to the "Target Technology" school that fully integrates technology throughout the curriculum. It has four (4) main indicators: hardware and connectivity, professional development, digital content, and student achievement and assessment.

Another framework is the UNESCO 2003[13], which has 5 main indicators and a comprehensive list of sub-indicators (the set of indicators adopted in this study), however, it did not define stages of ICT integration. This framework established a set of performance indicators, through a consultative workshop, on the impact of ICT use in education. The five (5) indicators are: 1) ICT-Based Policy and Strategy, 2) ICT Infrastructure and Access, 3) ICT-Based Curriculum, 4) Teaching Professionals Use and Teaching, and 5) Student Learning and Outcomes. Each indicator has a number of sub-indicators which reflects the aspects to be considered. Furthermore, each sub-indicator has an actual number of measurable entities. Table 1 shows the list.

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TABLE 1. Number of Indicators, Sub-indicators and Measures

Main Indicator	Number of Sub-indicators	Number of Measures
1	3	8
2	3	15
3	3	3
4	6	7
5	5	5

Still another framework is the UNESCO 2008[12] competency standards for teachers. It contains 6 main indicators: policy and vision, pedagogy, ICT, organization and administration, teacher professional development, curriculum and assessment; and 3 stages: technology literacy, knowledge deepening, knowledge creation. These stages were adopted in this study.

In this study, we made use of the UNESCO 2003 indicators and identified three stages of ICT integration (adopted from UNESCO 2008), which are: ICT Literacy-Driven, ICT Knowledge Application-Driven, and ICT Knowledge Creation-Driven. This completes the framework needed to specify development pathways to guide and assist each school through the different stages and various contexts of the ICT integration process as recommended by [16].

3. OVERVIEW OF THE DELPHI TECHNIQUE

The history of the Delphi technique started in Rand Corporation in the 1950s as a way to get an "expert opinion to the selection, from the point of view of a Soviet strategic planner, of an optimal U. S. industrial target system and to the estimation of the number of A-bombs required to reduce the munitions output by a prescribed amount"[9]. Since then, this method has been used widely in situations "when accurate information is unavailable or expensive to obtain, or evaluation models require subjective inputs to the point where they become the dominating parameters"[9].

Linstone, et al[9] defines Delphi as a "method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem." Some sample researches are in the development of curriculum [7, 17, 14], and determining research priorities [14] among others.

Strictly there are two forms of the Delphi method: 1) conventional Delphi which uses paper and pencil/electronic email just like any traditional surveys, and 2) real-time Delphi sometimes called "Delphi Conference" which automates compilation of group results in each round. This latter approach has the advantage of eliminating the delay caused in summarizing each round of Delphi, thereby turning the process into a real-time communications system [9]. A usual Delphi process involves these four (4) phases: 1) exploration of the subject, 2) reaching an understanding of how the group views the issue, 3) explores disagreement, and 4) feedback for consideration. This is done while preserving anonymity throughout the whole iterative process.

In this study we implement a real-time and web-based Delphi. This saves time and enables immediate interaction among the experts.

4. THE DELPHI PROCESS

4.1 Selection of Participants

A crucial element in the Delphi method is the selection of experts for the study conducted since the results depend not on statistical power as in the case of traditional surveys [10]. Pawlowski, et. al.[10] suggested a process in the selection of the participants, which this study has adopted. Since education is a joint effort of three major stakeholders, namely: academe, government, and industry; hence, we invited experts from each sector. It is also important that each sector will have an equal number of representatives in the final expert panel. We asked 26 identified experts in all sectors.

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The invitations were then sent through electronic mail or fax. Phone calls were made to ascertain that they received the invitations and to ask their confirmation. This was done a month before the actual Delphi study.

Of the 26 identified experts, 18 of them were able to make it on the actual Delphi study. Of this final list, five (5) come from the academe, six (6) come from the industry, and seven (7) from the government sector. This size of the Delphi panel is enough to come up with reliable results [10].

Since this is an on-site and web-based Delphi, experts were invited to a specific place one afternoon where they gather and exchange their comments and votes online.

4.2 Defining Consensus

The main question in Delphi studies is: How do you know if the group has already arrived at a consensus? Most of the researches[14],[15] use quantitative and statistical measures such as mean, median, mode, standard deviation, skewness index, interquartile range, and rank. Depending on the area of research, usually researchers define their own consensus criteria such as: items that did not receive "strongly disagree" from any member of the panel [7], when at least 75% of the participants rate any competency or course item as Very Important (4) or Important (3) on a four-point scale[3].

This study uses Intra-class Correlation Coefficients (ICC) [5] particularly the two-way random average class measures ICC (2, k) together with the other statistical measures: mean, standard deviation and median. The concise formulation of ICC (2,k) is given as[5]:

$$ICC(2,k) = \frac{BMS - EMS}{BMS + (JMS - EMS)/n}$$

,where n targets are rated by k judges. BMS refers to between-targets mean square, EMS refers to error mean square and JMS refers to judges mean square.

Intraclass Correlation literature suggests different thresholds according to the need of the research but most are in the range of 0.7 to 0.9. In this study, we used 0.7 as the consensus threshold.

4.3 Delphi Rounds

This study makes use of two Delphi sub-studies to come up with a detailed framework.

The objective of the first Delphi sub-study (Delphi I) is to distribute 100% to the five (5) main indicators of the UNESCO 2003[13]. The percentage given to each indicator reflects its relative importance in the whole framework according to each expert. The answers of all experts were averaged to get the final percentage for each indicator after the group has come to a consensus.

The objective of the second Delphi sub-study (Delphi II) is to identify the relative importance of sub-indicators in each stage of ICT integration. The experts rate the importance of the sub-indicator, indicate the percentage, or select the appropriate threshold requirement at each stage.

Delphi I consisted of three (3) rounds while Delphi II consisted of only two (2) rounds. On the first round, the participants were presented with the indicators or sub-indicators which they were to rate. For Delphi I, they can put their comments on why they choose that certain percentage distribution among the indicators. On the 2nd and 3rd rounds, the following elements were shown to the participant: his/her previous answer, the group answer (average), comments of each expert (in the case of Delphi I). For the Delphi I, other data visualizations were also shown in order to aid their decision such as percentage distribution among sectors, box plots to show distribution of individual

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answers, and juxtaposed group and the expert's answer.

5. REAL TIME DELPHI SYSTEM

This section describes and discusses the functions the Delphi web application provides.

The first function is the account security through the use of passwords. This feature is necessary in Delphi method to preserve anonymity among the participant-experts. Each participant was provided with a six-letter password with the first three letters indicating their subgroup and the rest a random combination of letters (e.g. "acdmeu", "gvtpba", "induxy").

The second function provided by the application is the use of comment system for the participants to support their choice in each round with an explanation. This feature distinguishes this Delphi implementation from a survey because the former's iterative nature is intended to go deep into the reasons of the participants' choices while making anonymous interaction possible among participants.

The third function concerns the controlled feedback to the participants as included in any Delphi implementation. In this study, all the feedbacks were displayed in the form of group averages, subgroup percentages, and percentage distributions among indicators along with the comments. We made use of the Google visualization libraries to create the dynamic charts.

The user interface was constructed using the jQuery UI library which provided Ajax facility. The whole application was developed in PHP and the database in MySQL. An administration system was also developed for the control of the Delphi rounds. Audit trail was implemented in the database for each round of the Delphi sub-studies to monitor every change made by the participants within a round and their final answers in each round.

6. DELPHI SUB-STUDIES AND RESULTS

This section is divided into two Delphi sub-studies but they form the one ICT integration framework with differences only in the level of detail.

6.1 Delphi I

There were three rounds in this Delphi sub-study. The question pertains to the percentage distribution to the 5 main indicators cited by UNESCO 2003. The goal of the participants is to distribute the 100% among these five (5) indicators based on their expert opinion. Table 2 shows the statistical summary over three rounds.

TABLE 2. Statistical Measures of Delphi I in 3 Rounds

Indicator	Mean			SD			Median		
	1	2	3	1	2	3	1	2	3
1	18	19	20	6.99	6.51	6.11	20	20	20
2	24	24	24	5.46	5.33	5.06	25	25	25
3	18	17	18	5.66	4.93	4.83	20	20	20
4	21	20	19	6.13	5.35	4.77	20	20	20
5	19	20	19	5.06	4.42	4.66	20	20	20

Among the three rounds, Round 2 has the highest ICC value=0.7, which lies in the threshold boundary, meaning it is the round where the consensus emerged among the participants as shown in Table 3.

TABLE 3. ICC Values in each round

Round	1	2	3
ICC	0.6	0.7	0.6

The standard deviation of Round 2 shows that the experts vary in their answers mostly in the first indicator: ICT-Based Policy and Strategy while they vary least with one another on the last indicator: Student Learning and Outcomes. It is also noticeable from Table 2 that the median values stayed the same for all indicators in all rounds.

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Figure 1 shows the actual distribution of answers in the form of a box plot, showing the 5 quartiles (i.e. 0th, 25th, 50th, 75th, 100th). The large standard deviation of the ICT Policy indicator is visually evident in the box plot. The extreme values were considered outliers (i.e. 0 and 50) and were excluded in the ICC computation. Figure 2 shows the average percentage of subgroups in each indicator, which reflects the internal consensus among them.

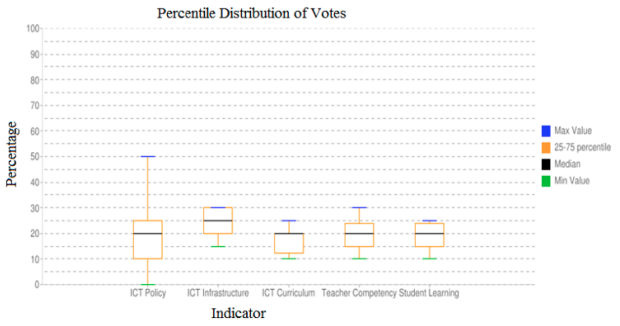

FIGURE 1. Box Plot Distribution of Votes in Delphi I Round 2

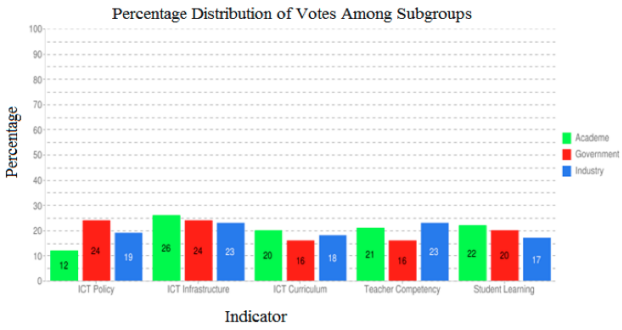

FIGURE 2. Percentage Distribution of Votes among Subgroups in Delphi I Round 2

The vote percentage distribution is explained in their comments. The academe subgroup sees ICT infrastructure as the primary mover in the ICT integration process while the curriculum, teacher competency, and student learning were seen as more of variable indicators. The low percentage they gave to the ICT Policy is also observable. The government subgroup, however, places ICT Policy as equally important with the ICT infrastructure. One of the comments said that the other indicators will necessary follow once the ICT Policy is in place. The industry subgroup places emphasis on the concerted effort among stakeholders. It recognizes the importance of the ICT infrastructure and Teacher Competency over others. One comment said that bigger emphasis should be focused on the mentioned two because they form the building blocks for the other indicators (e.g. Student Learning hinges on Teacher Competency and ICT Infrastructure).

6.2 Delphi II

This Delphi sub-study is intended to refine the expectations at each stage of the ICT integration process. Each indicator has sub-indicators, which narrow down specific aspects to be considered. The participants answered different type of questions ranging from scale of importance, percentage allocation, absolute values, and ideal frequencies. The consensus emerged in Round 2 with ICC=0.8, while in Round 1 the ICC value only reached 0.4. The outliers were handled accordingly. Following the logic of increasing sophistication across the stages, answers with the inverted pattern were replaced with the value in the highest stage. If the percentage of teachers with pre-service training is expected to increase from stage 1 to stage 3, then if answers were instead going down from 40%, 30%, 20% from stage 1 to stage 3, respectively, then the stage 1 and 2 answers were replaced with 20%. This may have resulted from an unguided criterion. Nevertheless, with this method of handling outliers we have preserved the intention of the experts.

7. CONSTRUCTION OF THE FRAMEWORK

As mentioned above, this study modified the three approaches of UNESCO ICT-CST document to fit

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the ICT integration stages. Each stage per question or measure is defined by a lower and upper limit requirement, which translates to a range of values. These values were the consensus values arrived in Delphi II. A school is said to be in a particular stage of ICT integration only on a direct relation to the individual measure concerned and indirectly to the sub-indicators and indicators. This is explained more in the next sections. This framework also defines the stage prior to stage 1 as the "ICT Ad Hoc Stage" of ICT integration where the efforts on ICT integration still falls below the stage 1 requirement.

The ICT integration score refers to the overall score the school obtains after the questionnaires are filled-out by a certain number of each type of respondents. A detailed matrix of scores is computed using the answers provided by each of the respondents. It shows the score per question which is cascaded to the sub-indicator and finally to the indicators. The structure of the computation is similar to the Global Competitiveness Index (GCI)[8] except that the indicators, sub-indicators, and questions assumed different percentage values.

8. IMPLEMENTATION MODEL

8.1 Case Study Description

We piloted the framework to one of the divisions in Ilocos Norte, Philippines, which consisted of three districts. Due to time and resource constraints, we conducted a stratified random sampling among the teachers and students. The respondents were: the head of school, 10 teachers (5 from first year/grade 4 and 5 from fourth year/grade 6), and 20 students (10 from first year/grade 4 and 10 from fourth year/grade 6). The Department of Education requires computer education starting at Grade 4. The entry and exit years in high school were chosen as it could provide a glimpse of all year levels. Online questionnaires were administered to all the participants with the supervision of the researcher.

Four schools, each with the biggest population, represented each district for the both elementary and secondary year levels as well as the public and private educational institutions, making a total of 12 schools. All these plans were communicated beforehand to the superintendent of the division to get her recommendation and support.

8.2 Results and Discussion

This section presents the results of the pilot implementation of the framework. The aim is to present the whole picture of the ICT integration efforts and status of the division while patterns are discovered among comparisons made. However, this is not meant to exhaust all the patterns and analysis but just to present some important insights about the division. A division star chart as well as its development path is presented at the end.

8.2.1 Star Charts

Figure 1 shows the ICT integration performance of the top ranking school in different levels of detail in comparison with the ideal scores in the framework. It is noticeable how low the teaching competency of the teachers are though the school has significantly well established ICT policies and strategies. The effect is clearly seen in the learning capacities of the students though the school scored fairly well in ICT infrastructure and ICT-based curriculum aspects. More concrete suggestions can be made by thoroughly examining the sub-indicators (see Figure 1b) while detailed by the performance score matrix (to large to present here). With different levels of detail, specifying development pathways for each school would be easier and more

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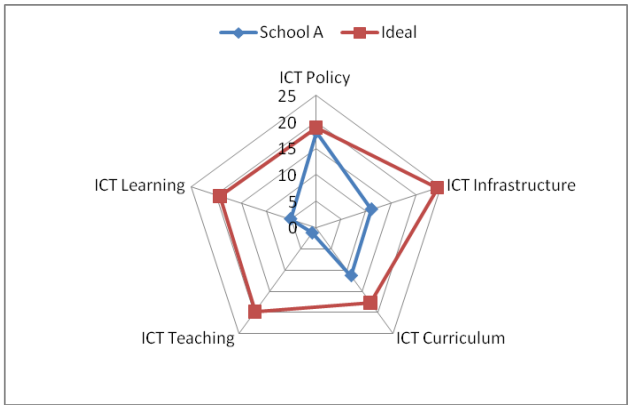
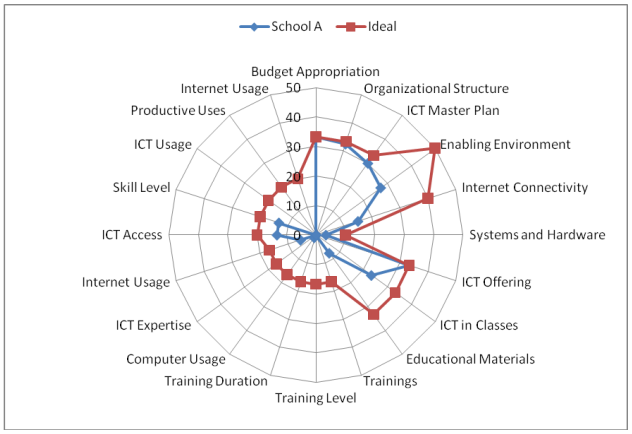
concrete. The results and the suggested development path for each school is to be discussed with the head of the school together with the teachers and other stakeholders.

Private schools outperform the public schools 58.37% considering all the main aspects of ICT integration while the secondary level is higher than the elementary level 52.38% on the overall framework (see Figure 2). Figure 3 shows the performance of each district and the whole division with respect to the ideal. District 2 surpasses the others in terms of ICT policy and strategy and ICT-Based Curriculum while District 1 is superior among the three in ICT infrastructure and ICT Learning of students. District 3 is only higher over the other two in ICT teaching and competency of the teachers. Each district has its own strengths and they can learn from one another. In general, with respect to the five (5) main indicators, the division is 67.05% lower than the ideal score. Particularly, 47.69% on ICT Policy, 60.82% on ICT Infrastructure, 48.73% on ICT Curriculum, 96.7% on ICT Teaching, and 81.3% on ICT Learning. All this deficiencies shall be worked out in the school level, though, as a division, it has to push primarily the most in need aspect, while not neglecting others. For example, it can organize more teacher training sessions of different competency levels while addressing different district needs. All the necessary details are ironed out and coordinated with the district supervisors and the head of schools.

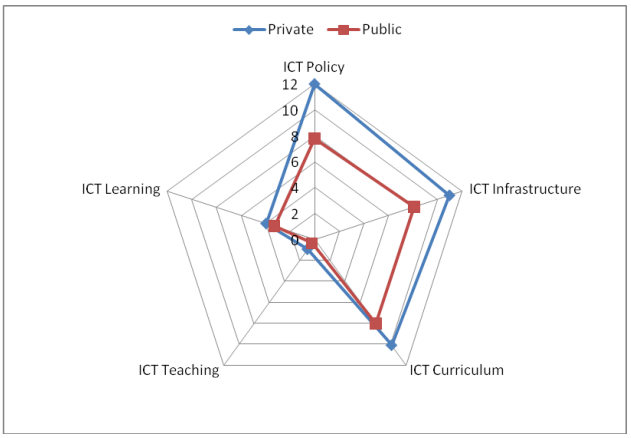


(a)



(b)

Fig. 1 Performance details of Top 1 school in the (a) main indicator level (b) sub-indicator level



(a)

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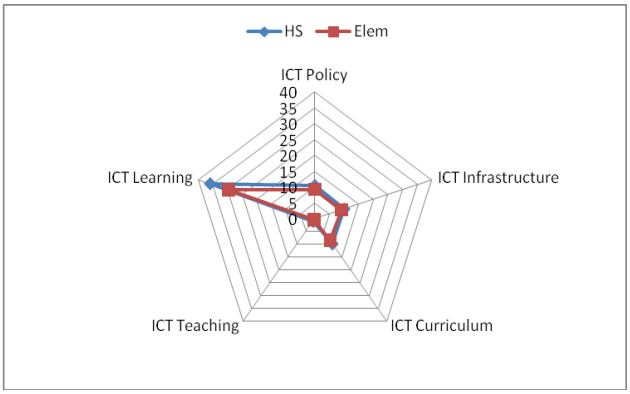
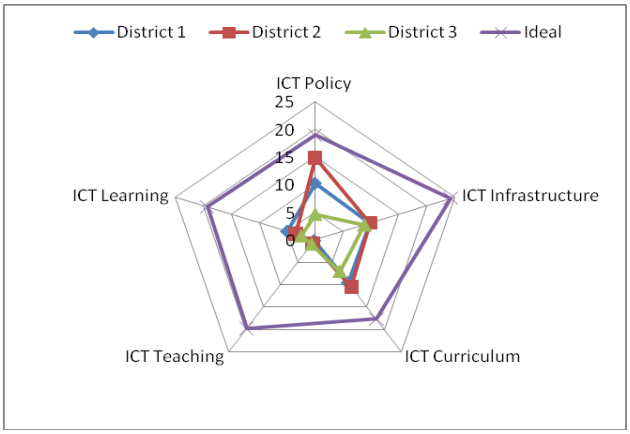
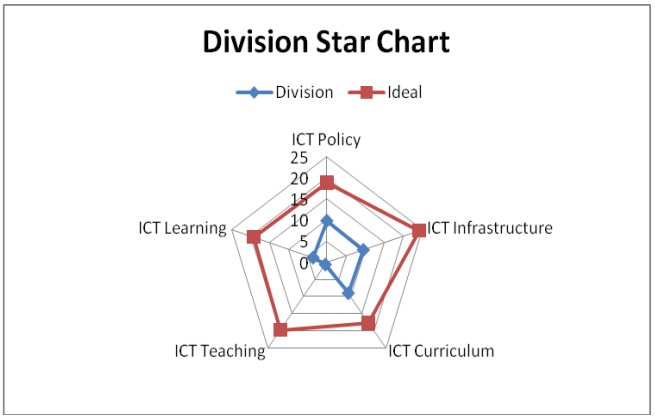


(b)

Fig. 2 Comparisons of (a) private and public schools (b) elementary and secondary schools



(a)



(b)

Fig. 3 (a) Comparisons among the 3 districts (b) Division Star Chart

8.2.2 Development Path

Based on Figure 1a, the school is in Stage 2 of ICT Integration with respect to ICT Policy; Stage 1 with respect to ICT Infrastructure and ICT Curriculum; and Stage 0 (Ad Hoc Stage) with respect to ICT Learning and ICT Competency. By drilling down to the sub-indicator level (Figure 1b), we concretely suggest its own development path. Particularly, the school has to work more on giving ICT training to teachers from literacy to application and integration in their classes. For instance, they can find ways to increase the in-service trainings as well as the level and duration of those trainings. The school can also devise ways to give incentives to teachers who demonstrate innovative ways in integrating ICT in their classes. Aside from trainings to teachers, the school can also purchase more educational software that can be used by teachers in their classes. On the

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infrastructure level, the school can work on increasing the computer to student ratio in the most cost-effective means possible. They can also increase their bandwidth subscription to be able to access multimedia materials that can be used by students and teachers in their classes. All these efforts should be guided and championed by the head of the school for without it nothing much could be achieved [17].

9. CONCLUSION

This study has presented a Delphi-based consensus framework for ICT integration in basic education. The experts reached a consensus for the whole ICT integration framework with ICC= 0.7 in Round 2 of Delphi I and ICC=0.8 in Round 2 of Delphi II, respectively. As an implementation model, a pilot survey was conducted in one division to test the framework and the development path was crafted for the top school. This will serve as a model for national implementation. Furthermore, indicator and sub-indicator relationships can be investigated to understand deeper the dynamics of ICT integration.

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