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THE OPERATING EFFICIENCY ANALYSIS FOR IMPORTING DIGITAL MOBILE LEARNING TO PUBLIC AND PRIVATE HIGH SCHOOLS BASED ON WINDOW CCR AND BCC MODELS

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ABSTRACT

The purpose of this study is to apply the Window Data Envelopment Analysis (Window-DEA) method to evaluate the operational efficiency of Public and Private High Schools after importing digital mobile learning. The empirical results of this research indicate the following results. (1) There are significant differences between those schools who imported digital mobile learning and who did not. (2) For those schools who imported digital mobile learning, the high school is better than vocational high school in terms of the operating efficiency. (3) Importing digital mobile learning can really enhance the efficiency of school management.

KEYWORDS

digital mobile learning, data envelopment analysis (DEA), window DEA analysis, operating efficiency, vocational and senior high school.

1. INTRODUCTION

Since the beginning of the twenty-first century, the development of information technology (IT) has been increasingly applied and, in turns, the utilization of e-learning in schools has also become popular. As the content of e-learning can be presented in many methods such as using multimedia for explaining a terminology, therefore, it has the advantage for students to enhance their learning. Since the e-learning is not restricted to time or space, therefore, each individual can obtain information and knowledge whenever he or she feels necessary. This makes the utilization of e-learning very important.

As the world getting "flat", the government of Taiwan (R.O.C.) also facing many challenges, including global challenges, such as population decline, globalization, and digitalization, etc. In response to the aforementioned challenges, the government of Taiwan (R.O.C.) intends to upgrade students' abilities and the IT competency through new types of teaching of learning. Hence, the e-learning plan from K to 12 is proposed since 2010. Started from 2014 a newer plan of e-learning from Taiwan Ministry of Education began to promote the mobile e-learning. This new e-learning plan is to promote and take forward the new mode of teaching and learning in school so that students can apply the mobile device for learning and to meet the growing needs of innovation and invention from the industry.

The study of educational reform and the analysis of school competitiveness are long being the important issues, if we take them from the government, the academia, and the industry point of view. To management a successful school, it must be able to deal with the rapid change of expectation both from the society and from the parents. It is obvious that if the school is not catching up the new trend of teaching and learning, greater challenges for management and for recruiting students will be suffered.

This research adopts the quantitative research method and uses DEA Window analysis method to measure the competitiveness of learning between two schools, one that utilized mobile e-learning and one that did not. The goal of this research is to evaluate the learning results of using digital mobile learning in public and private high Schools and. In addition, the results of this research can be the reference for the educational authorities when formulating related policies and regulations.

The organization of this paper is organized as follows: Section 1 introduce the research background and goal of the research, Section 2 begins with a brief review of e-learning, Section 3 reviews the DEA method and Window-DEA model, Section 4 explain the empirical analysis, and the Section 5 concludes our research results.

2. REVIEW OF LITERATURE

With the rapid development and popularity of science and technology, e-learning has become a new educational trend, and it is also a developmental priority for schooling in all countries. The United States is a leading nation in this regard, and it has paid a great deal of attention and exerted considerable effort in promoting e-learning. The national learning infrastructure initiative (NLII), launched by the United States in 1994, was designed to improve the quality of teaching and learning, as well as to reduce learning costs. Likewise, in 1996, Taiwan began to promote distance learning in higher education by commencing the development of e-learning programs. To date, e-learning is among the most important national science and technology programs (Yang, Lin, Chang, & Tseng, 2008), and it has proved to be remarkably effective.

At the beginning of their book entitled e-Learning and the Science of Instruction, Clark and Mayer (2003) eloquently point out that, "E-learning is a model of teaching delivered by means of the Internet or CDs." Piskurich et al. (2003) provided an even more explicit definition, and noted that the purpose of e-learning is to "construct a learning content delivery system for instructional designers and teachers, so that the advantages of e-learning design can be fully applied to the organizational learning of students and the needs of teachers."

This new type of learning entails participation in online or offline e-learning activities by means of information-delivering digital tools, or digital media, to obtain digital teaching materials via wired or wireless networks. In addition to learning in physical classrooms, this method enables both teachers and students to experience learning over the Internet without being constrained by time or place. It also affords students greater opportunities to access diverse channels of interactive

learning; this consequently influences the teacher-student relationship that is typical in traditional teaching, and changes the structure of teaching and the nature of education (Lockwood, 2007; Rosenberg, 2001).

As related studies have confirmed, e-learning research designs are quite diverse. Using meta-analysis, Wu et al. (2012) reviewed and analyzed e-learning-related studies published between 2003 and 2010. They concluded that e-learning can indeed facilitate educational opportunities and promote teacher-student interactions, and that the use of a classroom setting can improve students' e-learning performance. Furthermore, with the advancement and increasing popularity of mobile devices and communication technologies, mobile learning is attracting greater attention from researchers, particularly due to the proliferation of mobile phones. There are presently more than 3.2 billion mobile phones worldwide, and according to statistics from the United Nations, an average of 4 out of every 5 people in developed countries are mobile phone users. Moreover, it is estimated that mobile phone use in developing countries will reach 50% by the year 2017. Additionally, a study conducted by ComScore predicted that by 2014 the number of individuals who access the Internet using mobile phones would exceed those who do so using desktop computers.

Nevertheless, some may wonder what mobile learning is, and speculate on how mobile learning and e-learning differ. Generally, mobile learning is, "a way of learning that makes use of portable technology, and therefore transcends regional boundaries." Hence, it entails integrating "mobility" into the e-learning process. By using mobile devices, students can achieve their learning objectives more effectively, comprehensively, and independently regardless of time or location. Mobile e-learning is not only an extension of distance education, but also a model of e-learning that facilitates a concurrent balance between proactive and independent learning.

The advantage of mobile learning lies in the design of both mobile devices and mobile learning environments, which differ from those common in traditional e-learning. For example, the traditional e-learning teaching model, which is primarily dependent on hardwired networking technologies, has evolved to a model based on wireless networking and mobile devices (Liu & Hwang, 2009). Moreover, the devices used in mobile e-learning are capable of supporting interactions between different learners and learning environments.

When implementing mobile devices in an e-learning context, variables such as price, adaptability, and flexibility should not overshadow the fact that the adoption of a technology must be motivated by teaching scenarios, not merely factors such as technological functions (Lin, 2007). Therefore, the question of how to present the features of mobile devices in educational environments is extremely important. Furthermore, mobile learning emphasizes ubiquitous learning (u-learning), which is the notion that learning can occur at any time or place, not merely in schools or classrooms (Hwang, Tsai, & Yang, 2008).

The above discussion suggests that mobile learning is a new model of learning that has gained considerable interest among industrial, governmental, and academic sectors. In their literature review, Hwang and Wu (2014) point out that among the seven renowned Social Sciences Citation Index (SSCI) databases on e-learning, approximately 214 studies published between 2008 and 2012 were related to mobile learning. Most of these studies indicate that the introduction of mobile e-teaching can indeed increase learning motivation among students.

Presently, mobile learning and its various implementations are mainly geared toward individual learning. Ciampa (2013) examined an experimental teaching program in which instructors and students in a sixth grade classroom used iPhones and iPads as the primary teaching medium. The findings revealed that upon receiving the iPads teachers and students were initially intrigued. Nevertheless, the devices did not play a major role in the learning process until both parties adopted them as educational tools, wherein the device itself was no longer the focus of attention. Furthermore, the study indicated that mobile teaching indeed helped to enhance student motivation.

To enhance student interest and learning motivation, and ultimately cultivate innovative talents, in September 2012 the Taiwanese Ministry of Education and the Faith Hope Love Charity Foundation launched an initiative to develop courses that utilized various technological products. Teachers and students jointly participated in experimental teaching programs wherein HTC Flyer tablet computers were the primary mobile e-learning medium. The programs aimed to inspire a new conceptualization of e-teaching by combining the hardware features of tablet computers with innovative applications, and consequently demonstrate that learning does not need to occur in front of a computer or inside a classroom. However, studies concerning mobile learning in a Taiwanese context are scarce. By focusing on mobile learning, this study aims to explore differences in operational efficiency between schools that utilized mobile e-learning and those that did not.

In recent years, many scholars have conducted studies concerning operational performance analysis in order to assess whether improved performance was achieved, and thus to potentially improve upon management by utilizing DEA. Statistics reveal that the DEA method has been used in more than 1,000 empirical cases. DEA has been applied in relation to issues involving transportation, educational administration, courts, forestry management, medicine, banking, military-related maintenance, and administrative departments. Due to an abundance of prior research, the present study only reviewed relevant Taiwanese literature, which revealed that most studies focused on evaluating the operational performance of universities, high schools, middle schools, vocational schools, and national elementary schools (cf. Wang et al., 1991; Chen, 1998; Gu, 1999; Liu, 2000; Hwang, 2001; Wang, 2002; Li, 2009; Hwang, 2012).

Our literature review revealed that the CCR and BCC models were most often used for performance evaluation. The inputs mainly included human resources (teachers, staff members, and students), financial resources, material resources (equipment and books), and space resources (campus size). The outputs mainly included teaching functions (the current number of students, graduates, and certificate holders), research functions (the number of research projects, awards, and published articles), education and employment opportunities (enrollment rates, number of graduates, number of dropouts, and number of people employed), student behavior (the number of students rewarded and/or punished), and other items (e.g., the number of times books or CDs were borrowed).

In evaluating the operational performance of schools, a distinct characteristic of DEA is the concept of relative efficiency and the simultaneous examination of different units' inputs and outputs. The efficiency value of a decision making unit (DMU) is calculated by using the linear programming method; the efficiency value of a DMU is between 0 and 1, wherein 1 indicates an efficient unit and a value of less than 1 indicates an inefficient unit. Accordingly, a functional formula between the input and output is unnecessary, since the use of a method setting production function produces non-parametric errors that can be avoided. Moreover, this method is capable of processing both ratio and non-ratio information, and can therefore provide a DMU with the optimal weighted value, which in turn assists decision-makers in enacting policies to improve efficiency. Disadvantages of the above DEA model. The DEA is not used to analyze cross-sectional data and small sample.

The aforementioned studies concerning mobile e-learning and the literature review conducted by Sung (2011) reveal that research to date has primarily focused on the design and implementation of mobile e-learning, and how to introduce this mode of learning in a manner that will enhance student motivation. The research methods employed in prior studies were qualitative, experimental, quantitative, or mixed in nature, with the qualitative and experimental methods being the most widely used. However, research designs and implementations based on purely quantitative research models are scarce. Additionally, mobile learning experiments with high school students as study subjects were rarely conducted in earlier research, and no relevant studies have investigated whether schools that implemented mobile e-learning exhibited enhanced operational competitiveness afterward. Indeed, as Sung (2011) has noted, "Quantitative-oriented research methodologies will be an important driving force in moving e-learning a step closer toward becoming an independent discipline."

This study adopts a quantitative research method and uses DEA windows analysis to measure competitiveness between two schools: one that utilized mobile e-learning and one that did not. We sincerely hope that the results of this study will assist schools in assessing and planning for the implementation of mobile e-learning programs, while also providing educational authorities with a reference for formulating relevant policies and measures.

3. RESEARCH METHODOLOGY

The purpose of this research is to analyze the operational performance of public and private high schools, middle schools, and vocational schools that implemented mobile e-learning and teaching in an attempt to determine whether the operational efficiencies of these schools were significantly improved following mobile e-learning's introduction. Additionally, this study compares the operational efficiencies of schools that implemented mobile e-learning and teaching with schools that did not. Since Taiwanese high schools, middle schools, and vocational schools adhere to a school year credit-based system. We adopt the Window-DEA analysis in this paper for two reasons. It is since cross-year statistics and small sample. Accordingly, this paper will adopt the Window-DEA analysis method. Before discussing the model for Window-DEA, we briefly DEA.

3.1 STUDY MODEL

DEA

The DEA model, proposed by Charmes et al. (1978) and known as CCR, assumes the DMUs to be assessed operate within a technology where efficient production is characterized by constant returns to scale(CRS). As above is obtained from the following Equation (1):

$$\text{Max } h_k = \frac{\sum_{r=1}^{s} u_r y_{rk}}{\sum_{i=1}^{m} v_i x_{ik}} \quad (1)$$

$$s.t \ \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \le 1 \quad , \quad j = 1,...,n$$

$$u_r, v_i \ge \varepsilon > 0, \quad r = 1,.....,s, \quad i = 1,.....,m$$

where x_{ij} is the amount of the i-th input to DMU j, y_{rj} is the amount of the r-th output to DMU j ; u_r , v_i are called r virtual multiplier output and i virtual input multiplier; The value of h_k obtained is termed the relative efficiency and is called the CCR efficiency, theeis a non-Archimedean positive element smaller any real number(10^{-6}), the CCR model is called non-Archimedean small number.

Banker et al. (1984) modified this basic model to permit the assessment of the productive efficiency of DMUs where efficient production is characids by variable returns to scale(VRS).The VRS model, known as BCC,differs from the basic CCR model only in that in includes in the previous formulation the convexity constraint: $\sum_{i=1}^{n} \lambda_j = 1$

In summary, the following equation can be obtained for computing efficiencies:

Technical Efficiency = Pure Technical Efficiency × Scale Efficiency

WINDOW DEA ANALYSIS (Window-DEA)

The DEA is static, i.e. the analysis does not consider the time frame to which the input consumption and output production refers. Cook et al. (2009) pointed out that "Performing static DEA analyses on the data for each quarter, for example, and then apply standard regression concepts to study efficiency changes; such an approach of ten proves rather unsatisfactory, generally failing to capture important interactions from period to period".

The purpose of this research is to analyze the operational performance of public and private high schools, middle schools, and vocational schools that implemented mobile e-learning and teaching in an attempt to determine whether the operational efficiencies of these schools were significantly improved following mobile e-learning's introduction. Additionally, this study compares the operational efficiencies of schools that implemented mobile e-learning and teaching with schools that did not. Since Taiwanese high schools, middle schools, and vocational schools adhere to a school year credit-based system, cross-year statistics and vertical and horizontal data collection is difficult. Accordingly, this paper will adopt the windows analysis method.

To formalize, consider N DMU's (n=1… N) which are observed in T periods (t=1,…, T) and which all use r inputs to produce s outputs. The sample thus has N×T observations, and an observation n in period t, DMU_t^nDMUnt has an r-dimensional input vector$X_t^n = (X_{1t}^n, X_{2t}^n, ..., X_{rt}^n)$and a s-dimensional output vector $Y_t^n = (Y_{1t}^n, Y_{2t}^n, ..., Y_{st}^n)$. The window starting at time k, (1≤ K ≤ T) and with the width w, (1≤ W≤ T-K) is denoted by KW and has N×w observations.

The matrix of inputs for this window analysis is given by:

$X_{kw} = X_K^1, X_K^2, \dots, X_K^t, X_{K+1}^1, X_{K+1}^2, \dots, X_{K+1}^t, X_{K+w}^1, X_{K+w}^2, \dots, X_{K+w}^t$

and the matrix of outputs is:

$Y_{kw} = Y_K^1, Y_K^2, \dots, Y_K^t, Y_{K+1}^1, Y_{K+1}^2, \dots, Y_{K+1}^t, Y_{K+w}^1, Y_{K+w}^2, \dots, Y_{K+w}^t$

The input oriented DEA window problem forDMU_t^n under a constant returns to scale (CRS) assumption, is given by model (1) (Asmild et al, 2004):

$\theta_K' = min_{\theta,\lambda}(\theta)$

s. t. $-X_{kw}\lambda + \theta X_t' \ge 0$ t=1,…,T

$Y_{kw}\lambda - Y_t' \ge 0$ t=1,…,T

$\lambda_n \ge 0$ (n=1,2,…, N×w) (2)

The input oriented DEA window problem for DMU_t^n under a variable returns to scale (VRS) assumption, is given by model (2):

$\theta_K' = min_{\theta,\lambda}(\theta)$

s. t. $-X_{kw}\lambda + \theta X_t' \ge 0$ t=1,…,T

$Y_{kw}\lambda - Y_t' \ge 0$ t=1,…,T

$\sum_{n=1}^{N\times w} \lambda_n = 1$

$\lambda_n \ge 0$ (n=1,2,…, N×w) (3)

3.2 RESEARCH OBJECTS AND VARIABLES SELECTION

The research subjects of this study consist primarily of high schools and vocational schools in the Xindian District of New Taipei City. From the Ministry of Education and Board of Education of New Taipei City, the District houses nine schools in all. We include all the schools except Kang Hsuan High School, which did not meet the selection criteria of the study (as it had been established for less than five years during the time this study was conducted). All of two schools were imported digital mobile e-learning(ME) and six schools were not imported digital mobile learning. The names and characteristics of the schools are provided in Table 1.

In this paper, the input-output variables definitions of Xindian public and private vocational schools in Xinbei District, Taiwan are listed in Table 2 and Table 3. The including five input variables: school area, academic department, number of teachers, staff and school years. There are four output variables: number of students, the average area of use of the students, the numb, graduates student and classes. To evaluate those schools who imported digital mobile learning and who did not in the new area of Taipei City, Xindian District.

TABLE 1: SCHOOL NAMES AND CHARACTERISTIC

No.	School name	mobile e-learning(ME)
1	Chi Jen Senior High School	Yes
2	Juang Jing Vocational High School	Yes
3	New Taipei Municipal An Kang High School	No
4	Our Lady Of Providence Girls' High School	No
5	New Taipei Municipal Xsin Dien Senior High school	No
6	Nan Chiang Industrial and Commercial Senior High School	No
7	Neng Ren Home Economic And Commercial Vocational High School	No
8	Kai Ming Senior Technical and Commercial Vocational Schoo	No

TABLE 2: NINE MAJOR INDICATORS DEFINITION FOR IMPORTING DIGITAL MOBILE LEARNING

No.	Indicators	Code	Definition
1	school area	x_1	Total area of the premises.
2	academic department	x_2	Total academic department of the school.
3	number of teachers	x_3	The total number of teachers.
4	staff	x_4	The total number of staffs.
5	school years	x_5	The number of years the school has been established.
6	number of school students	y_1	the number of school students
7	average area used by students	y_2	Students use average space on the school.
8	graduate student	y_3	The number of graduate students.
9	classes	y_4	The number of school classes.

TABLE 3: THE WINDOW-DEA MODEL INPUT INDICATORS AND DEFINITIONS

No.	Indicators	Code	Definition
1	school area	x_1	Input Indicator
2	academic department	x_2	Input Indicator
3	number of teachers	x_3	Input Indicator
4	staff	x_4	Input Indicator
5	school years	x_5	Input Indicator
6	number of school students	y_1	Output Indicator
7	average area used by students	y_2	Output Indicator
8	graduate student	y_3	Output Indicator
9	classes	y_4	Output Indicator

The research to the establishment of the empirical model, we list as many preliminary assessment factors as possible for the input and output units. Any variable that may affect the DMU performance dimension is included for investigation, so that no pre-setting of output function type was required. After referring to the input and output data collected from the relevant literature and statistical reports, we select the following six operational variables as inputs for public and private high schools and vocational schools, namely school area; number of subject groups; number of teachers, instructors, and staff; and number of years the school has been established. We also select four operational variables as the outputs, namely the number of school students, average area used by students, and number of graduates and classes. Pearson's correlation analysis was then used for preliminary analysis of the level of correlation between the inputs and outputs (Table 4).and the result should be consistent with the results of the variable analysis showing positive correlation and the defined concepts of the DEA input and output variables.

TABLE 4: CORRELATION TEST AND ANALYSIS

	x_2	x_3	x_4	y_2	y_3	y_4
x_2	1	0.155	0.088	0.691	0.631	0.686
x_3		1	0.335	0.007	0.101	0.029
x_4			1	0.495	0.354	0.504
y_2				1	0.914	0.993
y_3					1	0.916
y_4						1

4. EMPIRICAL ANALYSIS

The empirical analysis of this study mainly comprised three parts estimation of the efficiency value. Since Taiwanese high schools, middle schools, and vocational schools adhere to a school year credit-based system. We adopt the Window-DEA analysis in this paper for two reasons. It is since cross-year statistics and small sample. Accordingly, this paper will adopt the Window-DEA analysis method. Followed by the application of the Window-DEA model and the efficiency analyses of the three estimation of the efficiency value.

4.1 TOTAL EFFICIENCY (TE)

As shown in Table 6 below after imported digital mobile e-learning, in 2011 two schools in the Xindian District introduced mobile learning as a teaching method: Chi Jen High School and Juang Jing Vocational High School. Over the course of five years, Juang Jing's TE value dropped below 1 between 2011 and 2012, which was when the school first implemented mobile e-learning; in the remaining years, Juang Jing achieved a TE value of 1 (TE=1), and ranked first in terms of TE value. Similarly, Chi Jen introduced mobile e-learning and teaching in 2011; during that year its TE value reached approximately 0.826, which is roughly a 15% increase when compared to Table 5 below in 2010. Chi Jen was the only school to exhibit a significant improvement in TE during the same year, thus displaying superior performance when compared to its public high school counterparts.

The above findings suggest that introducing mobile e-learning can increase efficiency in the use of school resources, and also dramatically enhance overall technical efficiency—which is more important in high schools than vocational schools. For example, as shown in Table 5 and Table 6 below, teaching efficiency at Chi Jen High School was not significantly different from other high schools prior to the introduction of mobile e-learning and teaching. However, following the introduction of mobile e-learning and teaching the school's overall efficiency in resource usage improved, which led to a significant increase in TE when compared to other high schools.

4.2 PURE TECHNICAL EFFICIENCY (PTE)

As shown in Table 8 below after imported digital mobile e-learning, in 2011 two schools in the Xindian District introduced mobile learning as a teaching method: Chi Jen High School and Juang Jing Vocational High School. Over the course of six years as shown in Table 6 and Table 7 below, Juang Jing was the only school to achieve a yearly PTE value of 1 (PTE=1), therefore suggesting maximum output and minimum input. PTE values indicate efficiency of use among input factors; thus, if environmental factors are not taken into account, Juang Jing does not need to make any improvements or adjustments.

TABLE 5: TOTAL EFFICIENCY BEFORE IMPORTED DIGITAL MOBILE E-LEARNING

DMU	2007-2008	2008-2009	2009-2010	2010-2011	Average
1	0.962	0.867	0.674	0.688	0.798
2	1.000	1.000	1.000	1.000	1.000
3	0.344	0.293	0.294	0.325	0.314
4	0.547	0.804	0.729	0.696	0.694
5	0.904	0.873	0.806	0.812	0.849
6	1.000	1.000	0.990	1.000	0.998
7	0.998	0.988	0.985	1.000	0.993
8	0.862	0.948	1.000	1.000	0.953

TABLE 6: TOTAL EFFICIENCY AFTER IMPORTED DIGITAL MOBILE E-LEARNING

DMU	2011-2012	2012-2013	Average	ME	Ranking
1	0.826	0.740	0.783	Yes	6
2	0.927	1.000	0.964	Yes	2
3	0.364	0.355	0.360	No	8
4	0.706	0.543	0.625	No	7
5	0.820	0.841	0.831	No	5
6	0.952	0.937	0.945	No	3
7	0.934	0.852	0.893	No	4
8	1.000	1.000	1.000	No	1

Regarding Chi Jen as shown in Table 7 and Table 8 below, its average TE value over a six-year period was approximately 0.96, which is superior to other high schools. Nevertheless, as shown in Table 7 below, its PTE value declined following the introduction of mobile e-learning and teaching. Further analysis revealed that this lower efficiency value was because the high school implemented mobile e-learning and teaching while its affiliated middle school did not.

TABLE 7: PURE TECHNICAL EFFICIENCY BEFORE IMPORTED DIGITAL MOBILE E-LEARNING

DMU	2007-2008	2008-2009	2009-2010	2010-2011	Average
1	1.000	1.000	1.000	1.000	0.798
2	1.000	1.000	1.000	1.000	1.000
3	1.000	0.686	1.000	0.712	0.426
4	0.986	0.959	1.000	1.000	0.705
5	0.909	0.874	0.876	0.871	0.962
6	1.000	1.000	1.000	1.000	0.998
7	1.000	1.000	1.000	1.000	0.993
8	0.947	0.948	1.000	1.000	0.976

TABLE 8: PURE TECHNICAL EFFICIENCY AFTER IMPORTED DIGITAL MOBILE E-LEARNING

DMU	2011-2012	2012-2013	Average	ME
1	1.000	0.760	0.880	Yes
2	1.000	1.000	1.000	Yes
3	0.816	0.703	0.760	No
4	1.000	0.685	0.843	No
5	0.861	0.878	0.870	No
6	0.985	1.000	0.993	No
7	0.958	1.000	0.979	No
8	1.000	1.000	1.000	No

4.3 SCALE EFFICIENCY (SE)

As shown in Table 10 below after imported digital mobile e-learning, in 2011 two schools in the Xindian District introduced mobile learning as a teaching method: Chi Jen High School and Juang Jing Vocational High School. Over the course of six years as shown in Table 8 and Table 9 below, Juang Jing achieved an SE value of 1(SE=1) for five of those years, and therefore reached a constant scale. This is indicative of a balanced input/output ratio (i.e., maximum productivity), and also indicates that the school reached high scale efficiency. Accordingly, no changes need to be made.

Chi Jen had a generally low SE, and was experiencing a gradual decrease in SE prior to the introduction of mobile e-learning and teaching as shown in Table 8 below, thus indicating a need to adjust its input/output ratio. Following the introduction of mobile learning as shown in Table 9 below, the school's SE value improved substantially. When compared to the academic year before and after mobile learning's introduction as shown in Table 8 and Table 9 below, SE grew by approximately 15% (in 2011-12) and by 30% the year afterward (in 2012-13). Thus, in terms of SE, Chi Jen had the best performance of all high schools in the 2012-13 academic year.

TABLE 9: SCALE EFFICIENCY ANALYSIS BEFORE IMPORTED DIGITAL MOBILE E-LEARNING

DMU	2007-2008	2008-2009	2009-2010	2010-2011	Average
1	0.962	0.867	0.674	0.688	0.798
2	1.000	1.000	1.000	1.000	1.000
3	0.344	0.535	0.294	0.530	0.426
4	0.555	0.838	0.729	0.696	0.705
5	0.994	0.999	0.920	0.933	0.962
6	1.000	1.000	0.990	1.000	0.998
7	0.998	0.988	0.985	1.000	0.993
8	0.904	1.000	1.000	1.000	0.976

TABLE 10: SCALE EFFICIENCY ANALYSIS BEFORE IMPORTED DIGITAL MOBILE E-LEARNING

DMU	2011-2012	2012-2013	Average	ME
1	0.826	0.973	0.900	Yes
2	0.927	1.000	0.964	Yes
3	0.464	0.592	0.528	No
4	0.706	0.849	0.778	No
5	0.952	0.958	0.955	No
6	0.966	0.937	0.952	No
7	0.974	0.852	0.913	No
8	1.000	1.000	1.000	No

5. CONCLUSIONS AND DIRECTIONS FOR FUTURE RESEARCH

This paper has reached the following conclusions, and subsequently makes the suggestions below based on its empirical findings.

5.1 CONCLUSIONS

According to the aforementioned research findings, the implementation of mobile e-learning as an innovative teaching model can lead to improved operational performance and higher enrollment. Furthermore, this study demonstrated that improvements were more significant in high schools than vocational high schools. This indicates that mobile e-learning is a new teaching model that is appropriate in this technological era. In order to implement and maintain mobile e-learning,

schools will require increased funding for software and hardware installations. Therefore, to enable schools to achieve sustainable development and further increase competitiveness, the government should provide technological resources and funding in a timely manner as to encourage the implementation of mobile e-learning.

5.2 DIRECTIONS FOR FUTURE RESEARCH

This study primarily examined the operational performance of schools that implemented mobile e-learning. Follow up studies should account for environmental variables in their analyses to identify the true causes of mobile e-learning's impact. This study only examined internal structural variables that schools can manage independently, and in doing so overlooked environmental variables such as schools' administrative regulations, financial standings, and locations. Therefore, it is possible that differences or gaps exist between the research findings and reality. Further analysis should be conducted to address this issue in order to ensure that the findings better reflect current social conditions.

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