Analyzing the Effects of Learning Error in e-learning via Mobile Phones

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This paper analyzes quantitatively the learning effects of using the English educational contents for mobile, 'Eigo de Company' provided by ALC Press Inc. The aim of this research is to analyze objectively how 'error' on answering questions affect mobile learning by analyzing quantitative data from log data. Accuracy in answers are generally used to evaluate learning attainment. However, rates of error can be more applicable as an indicator of learning attainment, because users memorize information better with higher entropy. Evaluating learning attainment with this indicator is a new approach in mobile learning study.

In this paper, first, the causal relationship of 'error' and learning environment or learning status or review status are statistically explained. Then how the 'error' influences on learning attainment is evaluated by analyzing quantitative log data. As a result, effective indicator with introduction of 'error' in mobile learning is presented.

1.Introduction

Recently e-learning, educational method using information technology has gained attention and various related approaches have been done in schools, company training and lifelong learning, etc. E-learning is sometimes defined as all educational contents, for instance, CBT (Computer Based Training) using such as CD-ROM, WBT (Web Based Training) which are distributed through IT networks and the real-time delivery of coursework to remote places, etc. However, in other cases, e-learning is limited to education using the network which has activated e-learning itself. Currently, the latter is often introduced as the definition of e-learning and major examples are distance learning with special networks used by schools (or companies) and the e-learning with the system to deliver or stream the class contents by connecting student's and school's (company's) server and PC terminals (personal desktop PC or laptop PC).

The second example for e-learning doesn't have time and spatial restriction and it enables learners to study anywhere anytime. Thus, it is reported that it has some effect on training or educating working people (e-learning white paper 2005). However, in the classrooms of higher education such as in universities, these restrictions don't exist. Therefore, it is difficult to keep them motivated and it is not that effective. In fact, it was reported that the continuation rate of e-learning by WBT was about 50% in U.S. and quite a lot of students would drop out (Morita 2002). One of the reasons is that most PCs for e-learning don't provide constant setting to learners. Thus, learners have moderate restrictions in terms of space and time, and it is difficult to say that they can learn anytime anywhere.

In this situation, mobile phones attract attention as information and telecommunications device which can provide constancy to learners. At the end of March 2004, penetration rate for households of PC was 77.8% and for mobile phone it was 91.1%. The penetration rate of mobile phones was already higher than that of PCs (e-learning white paper 2005). Besides, its technology has been developed and there is no problem to use general networks with it. As stated above, mobile phones are effective information and telecommunications devices. Today e-learning with mobile devices i.e. mobile phones are often referred to as mobile learning. NAGAI et al. (2005) created the system of web discussion board which enabled collaborative learning on both PCs and mobile phones. They mentioned the usefulness of this system based on the subjective ratings by learners. In this case, although the mobile phone had an accessory role to the system, the increased motivations for learning were proved from the subjective ratings and the usefulness of mobile phone in the system was indicated. KUNORI (2005) had question-and-answer sessions, attendance checks and exchange of opinions on mobile phones during the actual courses in the university. In his questionnaire surveys, a little less than 80% of students agreed to the usefulness of mobile phone. The results in these researches are important to show the possibility of mobile learning. However they may include learner's subjectivities and turn to be qualitative evaluations since they were mainly based on survey questionnaire.

As the measure of effectiveness in e-learning, the Kirkpatrick Evaluation Model (Four Levels of Evaluation) and ROI (e-learning White Paper 2005), etc. are used to measure general factors including introduction of e-learning. Thus, it is difficult to measure the specific learning effects with them. Evaluation approaches focusing on learning effects include survey questionnaire to students and measuring effectiveness by specialists. They are qualitative evaluations which reflect learner (respondent) subjectivity. Thus, it is not suitable to evaluate learning effect with them because learners (respondent) have different standards to evaluate each learning effect and it is difficult to expect the same effect as the result of the same learning (reproducibility). Therefore, the evaluation of learning effect should be objective and quantitative. Evaluating the number of correct answers in exams and grading papers are often used as objective and quantitative evaluation of the learning effect. In order to measure based on objective evaluations, it is preferable to use the former such as multiple choice questions than the latter method which may include graders' bias. If learning evaluation is done through the multiple choice tests, higher accuracy rates are considered to show higher learning attainment. But humans tend to learn from 'error' which comes with 'failure' and 'embarrassment'. Therefore, rates of error can be more or equally applicable as the indicator of learning level like accuracy rates. The problem is that humans tend to hide 'error' and even in anonymous surveys some data are suppressed unconscious. Thus, it is necessary to use data such as log data which will not include learner subjectivity.

In this paper, we measure and analyze how 'error' influences learning effect using the English educational contents. This research utilizes an approach analyzing learning evaluation quantitatively and evaluating based on 'error' which has not been presented so far.

2.Purpose of this Study

Purpose of this study is to analyze how 'error' in multiple choice tests affect learning (Fig.1). We use 'learning environment', 'learning status' and 'review status' as learning factors. By finding the correlation between these factors and 'error', we analyze how 'error' influences learning. These factors are categorized as outside factor, inside factor and secondary factor and they are likely to have an impact on learning. Therefore, analyzing these correlations objectively and quantitatively will enable us to use 'error' to achieve effective learning.

3.General Description of the Learning Contents

In this research, we analyze the English educational contents for mobile phone, of 'Eigo de Company（http://alc.edia.ne.jp）' from ALC Press Inc. which aims to promote English Proficiency through simulating the work environment in a multinational company. For example, users who join the company (registered users) will collect scoring points by giving correct answers to English questions. Each set has five questions. They will be promoted according to the total points. Fig.2 indicates the screen of 'Eigo de Company'.

The contents have three functions to sustain motivation for learning.

1) Promotion raises the difficulty level of questions. Then it will be more difficult to be promoted.
2) The ranking of all users will be displayed. Therefore, it motivates them to compete.
3) After work, the correct answers to questions will be linked to the description in Pocket Eijiro (English dictionary). Thus, they can review them in real time.

4.Method of Study

4.1 Subjects

The registered members in 'Eigo de Company' are the subjects in this study. Members pay a registration fee and approximately 179 yen per month to use this mobile phone service.

4.2 Research Period

We use the log data collected from August 1st, 2004 to May 31st, 2005.

4.3 Details of Research

As mentioned in the purpose of this study, we analyze and evaluate the correlation between learning and 'error' statistically.

First, rate of error is chosen as measurement of 'error'. We calculate 'rate of error' by dividing total number of mistakes by total number of questions. In other words, it is the average percentage error during learning. In this experiment we analyze using the above-mentioned value as the objective variable and several explanatory variables in Table 1, and then we analyze the statistical results.

Review status, learning environment and learning status are explanatory variables. Learning environment is the factor which affects users through interface when they use contents. It is also categorized as an outside factor since the learners basically cannot control the factor ('mobile phone model' and 'Speech capability'). Second, learning status is the factor relating to time and it affects learners in their subconsciousness ('average interval of days for playing', 'interval days between play days', 'average time for playing per day', 'average number of questions per day', 'average time to answer a question' and 'company job title') (inside factor). Third, review status is the factor which has secondary influence and learners can modify consciously ('rate of reading notes') (Secondary factor).

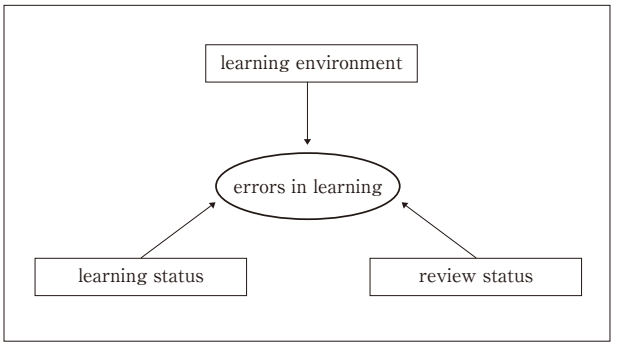

Figure 1. Correlation between Learning and Error

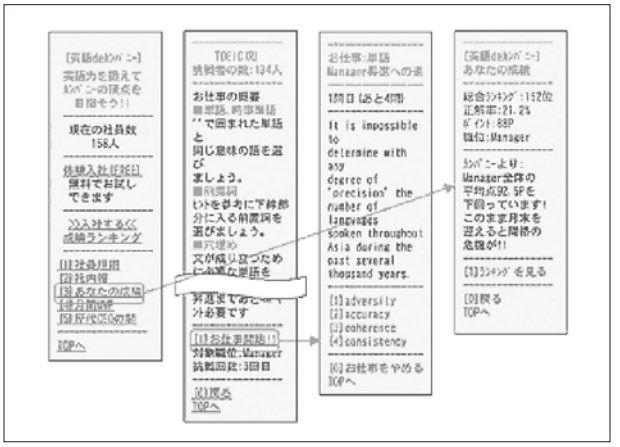

Figure 2. The Screen of 'Eigo de Company'

【objective variable】		
1	rate of error（err）	number of mistakes/total number of questions（0<err<1）
【explanatory variable】		
〈learning environment〉		
1	mobile phone model	I-MODE, J-SKY, EZWEB
2	speech capability	yes, no
〈learning status〉		
3	average interval of days for playing（ave_intval）	average number of days between the last and the next day for playing（day）
4	standard deviation of interval of days for playing（std_intval）	showing dispersion of number of days between the last and the next day for playing
5	average time for playing per day（second）（day_ave_sec）	total time for playing（second）/total days for playing（day）
6	average number of questions per day（day_ave_try）	total of answered questions for trial/total days for playing（day）
7	average time to answer a question（second）（try_ave_sec）	total play time（second）/total answered questions（second）
8	company job title（level）	job title in company（1<level<10）
〈review status〉		
9	rate of reading notes or explanation about answers（gloss）	total number of reading note/total number of answered questions（0<gloss<1）

Table 1. Objective Variable and Explanatory Variables in the Experiment

5.Result and Discussion

5.1.1. Correlation between 'error' and learning environment

Table 3 shows the correlation ratio of 'rate of error' as objective variable to 'mobile phone model' and 'speech capability' as explanatory variables. In addition, the interclass variations in the table show the degree of dispersion within each class (Equation 1), and the between-class variations show the degree of class dispersion from the mean (Equation 2). The correlation ratio variations are found by calculating the Equation 3 using the interclass variations and between-class. In table 3, the correlation ratios of 'rate of error' to 'mobile phone model' and 'speech capability' are 0.02 and 0.00 (weak correlation). Generally, if correlation ratio is over 0.25, it will be considered as correlated. Thus, it is possible to say there is no correlation between them.

objective variable	rate of error	
explanatory variable	mobile phone model	speech capability
interclass variation (Sw)	9.93	10.06
between-class variation (SB)	0.17	0.00
correlation ratio (n^2)	0.02	0.00

Table 3. Correlation Ratio of 'Error' to Learning Environment

$$S_w = \sum_{i=1}^{m}\sum_{j=1}^{n}(x_{ij}-\overline{x_i})^2 \quad (1)$$

$$S_B = \sum_{i=1}^{m} n_i(\overline{x_i}-\overline{x})^2 \quad (2)$$

$$n^2 = \frac{S_B}{S_w+S_B} \quad (3)$$

xij: data within class
xi: mean within class
x: mean in total data

5.1.2. Correlation between 'error' and learning status

Next, when 'rate of error' is set as the objective variable and variable numbers 3-6 in Table 2 are explanatory variables, the coefficients of correlation are indicated in Table 4. The result of multiple linear regression analysis is shown in Table 5 (We use Microsoft Excel for all the calculations in this paper). In Table 4, the factor which seems to have the strongest positive correlation with 'error' is 'average interval of days for playing' (the coefficient of correlation is 0.36). However, we cannot admit it as the contributing factor because the hazard rate is 62% (0.62) referring its p-value in Table 5. Thus, regression model with all variables in learning status are not suitable. The applicable regression model is established after we use explanatory variable selection criteria (Equation 4) introduced by UEDA (1997) to choose the variable which has the strongest positive correlation with 'error'.

variable		explanatory variable						objective variable
variable number		3	4	5	6	7	8	1
explanatory variable	3	1.00						
	4	0.78	1.00					
	5	-0.04	-0.02	1.00				
	6	0.06	0.02	0.13	1.00			
	7	0.05	0.08	0.72	-0.10	1.00		
	8	-0.52	-0.41	0.20	0.30	-0.06	1.00	
objective variable	1	0.36	0.28	-0.30	0.08	-0.24	-0.51	1.00

Table 4. Coefficient of Correlation of 'Error' to Learning Status

Table 6 shows the result of applicable regression model which meets the criteria of selecting explanatory variable. As explanatory variables, we narrow down to three variables such as 'average number of questions per day', 'average time to answer a question' and 'company job title'. The multiple correlation coefficient ($0 \leqq R \leqq 1$) shows how close it can fall into the regression formula and the value is 0.61. Although it is not so close, the hazard rates for all of p-values are below 5% (0.05) and it is the most applicable model. Next, degree of effect by explanatory variables to objective variables with t-value is shown in Figure 3. 'Average number of questions per day' has a positive sign and it is proportional to 'rate of error'. In other words, it shows that percentage rate of error will increase if they try more questions. In addition to this, 'average time to answer a question' has negative sign and it is inversely proportional to 'rate of error'. This means that the percentage rate of error will be higher if the time to answer is shorter. Moreover, the 'company job title' will rise if 'rate of error' decreases, because 'company job title' also has negative sign.

Regression Statistics

multiple correlation R	0.62
multiple determination R2	0.38
correction R2	0.37
standard error	0.79
number of sample	349.00

Table for Analysis of Variance

	coefficient	standard error	t	p-value
intercept	0.91	0.10	8.79	0.00
3	0.04	0.07	0.50	0.62
4	0.04	0.07	0.55	0.58
5	-0.07	0.07	-1.09	0.27
6	0.23	0.05	4.80	0.00
7	-0.20	0.07	-3.00	0.00
8	-0.18	0.02	-9.63	0.00

Table 5. Result of Regression Analysis of 'Error' and Learning Status

$$R_u = \frac{1-(1-R^2)\times(n+k+1)}{n-k-1} \quad (4)$$

R_u: criteria for selecting explanatory variable
R : multiple correlation coefficient
n : number of data
k : number of explanatory valuable

These three explanatory variables are the most influential factors on 'error'. It means that the other explanatory variables 'average interval of days for playing', 'standard deviation of interval of days for playing' and 'average time for playing per day' have insignificant effect on 'error'. Thus, it is possible to say that broad time elements such as total learning hours of day or the interval days have weak correlation to 'error' in terms of learning, whereas focal time elements including total hours for study have a stronger correlation.

5.1.3. Relation between 'error' and review status

The result of simple linear regression analysis is shown in Table

Regression Statistics

multiple correlation coefficient R	0.61
multiple determination R2	0.38
correction R2	0.37
standard error	0.79
number of sample	349.00

Table for Analysis of Variance

	coefficient	standard error	t	p-value
intercept	1.00	0.09	11.61	0.00
6	0.23	0.04	5.20	0.00
7	-0.25	0.04	-5.75	0.00
8	-0.19	0.01	-13.32	0.00

Table 6. Result of Applicable Regression Analysis

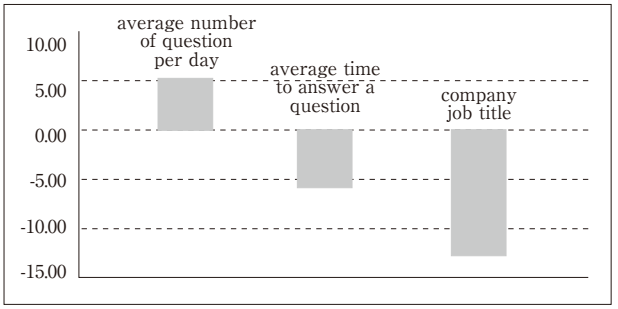

Figure 3. Degree of Effect by Explanatory Variables to Objective Valuables with T-value

Regression Statistics

multiple correlation coefficient R	0.199229
multiple determination R2	0.039692
correction R2	0.036909
standard error	0.977547
number of sample	347

Table for Analysis of Variance

	coefficient	standard error	t	p-value
intercept	-0.01878	0.05297	-0.3546	0.723103
3	-0.50064	0.132576	-3.77623	0.000187

Table7. Regression Analysis of 'Error' and Review Status

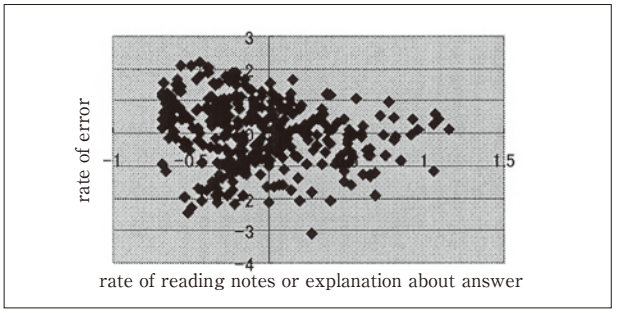

Figure 4. Correlation of 'Rate to Error' to 'Rate of Reading Notes
※ Standardized data

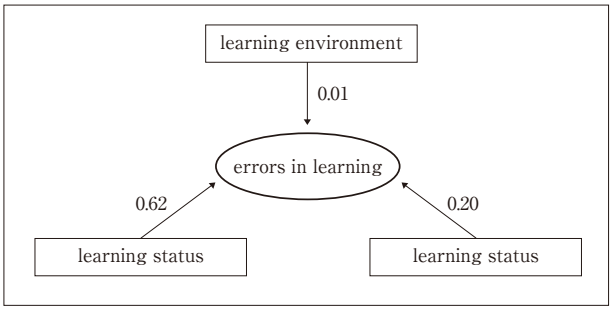

Figure 5. Correlation between Learning and Error

with 'rate of error' as objective valuable and 'rate of reading notes' as explanatory variable. And Figure 4 is the scatter plot showing the correlation of 'rate of error' to 'rate of reading notes'.

From the multiple correlation coefficients (0.20) in Table 7, 'rate of error' and 'rate of reading notes' have very weak correlation. The disorderly plotted data in Figure 4 shows that. Generally, either reading note or explanation about answers is considered as behavior to reduce rate of error. However, from this result this kind of process does not affect 'rate of error'.

5.2. Discussion

Figure 5 shows the relation (correlation ratios and coefficient of correlations) of 'error', learning environment, learning status and review status after the experiment.

Results show that the influential learning factor is learning status. Influence by learning environment is weak and mobile terminals themselves have no direct influence on 'error'. Review status has also very weak correlation and it does not relate to 'error' directly.

Although the coefficient of correlation for learning status (0.62) does not show strong correlation, it has still quite strong influence compared to other learning factors. As to learning status, the elements relating to content of questions have more influence on learning than time-related elements. This means that 'error' affects learning as inner factor rather than as outer factor. Thus, in order to use 'error' effectively in learning, it is desirable to add inner factor, for instance, questions that cause 'error'. And it is difficult to say that it is efficient to use 'error' by relating it to time restriction, restriction of mobile functions and performance after learning.

6. Summary

This research analyzes quantitatively the learning effect by 'error' and it reveals that the factors of learning status affect 'error' more than learning factors such as learning environment and review status. If it is possible to learn anytime anywhere like mobile learning, environment has no relation to 'error' in learning. Therefore, mobile learning has the possibility to provide the same learning as e-Learning. It was found that there is significant correlation between 'error' and learning status and by analyzing more details of the relation may lead to find key factors to learning. Furthermore, it will help find the fundamental factors to the mobile learning in general.

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