Journal of Physics: Conference Series

PAPER • **OPEN ACCESS**

The Effectiveness of E-Learning: A Meta-Analysis

To cite this article: K T Yuwono and H D Sujono 2018 *J. Phys.: Conf. Ser.* **1140** 012024

The Effectiveness of E-Learning: A Meta-Analysis

K T Yuwono[1] and H D Sujono[2]

[1 2] Faculty of Engineering, Yogyakarta State University, Indonesia.

E-mail: arispa@uny.ac.id

Abstract. The aims of this study were to: (1) test the effect size of the research findings under the issue of the effects of e-learning on the students' learning outcomes, (2) investigate the combined effect sizes by doing the weighting of each finding, and (3) know the homogeneity of the research findings. A meta-analysis was conducted to synthesize research on the implementation of e-learning from Year 2000 to 2013. The search of the researh articles was done through several data sources namely ScienceDirect, Springer, IEEE, ProQuest, Sage, and BMC. The search was also conducted in libraries. In this study, there were 15 research articles selected based on the several predetermined criteria. The results of this study indicate that there is research with a negative effect size (-0.05), meaning that the learning outcomes in the implementation of e-learning are lower than those in conventional learning. There is a study with an effect size value of 0.00. Based on the value, there is no significant difference on learning outcomes in e-learning and conventional learning. The other studies have shown positive results; it means that the outcomes of e-learning are better than those of the conventional learning. However, there are 4 studies whose results are not significant. The combined effect size is 0.67 with a confidence interval of 0.42 to 0.91. Regarding this, the overall learning outcomes in the implementation of e-learning are higher than those in conventional learning. The result of the heterogeneity test using I2 formula is 71.95%, which means that the sample of this study is not homogeneous. Therefore, the generalization is not possible to be achieved.

1. Introduction

E-learning has been widely implemented. This is done to create effective learning. The students' learning outcomes of e-learning vary. Some studies state that the results are positive, meaning that e-learning can improve the students' learning outcomes. CAI (Computer Assisted Instruction) learning is more effective than traditional or conventional learning, especially in Taiwan [1]. Liao's research is supported by Gursul and Keser's findings [2] which claim that there is a significant statistical difference on the learning outcomes between online problem-based learning and face-to-face problem-based learning. The students' learning outcomes in online learning are bettter than those in face-to-face learning.

There is no significant difference on the post-test results between students who join distance learning and those who attend traditional learning [3]. There is no significant difference on the learning outcomes of the students who engage in online learning and those who join face-to-face learning. Therefore, it is necessary to synthesize the various studies [4].

The research synthesized uses the scores of learning outcomes as a variable indicator. The hypothesis testing in each of the selected studies is done by comparing the means in both e-learning and

conventional learning. The standard deviation is also used as the variable indicator for the synthesis. This synthesis result is used to reveal the real contribution of e-learning. It is used to investigate the effects of e-learning on the students' learning outcomes.

The effect size is used to test or find out the effectiveness of the treatment on the experiment class. In synthesis research, an effect size is a metric that is used to combine all the research findings to be generalized. The effect size calculations involve a weighting to correct the sample size and errors due to the sample determination. Meanwhile, the weighting involves an error standard, which is an important statistical component in the interpretation of the research results. The basic principle of the effect size is to compare the experiment results by dividing the standard deviations.

The main objective of the synthesis research is to integrate similar empirical research and then is generalized. So that synthesis research can be regarded as a combination of characteristics of literature review. Besides focusing on relevant theories, synthesis research also critically analyzes the conducted study, resolves conflicts based on the literature, and identifies the main problems for future research [5]. Synthesis research is one of the series of integrative activities involving scientists, in which the intellectual heritage can be traced back.

One of the synthesis research is a meta-analysis. The effectiveness of a meta-analysis depends on the quality of the effect size estimation of the results of the primary research. It is very important that the effect size estimation be not biased and the sampling properties of the effect size estimation be known. Specifically, the meta-analysis procedure requires estimation on the sampling variance of the effect size to obtain an optimal weight, to construct confidence intervals, and to estimate the variant components among studies [5].

The difference of mean standard d is a general index of the effect size for a meta-analysis of the effectiveness of organizational interventions. The meta-analysis technique d was developed based on the general assumptions of independence, normality, and homogeneity of variance [6]. Research has shown that violating this assumption can result in a biased meta-analysis [7]. Therefore, it is important to develop strong methods to avoid the violations of these assumptions.

This study tries to find out: (1) the effect size of each research result under the issue of the effectiveness of e-learning on the learning outcomes, (2) the combined effect size of the research results examined after weighting, (3) the homogeneity of the research results on e-learning, and (4) the generalization of the research findings using a meta-analysis method.

2. Research Method

Meta-analysis is a statistical analysis of some research results from individual studies for the purpose of integrating the findings, Glass [8]. Meta-analysis can be understood as a form of survey research in which the survey was conducted on the reports instead of people. The coding form (survey protocol) was developed; the sample or population of the research report was collected, and each study was examined by a coder who carefully read it and encoded appropriate information on its quantitative characteristics and findings. The resulting data were then analyzed using a special adaptation of conventional statistical techniques to investigate and describe the finding patterns in the selected studie s[9].

According to Meca and Martinez [10], to conduct a meta-analysis, researchers must follow several steps such as (1) problem formulation, (2) literature search, (3) study coding, (4) statistical analysis and interpretation, and (5) meta-analysis publications. In the meta-analysis, the aim is to review experimental studies on the effects of instructional learning with the manipulation of e-learning [11]. In

this study, the researchers tried to determine the extent to which the effects of the treatment can be generalized. The literature search was conducted through several data sources namely ScienceDirect, Springer, IEEE, ProQuest, Sage, and BMC. The search criteria were determined by (1) types of the study (experimental or quasi-experimenta), (2) design (pretest-posttest-control), and (3) mean, standard deviation, and the number of samples. The year of publication should range from 2000 to 2013, with e-learning as the main variable. In addition, the literature search was also carried out in libraries. According to Morris [12] the effect size for a pretest-posttest-control design can be obtained using the following formula:

$$d_{ppc1} = c_T\left(\frac{M_{postT} - M_{preT}}{SD_{preT}}\right) - c_C\left(\frac{M_{postC} - M_{preC}}{SD_{preC}}\right) \quad (1)$$

Based on formula (1) on the effect size, each average value is divided by the standard deviation of each pretest. The correction factor is presented as the formula below:

$$c_j = 1 - \frac{3}{4(n_j - 1) - 1} \quad (2)$$

Formula (2) is applied to c_T and c_C.

$$d_{ppc2} = c_P\left[\frac{(M_{postT} - M_{preT}) - (M_{postC} - M_{preC})}{SD_{pre}}\right] \quad (3)$$

Based on the formula (3), on the effect size, each average value is divided by the standard deviation of each pretest. Formula (4) on the combined standard deviation is as follows:

$$SD_{pre} = \sqrt{\frac{(n_T - 1)SD_{preT}^2 + (n_C - 1)SD_{preC}^2}{n_T + n_C - 2}} \quad (4)$$

The correction formula for dppc2 is as follows:

$$c_P = 1 - \frac{3}{4(n_T + n_C - 2) - 1} \quad (5)$$

According to various experiences, dppc2 is more reliable than other formulas. Formula (6) for the weighting of each study is presented below:

$$W_i = \frac{2(n_{i1} + n_{i2})n_1 n_{i2}}{2(n_{i1} + n_{i2})^2 + n_{i1} n_{i2} d_i^2} \quad (6)$$

After the weighting, the effect size was calculated using this formula.

$$d = \frac{\sum_{i=1}^{k} d_i w_i}{\sum_{i=1}^{k} w_i} \quad (7)$$

The calculation of the confidence intervals (95%) used Formula (8) presented as follows.

$$CI_{d.95\%} = d \pm z_i\sqrt{\frac{1}{\sum_{i=1}^{k} W_i}} \quad (8)$$

To calculate the heterogeneity, the researchers employed Formulas (9) and (10).

$$Q_t = \Sigma_{i=1}^{k} W_i d_i^2 - \frac{\left(\Sigma_{i=1}^{k} W_i d_i\right)^2}{\sum_{i=1}^{k} W_i} \quad (9)$$

$$I^2 = \frac{Q-df}{Q} \times 100\% \quad (10)$$

In a meta-analysis, it is necessary to know the publication bias of the studies through the funnel plot graph. Meanwhile to see the entire results of the meta-analysis, besides using tables, the display could be in the form of forest plot graphics.

An expanded threat analysis to the validity of the research synthesis needs to be presented. It is also necessary to provide a thorough assessment of how conclusions from synthesis can be limited or proven incorrect, and to collect many concerns expressed. Several potentials and limitations of the research synthesis exist [13]. The possibility of further development in the synthesis methodology, feasibility, and costs to conduct qualified synthesis research should be taken into account, as well as what makes the research synthesis qualified or not. There is no secret that will be disclosed by stating the previous conclusion if the procedure for the synthesis research is carried out based on the standards of objectivity, systematics, and accuracy.

Table 1. The Results of Meta-Analysis

no	study	es	weight	smpl size	se	var	ci.lo	ci.hi
1	ppc1	1.1230	5.0581	24	0.4446	0.1977	0.2516	1.9945
2	ppc2	0.6796	44.2386	200	0.1503	0.0226	0.3849	0.9743
3	ppc3	0.3831	9.2713	39	0.3284	0.1079	-0.2606	1.0267
4	ppc4	-0.0474	9.4333	39	0.3256	0.1060	-0.6856	0.5907
5	ppc5	1.6521	22.3682	120	0.2114	0.0447	1.2377	2.0665
6	ppc6	1.1777	14.6985	69	0.2608	0.0680	0.6665	1.6889
7	ppc7	0.4535	16.8142	69	0.2439	0.0595	-0.0245	0.9314
8	ppc8	0.3183	16.7874	68	0.2441	0.0596	-0.1600	0.7967
9	ppc9	0.6999	22.1346	94	0.2126	0.0452	0.2833	1.1165
10	ppc10	0.0000	15.1475	61	0.2569	0.0660	-0.5035	0.5036
11	ppc11	0.2677	12.3890	50	0.2841	0.0807	-0.2891	0.8245
12	ppc12	0.8766	14.1418	62	0.2659	0.0707	0.3554	1.3977
13	ppc13	0.5765	17.7620	74	0.2373	0.0563	0.1115	1.0416
14	ppc14	0.5233	14.7108	61	0.2607	0.0679	0.0123	1.0343
15	ppc15	1.2201	13.9115	66	0.2681	0.0719	0.6946	1.7455

3. Research Findings

Section on the topic can be more than one according to the needs of the author. The content of the topic section according to the author's needs. This is an example. This is an example. This is an example. This is an example. This is an example. This is an example. This is an example. This is an example. This is an example. This is an example. This is an example. This is an example.

Based on the search results of the research articles, using the intervention model, 152 articles were found. Those were selected and 51 articles were obtained. After that, they were examined based on the type of the research (experiment or quasi-experiment) and 28 articles were selected. According to the variables such as mean, standard deviation, the number of the samples, t value, p value, only 21 articles were obtained. Furthermore, the researchers checked the design (pretest-posttest-control) as one of the

variable indicators, and 15 articles were selected. Therefore, the meta-analysis was carried out on these 15 research articles. It can only be done for the similar research, based on the research method and type. The results of the meta-analysis with R studio software using a standardized mean difference are presented on Table 1. The graphical representations can be seen in the following forest plots:

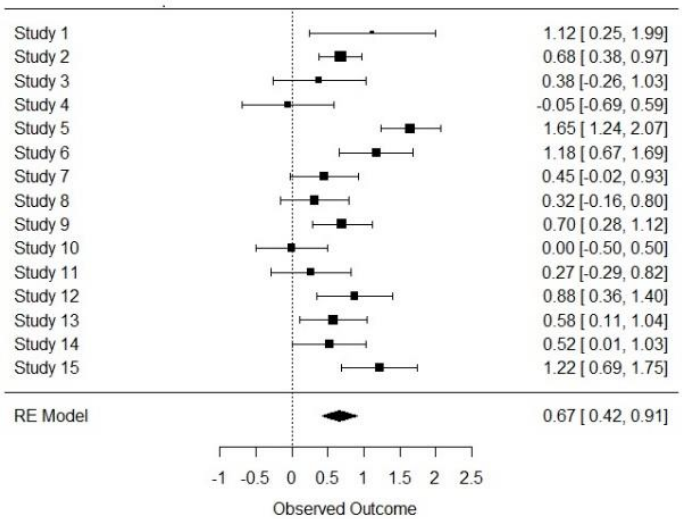

Figure 1. Forest Plot

The forest plot above shows that the black box is the value of the effect size of each study. It can be noticed in the right value, outside the brackets, while the numbers in brackets are the limit values of the confidence interval with the significance of 95%. Meanwhile, the black diamond is the effect size of all studies. The horizontal line of each effect size is the limit value of the confidence interval. It can be seen in the figure that there is a vertical line which is regarded as the limit for accepting the confidence interval. If the horizontal line passes the vertical line, the study is not significant. The dashed upright line also shows the effect sizes. If the value of the effect size is on the left side of the dashed vertical line, the study has a negative value. Furthermore, if it is right above the dashed vertical line, it means that the value is zero (0). Meanwhile, the others have positive values.

Table 2. Effect sizes by Glass

Relative Sizes	Effect Sizes	Percentile	Percentage (%)
	0	50	0
Small	0.2	58	15
Medium	0.5	69	33
Large	0.8	79	47
	1.0	84	55
	1.5	93	71
	2.0	97	81

From the forest plot, it can be seen that the effect size on Study 4 is negative. This shows that e-learning is less effective than conventional learning. Related to the Study 10 whose the effect size is 0, there is no significant difference on the outcomes after e-learning and conventional learning are implemented. At the first glance, the 13 studies have positive effects, meaning that e-learning is better than conventional learning. Furthermore, there are findings of 4 studies that are not significant although the

effect size values are positive (Study 3, Study 7, Study 8, and Study 11). However, the combined effect size in overall obtains a pretty convincing value of 0.67 with a confidence interval of 0.42 - 0.91 and a significance of 95%. Based on the combination, it shows that the implementation of e-learning shows better results than those of the conventional learning. Can these results be generalized or not?

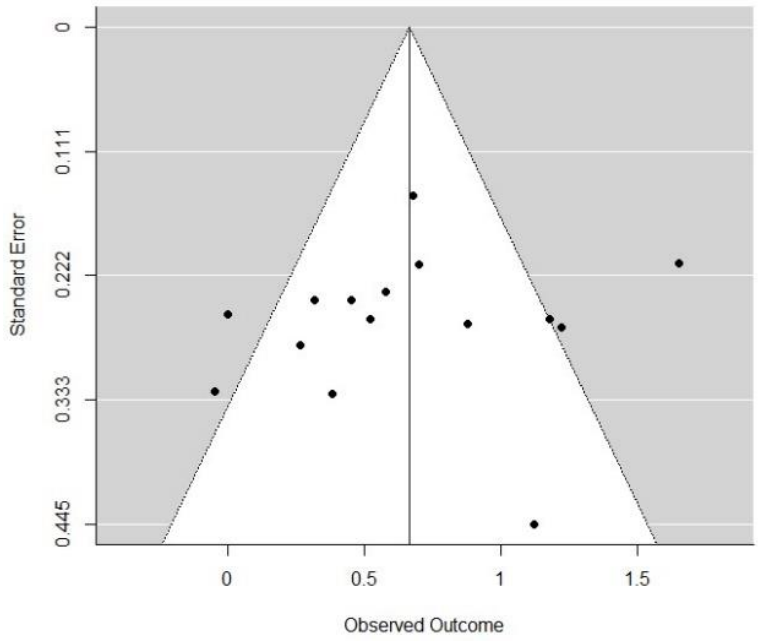

Figure 2. Funnel Plot

Figure 2 above is a graphical way to determine whether there is a tendency for a publication bias of the synthesized articles or not. Also the value distribution in the funnel plot shows the heterogeneity. At the same time, it can be seen whether the data outside the triangle were out layers. The determination of whether the publication bias exists or not cannot be observed from the triangle depicted in the funnel plot. The symmetric triangle shows that there is no publication bias. If the triangle is not symmetrical, there is a tendency for a publication bias. Regarding the results on the figure above, it can be concluded that there is no tendency for a publication bias. However, some data are scattered outside the triangle, so it is possible to have an out layer. In addition, there is a tendency for the data to be heterogeneous.

To test the heterogeneity, the researchers used Formulas (9) and (10). The complete result can be seen in Figure 3. The heterogeneity is accepted if the value is less than or equals to (≤) 50%. In other words, if the I2 value is less than 50%, the research data for the synthesis are homogeneous. However, if the I2 value is more than 50%, the research data used are heterogeneous.

```
Random-Effects Model (k = 15; tau^2 estimator: REML)

  logLik  deviance       AIC       BIC      AICc
 -9.5107   19.0214   23.0214   24.2995   24.1123

tau^2 (estimated amount of total heterogeneity): 0.1577 (SE = 0.0853)
tau (square root of estimated tau^2 value):      0.3971
I^2 (total heterogeneity / total variability):   71.95%
H^2 (total variability / sampling variability):  3.57

Test for Heterogeneity:
Q(df = 14) = 48.8787, p-val < .0001

Model Results:

estimate      se    zval    pval   ci.lb   ci.ub
  0.6653  0.1232  5.4025  <.0001  0.4239  0.9067  ***

---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Figure 3. Heterogeneity Test

The smaller the I2 value is, the more homogeneous the data of the articles which are used. Furthermore, because the article data used are not homogeneous, and the combined effect size value is 0.67, it means that e-learning can improve the outcomes. However, these results cannot be generalized directly.

To generalize the research findings, a further investigation on whether there is a moderator variable that affects the results, or whether there is an error in determining the research sample needs to be conducted.

Table 3. Heterogeneity Test

I2	Relative Sizes
0% - 30%	Low (minimum)
30% - 60%	Moderate
50% - 90%	Substantial
75% - 100%	Considerable

4. Conclusion

The results of the meta-analysis of 15 research articles that have been rigorously selected are mentioned in the following conclusions:

1. One of the studies shows a negative value in the finding, which means that the outcomes thorugh e-learning is lower than those in conventional learning. Another study shows a value of 0.00, meaning that there is no significant difference on learning outcomes between e-learning and conventional learning. Meanwhile, positive values are found in the other studies. Based on this, the learning outcomes of e-learning are better than those in conventional or traditional learning. However, some studies show insignificant results, although the value of the effect size is positive.
2. The combined effect size shows a value of 0.67 with a confidence interval of 0.42 - 0.91 and a significance of 95%. This shows that overall outcomes of e-learning are greater than those in

conventional learning. However, if the combined effect size value is referred to the effect sizes by Glass, the effectiveness is approximately 35% and it is not too large.

3. According to the homogeneity test using a Q formula, the Q value is 48.88 (df = 14) p-val <0.0001. Meanwhile, with the formula I2, the total heterogeneity test obtaines a value of 71.05%. When consulted to Table 3, it is classified as relatively substantial in size. It means that the research data are heterogeneous or highly varied.
4. The tendency of publication bias is very low as seen in the funnel plot, and the size of the combined effect produces a positive value. However, by taking into account that the research data are not homogeneous, the results of the study cannot be generalized.

This meta-analysis study is very useful even though it takes longer time and uses meticulous statistical anaysis. Unfortunately, many primary studies, as the basis for the meta-analysis research, report incomplete information, so that it is difficult to conduct further research. It is suggested that primary researchers report the complete statistical values of their research findings.

5. References

[1] Y C Liao 2007 *Effects of computer-assisted instruction on student's achievement in Taiwan: A meta-analysis* (Computers and Education) Vol 48 p 216–233

[2] F Gürsul and H Keser 2009 *The effects of online and face to face problem based learning environments in mathematics education on student's academic achievement* in (Proceeding of World Conference on Educational Sciences IEEE) p 2817–2824

[3] M Allen E Mabry M Mattrey J Bourhis STitsworth and N Burrell 2014 *Evaluating the Effectiveness of Distance Learning: A Comparison Using Meta-Analysis* (Journal of Communication)

[4] C A Dell C Low and J F Wilker 2010 *Comparing Student Achievement in Online and Face-to-Face Class Formats MERLOT* (Journal of Online Learning and Teaching) Vol 6 p 30–42

[5] H Cooper 2010 *Research Synthesis and Meta-Analysis* (Los Angeles, USA: Sage, Inc., USA)

[6] L V Hedges and I Olkin 1985 *Statistical Methods for Meta-Analysis* (Florida, USA: Academic Press, Inc)

[7] R J Grissom and J J Kim 2005 *Effect Sizes for Research: A Broad Practical Approach*, (New Jersey: Lawrence Erlbaum Associates, USA)

[8] G V Glass, B McGaw, and M L Smith 1981 *Meta-Analysis in Social Research* (California: Sage Publications, USA)

[9] M W Lipsey and D B Wilson 2001 *Practical Meta Analysis* (California: Sage Publications, USA)

[10] J Sánchez-Meca and F Marin-Martinez 2010 Meta Analysis *International Encyclopedia of Education* Vol 7 p 274–282

[11] D Kim B nyun Kim K Lee J K Park S Hong and H Kim 2008 *Effects of Cognitive Learning Strategies for Korean Learners: A Meta-Analysis* (Asia Pacific Education Review) vol 9 p 409–422

[12] S B Morris 2007 *Estimating Effect Sizes From Pretest-Posttest-Control Group Designs* (Organizational Research Methods) p 1–23

[13] H Cooper L V Hedges and J C Valentine 2009 *The Handbook of Research Synthesis And Meta-Analysis 2nd ed* (New York: Russell Sage Foundation USA)