International Journal of Business, Human and Social Sciences
ISSN: 2517-9411
Vol:11, No:4, 2017

Measuring E-Learning Effectiveness Using a Three-Way Comparison

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***Abstract*—**The way e-learning effectiveness has been notoriously measured within an academic setting is by comparing the e-learning medium to the traditional face-to-face teaching methodology. In this paper, a simple yet innovative comparison methodology is introduced, whereby the effectiveness of next generation e-learning systems are assessed in contrast not only to the face-to-face mode, but also to the classical e-learning modality. Ethical and logistical issues are also discussed, as this three-way approach to compare teaching methodologies was applied and documented in a real empirical study within a higher education institution.

***Keywords*—**E-learning effectiveness, higher education, teaching modality comparison.

I. Introduction

THIS paper is about the way e-learning researchers measure the medium's effectiveness and outcome. Before embarking on what methods are traditionally employed and what is being proposed, it is essential and critical to clarify the concept of effectiveness itself. The best place to start this process is precisely with the 2-Sigma problem that Bloom [1, p. 15] refers to when he claims that individual human tutoring increased the effectiveness of learning by two standard deviations. Bloom was not only convinced that the direct teacher-to-student interaction enhanced the effectiveness of the educational process, but challenged educational researchers to "find methods of group instruction as effective as one-to-one tutoring". Other research work [2]-[6] employed a plethora of methods to evaluate e-learning effectiveness but always stuck to the same comparison of placing side-by-side the e-learning environment under scrutiny with the equivalent material being physically taught in class. A control class is usually employed and a set of assessment outcomes are used as a quantitative measure to evaluate their research outcome. The results overall were not conclusive or consistent across the studies and this is due to the lack of a standard and consistent way of how to measure e-learning effectiveness. The way and logistical details of how the studies were held are usually minimal or not considered important with additional ethical issues ignored or not considered influential. In a similar research performed on the effectiveness of a VLE, Piccoli et al. [7] arrived at the same conclusions that no major improvements could be reported when they attempted to assess a Web-based VLE's effectiveness in relation to basic ICT skills training. So, what characteristics better depict e-learning effectiveness to be able to measure it? What factors have the studies mentioned earlier taken into consideration when investigating the effectiveness of e-learning? As already mentioned, the majority of these studies predominantly investigated and compared e-learning in relation to face-to-face instruction giving a mixture of outcomes. In a 2011 white paper, Academic Partnerships [8] identified four types of research trends that investigate the effectiveness of online learning. The first type categorises those studies that focus primarily on the learning outcomes, while three other types of studies focus on growth of online learning, costs involved, and the impact on instructional design and delivery. Clearly, the first category focuses directly on the topic under investigation; namely, the effectiveness of e-learning. This periodic compilation of research on online learning also points out that comparisons between distance learning and face-to-face instructional settings reported in hundreds of studies have consistently reported that no significant differences have resulted. In another report [9] that reflects latest studies, a meta-analysis of similar studies was performed and concluded that a slight improvement in the effectiveness of online education could be reported, even though the approaches adopted by the different studies were quite broad across different content and learner types. Yet again, the comparison was consistently done against the face-to-face control group with no particular detail of how the empirical study was administered and no concern about those learners who were within the control group and potentially at a disadvantage.

Chan et al. [10] proposed a framework to evaluate e-learning effectiveness based on four underlying components (Fig. 1). The authors argue that in order to successfully evaluate the effectiveness of an e-learning course then a number of issues need to be taken into consideration including methods used for evaluation, results obtained, and the course itself. According to the authors, the proposed framework can be easily adapted to assess and evaluate the effectiveness of online teaching as well. Other studies [9], [11]-[13] have been reported over the years where a serious of mixed results simply show that online learning can potentially increase the completion rate at higher education. It also goes on to show that further research and investigation is required to assess the way e-learning courses are assessed to be effective or not. The conflicting findings from these studies also raise the question of which factors from e-learning need to be taken into consideration and measured in some way.

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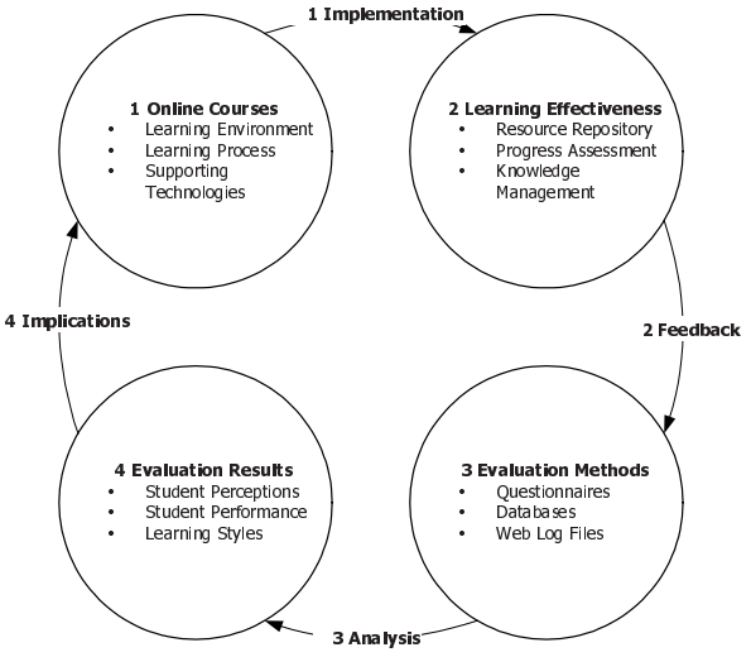

Fig. 1 Framework for evaluation of learning effectiveness in online courses [10]

Neuhauser [14] performed a study that characteristically included a number of best practices that were employed at the time, and have also been employed since then. The study took two sections from the course that was delivered in both modalities and compared them together. Learning preferences together with gender, age, preferences, and style were compared to extract the overall effectiveness of the final outcome. It is worth highlighting the fact that even though this study by Neuhauser, like all others mentioned earlier, reported the effectiveness of e-learning in comparison to the standard face-to-face instruction, details of how the empirical study was administered reflect an unbiased delivery of the course in both modalities.

The rest of the paper is organised as follows: The next section will justify the reason why an innovative comparison methodology is required as e-learning systems evolve beyond their static format. Section III presents all the necessary details about the proposed three-way comparison methodology, which is applied and documented in the following section. Finally, the conclusions are drawn in the last section to close this paper.

II. Beyond Standard E-Learning

Next generation e-learning systems go beyond the standard e-learning course that learners access, whether blended or entirely online, with a one size fits all ideology. Dynamic systems, similar to [15], that personalise the learning process have taken online education to the next level including personal and virtual learning environments. In a recent empirical investigation, Xu et al. [16] employed a personalised VLE, supported by intelligent software, to enhance the overall outcome while employing an e-learning system. An empirical field experiment was held to test the embellished VLE and the results "suggested that personalized e-learning facilities enhance online learning effectiveness in terms of examination, satisfaction, and self-efficacy criteria" [16, p. 430]. The authors conclude that e-learning effectiveness improves as a result of automatic and intelligent content management, instantaneous customised feedback and self-evaluation management. The inferences drawn from their work also state that tailored tasks and adapted learning methods extend the learners' capabilities academically, enhance their thinking processes and amplify the educational experience.

Aeiad and Meziane [17] present their work about an e-learning platform that makes use of free online resources to customise and tailor the experience. The system that was developed and tested retrieved information and content from online websites and free content providers, while it presented the learner with purposely planned and designed content that takes into consideration their background and requirements. The authors claim that their "approach, functionality and architecture are improvements on existing e-learning systems" [17, p. 298]. They also propose to include and take into consideration the learners' characteristics together with their academic outcome in the next generation of the same system.

Finally, a Malaysian-based learning management system [18] called iClass resulted from a project that aimed in establishing a personalised framework that could adapt to the different needs of the learners. The collaborative nature of this web-based system allows the adaptation of content and graphical interface to ensure the learner takes advantage of the academic environment. Similar to other LMSs, iClass has the flexibility of allowing additional plugins developed and made available by third-party services that further reinforce the personalisation element. The system has been adopted and

applied also to secondary schools by Oxford University [19], as it provides students with an enhanced learning experience in class. The University of Hong Kong are very proud of their next generation e-learning system as "its instant performance analysis helps teachers understand students' learning progress, which greatly enhance effectiveness in teaching and learning" [19, p. 3].

The e-learning systems presented above even though at a higher functional and philosophical level than standard static e-learning systems, still employed the basic face-to-face comparison to determine any added-value or an enhanced effectiveness. For this specific reason, a three-way methodology is being presented as an adaptation from the original comparison technique and which conveniently suits the required measurement techniques to evaluate an above-standard e-learning system.

III. Three-Way Comparison

When the effectiveness of an e-learning system is to be measured, academic researchers traditionally simply compare it to an equivalent face-to-face delivery and employing a control class within an empirical study scenario. In the previous section we have argued that next-generation e-learning systems operating within a personalised environment require more than just a simple comparison to direct human tuition. As a matter of fact, such dynamic e-learning systems with numerous variables require that they are investigated in contrast to both face-to-face instructions as well as to the standard static e-learning delivery. The proposed methodology is administered in a very specific and scheduled arrangement, together with a well thought-out logistical plan to ethically ensure that no participant taking part in the empirical study is disadvantaged in any way.

A. Underlying Philosophy

In an effort to ensure the validity and reliability of the comparison study, best practices from the different studies were adopted as proposed by Neuhauser [14]. In her study to investigate the effectiveness of online learning in comparison to face-to-face instruction, sections of the academic content were delivered to the same group of informants to draw conclusions from the relevant data collected. In this case the three-way comparison engages the same course content throughout the study and delivered to the participants at the same time through the three different kinds of delivery, namely, Face-to-Face (F2F), the standard e-learning mode (SEL), and finally via a dynamic personalized e-learning environment (DEL). Similar to the Neuhauser study, the data collected to test the effectiveness of all three modes of delivery is consistently the same in its approach. Mixed data collection can be employed before, during, and after the modalities are being employed, but how is it possible to deliver the same material content to the participants using three different modalities all at the same time?

B. Delivery and Logistics

The group of participants is randomly divided into approximately three equal groups, and the material content to be delivered is also divided into approximately three equal parts. The delivery sessions are also carefully divided into exactly three section; be it three days, three weeks, three months, as long as they are three equal time periods.

TABLE I
Logistics of Empirical Study

Period	Grp A	Grp B	Grp C	Material
P1	F2F	SEL	DEL	M1
P2	SEL	DEL	F2F	M2
P3	DEL	F2F	SEL	M3

During the first period, P1, as shown in the table above, the three groups will simultaneously attend three different modalities respectively covering the first set of materials, M1. During the second and third periods (P2 and P3), the groups will alternate through the other two modalities they have not been exposed to as they cover materials M2 and M3. At the end of the empirical study, every participants group will have been through the entire academic material and exposed to all three modalities.

C. Ethical Soundness

As each group of participants is exposed to all the academic material and all the modalities alike, no particular group is advantaged or disadvantaged in any way. Ethically this constitutes an ideal scenario and imperative to ensure that the participants are treated equally and fairly. All academic research projects require ethical clearance and thereby this methodology not only ensures that such a clearance is obtained, but also gives a sense of reassurance that strong academic rigor is followed without any loss of academic and empirical detail due to the ethical constraints.

IV. Empirical Study

The three-way comparison was employed in a real empirical study at the University of Malta where an intelligent personal learning environment was to be tested and assessed in ways, as to establish whether any improvements on the medium effectiveness was achieved as two variables, personalization and user interests, were held under investigation. One hundred and twenty informants were enrolled from the higher education sector and randomly divided into three groups of 30 each. A mixed set of data collection methods were accurately and meticulously planned and developed to ensure to collect the required data to ultimately assess the environment's effectiveness. The proposed methods for this empirical research study were the following five data collection (DC) instruments:

DC1 – A pre-test using a survey tool for data collection was designed to extract information about the informants prior to their exposure to the proposed system. The survey tool itself was adopted and adapted from the validated Technology Acceptance Model (TAM) instrument [20], whereby the attitudes and level of technology acceptance by the participants was captured. The reason this model was chosen is due to its popularity and the frequency of its use in such

situations [21]-[23]. The technology acceptance model is intention-based and developed specifically for justifying user acceptance of computer technology. Masrom [24] makes extensive use of the TAM within an e-learning environment to investigate the effects of user acceptance and attitudes on the use of e-learning within an application. The pre-test survey covered the basic personal information, qualifications and work related details, the sections included personal use of technology, and the participants' views about e-learning courses, e-learning design and online assessment. The data collected in this pre-test was employed as a baseline to create a realistic contrast with the post-test together with additional data that were collected.

DC2 – An intermediate participant opinion tool using dichotomous questions to record quick participant opinions at different intervals during the progress of the delivery mode under investigation. Simple questions were purposely designed to minimise the interruption of the flow of instruction while gathering minute, yet frequent input from the participant. Such a methodology is similar to the momentary time sampling methodology [25] from which it was adapted. The data collected was meant to record the participants' evolving sentiments and opinions that could not be captured with the other data collection methods adopted.

DC3 – An intermediate assessment using a questionnaire as an evaluation tool was made up of a series of assessments following the completion of each part of the course was employed to collect participants' scores on their understanding of the presented content. This is in no way meant to measure the ability or the academic achievement of the participants, but merely to complement and support the results from the other methods employed. Similar studies [14], [26], [27] have employed this instrument to assist them in measuring learning effectiveness. In this study the participants' scores resulting from the various assessments were used to shed additional light on the finding and eventual outcome. It was entirely based on the content and was distributed in a printed format in the case of the face-to-face mode of delivery, while in the other two modalities it was made available as a soft copy at the end of the static and dynamic sessions.

DC4 – A final experience evaluation using a number of focus group sessions was planned. The reason behind these focus group sessions was to understand further the participants' perceptions and attitudes towards the proposed dynamic learning environment. A semi-structured focus group tool was used with randomly selected participants in three (3) groups of between eight to 10 participants. The structure and content of these sessions have been adopted and adapted from Wilkinson [28] and were meant to mainly discuss the following questions:

- Q1: Which modality was most effective and functional?
- Q2: Did the dynamic environment add value to the experience?
- Q3: Which mode or combination of modes would you prefer/recommend?

DC5 – A post-test using a survey tool for data collection was designed as a final quantitative instrument in tandem with the DC1 pre-test survey to extract information from the participants prior to their experience and exposure to the intelligent personal learning environment. The TAM model, mentioned in DC1, was also adapted and employed as an instrument to design and develop this data collection survey tool. The post-test survey contained five sections which covered the basic participant information, the effectiveness of the proposed medium in comparison to the other two modes, any changes related to e-learning, its design and online assessment.

TABLE II
DATA COLLECTION SCHEDULE

DC1 Pre-test				
	Grp A	Grp B	Grp C	
DC2	F2F	SEL	DEL	DC2
		DC3		
DC2	SEL	DEL	F2F	DC2
		DC3		
DC2	DEL	F2F	SEL	DC2
		DC3		
DC4 Focus Groups				
DC5 Post-test				

The table above depicts how the data collection instruments fitted well with the three-way comparison described in the previous section. All the participants were exposed to the proposed e-learning modality and successfully contributed to the data collected. The absence of a control group also helped not to reduce the number of the sample population and thereby improve the quality of the final evaluations. All the instruments where employed consistently across the groups independent of the modality. All the data collected were fruitfully processed and analysed to enable an informed interpretation and presentation of the results. The data analysis was then performed on the collected data confident in the fact that the methodology employed optimised the participation of the whole corpus of enrolled participants, and that the instruments used across all three the modalities purposely overlapped to strengthen the validity of the final results extracted. A number of statistical tests were employed to analyse the data. The study followed best practices to ensure a fitting analysis for the purpose of this research was performed [29]. Similar studies in the effectiveness of e-learning [10], [14], [27], [30] have also made use of a mixture of data analysis instruments that have been widely employed in different areas of education research [8], [11], [26], [31]. The analysis of the available quantitative data was kept as simple as possible, while statistical tools and graphical representations facilitated the presentation of the results as well as the interpretation of the analysis. The qualitative data resulting from some of the data collection instruments used, such as the focus groups and participants' comments, were thematically analysed in a systematic way to ensure that the same conclusions were drawn should the empirical study be repeated and the data collected recreated.

Thematic content analysis is a widely employed and accepted tool to analyse qualitative data [32]. Such an

instrument is ideal in the absence of numerical or quantitative data as the processing of textual data collected can be analysed and investigated to identify and report any patterns which are referred to as themes. According to Braun and Clarke [33, p. 82], a "theme captures something important about the data in relation to the research question and represents some level of patterned response or meaning within the data set". Additionally, Thomas and Harden [34] conclude that, in an effort to understand how to optimally take advantage of qualitative research in order to inform policy and practice, thematic analysis takes advantage of years of methodological qualitative research development. The data analysis instruments that were employed in this study were the following:

- Standard descriptive statistics including percentages, mean and standard deviations about the data collected from the pre-test and post-test (DC1 and DC5) to highlight any significant and relevant findings. These instruments were also employed to underline and report any notable differences between the mode of delivery under investigation and the other two modes. The data from DC4 and DC5 were both employed to shed light on this aspect of the research;
- Pearson Chi-Squared tests and Friedman tests to assess the validity of the null hypothesis and the fitting between the two variables, namely 'personalisation' and 'interests', as observed and as expected theoretically. Data from DC2 & DC3 was employed to extract such results in preparation for critical evaluation and discussion;
- Thematic Content Analysis using data collected from DC4 was performed to further draw additional results to supplement the previous ones. Full transcripts from the focus groups were done and employed within a purposely designed qualitative data analysis tool.

V. Results

Due to the extensive data collected through the use of the three-way comparison methodology, the resulting outcomes are academically robust and theoretically well founded. Much granular data collection allows the analysis of specific variables, like user interests, especially when the researcher is evaluating finer details between the static and dynamic e-learning modalities.

The results that emerged from this empirical study presented sets of data directly related to such variables like personalisation, and the statistical analysis show a Chi-square value of 39.441 with a degree of freedom (df) of 1 and a p-value of less than 0.01. In this case, the result clearly shows that personalisation and the learning process are definitely dependent on one another. In a second instance, it was possible to perform an analytical analysis using the Chi-Squared test between the dynamic e-learning platform and the user interests' variable giving a result of 38.463 with a degree of freedom of 1 and a p-value of less than 0.01. A cut-off standard significance level for the p-value is 0.05 and anything below this 5% threshold is statistically considered a very low probability. This means that the targeted variable and e-learning effectiveness are dependent on one another. This outcome was also reflected in the focus group results and the thematic analysis outcome where the term 'interests' featured as the second most frequently referred to word confirming the strong integration and overlap between the qualitative and quantitative data analysis throughout the three-way comparison.

Finally, it was also possible to perform a pairwise comparison between the three variables, namely personalization, user interests, and the dynamic platform, was done to test the extent of how much the distributions of the different pairs are close to each other. To do so, a non-parametric statistical analysis was done on K-related samples. The output shown in Fig. 2 and what emerges from this pairwise comparison is that the mean DEL score and the Interest score are significantly different from the mean Personalisation score. This result is even more significant since the p-values are less than the 0.05 level of significance; however, the mean DEL score is comparable to the Interest score as the p-value exceeds the 0.05 criterion.

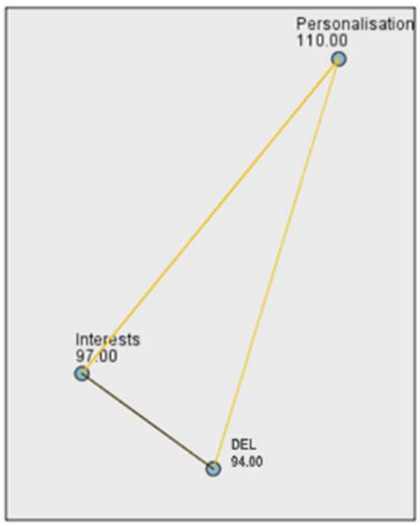

Fig. 2 Pairwise Comparison

VI. Conclusions

This paper has introduced the use of a three-way comparison methodology to measure e-learning effectiveness, especially when details and finer analysis of specific variables are required. It was argued that it is not only necessary to meticulously design a research project, adopt the proper methodologies grounded in respective learning theories, but it is also essentially crucial to plan, design and execute an adequate and fitting testing methodology to tightly match and complement the empirical study. The three-way methodology has been documented in detail together with details of how logistical and ethical issues are rigorously handled. To further demonstrate the benefits of this comparison methodology a real empirical study within a higher education institution has shown how it can serve as an excellent channel to collect the necessary data to critically evaluate what is being proposed

through a number of quantitative and qualitative data collection instruments. The results show that the entire sample population of participants generated over a period of three weeks were possible due to the rich amount of data collected. All the participants equally experienced exposure to a standard e-learning platform, traditional face-to-face, and a proposed dynamic personalised e-learning environment which were duly analysed. Standard and complex statistical analysis together with thematic content analysis was performed to extract meaningful information that shed light on the outcome of the empirical study and the entire research project.

Previous e-learning effectiveness studies consistently compared their proposed e-learning system to the traditional face-to-face including those studies that proposed next generation e-learning environments. This paper has shown that the three-way comparison is specifically designed to evaluate whether a proposed system improved effectiveness from a standard e-learning environment rather than simply from the face-to-face modality. This adds a new dimension to the field of e-learning effectiveness evaluation as, above and beyond the methodologies employed by the reported studies, it additionally enables the comparison of three modalities while proposing a methodological shift towards how to best design a test plan that gave rise to this discussion. The outcomes from this discussion are not intended to simplify or curtail the complexities that this research has delved into. They have barely scratched the surface of an intricate and multifaceted concept that at face value helps and assists in the correct evaluation of the e-learning effectiveness process rather than hindering or has no effect whatsoever.

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