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EFFECTIVENESS OF INSTRUCTIONAL MODELS IN TEACHING AND LEARNING TECHNICAL SKILLS: A SYSTEMATIC REVIEW AND META-ANALYSIS

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ABSTRACT:

Variety of instructional models for teaching and learning skills are in use today without any study jointly investigating their effectiveness. This study critically reviewed the effectiveness of instructional models in teaching and learning technical skills in TVET at technical colleges. Articles were searched electronically, and only 16 randomly controlled trial articles based on certain search criteria were included in the review out of which ten studies were used in the meta-analysis. Data were analyzed using Review Manager 5.3 and heterogeneity estimated with Cochrane's χ^2 test and I^2. The meta-analysis indicates a significant pooled effect size of (SMD =1.52, at 95%, CI = 3.34 – 8.67, p < .00001) from the test scores in favour of the experimental group and a high sensitivity analysis reliability. The result of the sub-items achievement test scores of the included studies shows a significantly positive difference in all category tested. This paper implies that using instructional models in teaching and learning improves students' technical skills in TVET courses. Based on the study limitations, we recommended that a review study on the interaction effect of instructional models and lesson duration, teachers' qualification on students' achievement test scores be conducted.

INTRODUCTION

The instructional model is defined as "a systematic and reflective process of arrangement of resources and procedures for teaching and learning" (Dick, Carey, & Carey, 1996). Its development provides guidelines for proposing a new teaching system (Shafique & Mahmood, 2010). Teaching technology-related trades requires teachers to properly plan or follow a laydown guide to carryout instructional activities using available facilities to realize stipulated objectives. (Uwaifo & Uwaifo, 2009) maintained that enshrining teaching guide in course outlines helps to provide uniformity of content for a subject area. Besides, a wellplanned learning activity could be potent to stimulate the development of new educational innovations in teaching strategies and tactics, assist teachers to develop their capacities to create a conducive environment for teaching (Odigiri & Ede, 2010; Stav, 2008,) and it helps curriculum planners to plan learning activities and content material which provide a variety of educational experiences to learners. Studies have shown that learning by doing in vocational institutions facilitated through a successful experimental learning practice that is guided by a procedure of instruction have a direct association with students' psychomotor skill development (Atchoarena & Delluc, 2002). Additionally, the exploit recorded by Singapore's instructional regime was attained because teachers adopted the application of scholarly frameworks that shows the transmission of factual and procedural knowledge in teaching (Hogan, 2014).

Teaching frameworks are understood to be successive, in that one level is mastered before the next level can be reached (Huitt, 2009). This arrangement of educational objectives is fundamental to the field of TVET because according to (Ogwo & Oranu, 2006), practical skills are organized and coordinated forms of physically observed activities exhibited in the process of carrying out practical tasks. However, lack of procedural, practical teaching framework for teaching technical subjects in colleges explained why (Uwaifo & Uwaifo, 2009) noted that the mere listing of topics to cover without adequately outlining the knowledge (theoretical) and skills (practical) components together with the procedural learning activities or tasks to accomplish could make teachers' approach to the course content coverage and areas of emphasis to varying. (Olaitan & Ali, 1997) observed that the teaching guide operated by most TVET teachers for skill teaching are adequate in the theoretical component but inadequate in practical skill component and as (Aworanti, 2012) argued, the lack of uniformity in teaching skill might be one of the factors contributing for graduates lack in employable skills and youth unemployment in Nigeria. We understand that they are a few instructional models in use today. Whether these models have been successful implementation and effectiveness has not been ascertained [Qureshi, 2016] . However, the objective of this study is to find out if these instructional models are suitable for use in teaching and learning technical skills in a vocational context.

METHOD AND MEASURES

Literature search process and inclusion criteria

The searches process were conducted in databases of Web of Science, Google Scholar, Research gate, Academic Search Premier, Econ Lit, ProQuest, Scopus, Universiti Teknologi Malaysia, UTM Library and Chinese National Knowledge Infrastructure (CNKI) involving both published and unpublished articles through electronic search. We used various keywords like "Instructional models* skills", "Instructional design* practical skills", "Instructional model* technical skills", Instructional model* teaching", "Instructional model* learning", Instructional model* psychomotor skills to aid our search. This was to the identification of relevant literature, and only articles that met the interest of the study based on the authors' inclusion criteria were used in the review. Before the inclusion of articles in this study, a methodological quality examination was carried out by two reviewers independently to assess the validity of the selected studies based on the general sources of bias to satisfy the criterion for inclusion as described in Cochrane handbook for a systematic review of interventions (J. P. Higgins & Altman, 2008). This follows the scientific sequence of randomization, allocation concealment, blinding, incomplete report, selective data report and others as reported in work. All disagreement that arose between the reviewers were handled amicably before reaching a consensus. See the PRISMA method of reporting items for systematic reviews or meta-analyses in Fig. 1.

Statistical methods

Data were analyzed using Revman 5.3 software. We calculated the standard mean difference (SMD) and weight mean difference (WMD) for effect sizes based on sample size and 95% confidence intervals (CIs) for each study and the pooled studies using variance analysis. We adopted the two models of meta-analysis (fixed and random effect models) and the fixed-effects model was employed if heterogeneity was detected after the pooling data generated in the study otherwise, the random-effects model was employed. We calculated heterogeneity using Cochran's ($\chi 2$) test p-value and the percentage of variation attributed to heterogeneity (I2). Heterogeneity with $p < 0.10$ and I2 > 50% were considered significant (J. P. Higgins & Altman, 2008; J. P. Higgins & Thompson, 2002) whereas, I2 -values of 25% to 50% were considered low, 50%–75% moderate and > 75% were considered high. Where heterogeneity existed, we performed a sensitivity analysis to ascertain if it significantly alters the results of the meta-analysis. We carried out sensitivity analysis by excluding each one of these studies and subsequently recalculating the pooled estimates for the remaining studies. This is to ensure that it did not significantly alter the results (Saltelli et al., 2008) and publication bias assessment by funnel plot from Begg's rank correlation test, and Egger's linear regression test using STATA 13.0 (Egger, Smith, Schneider, & Minder, 1997).

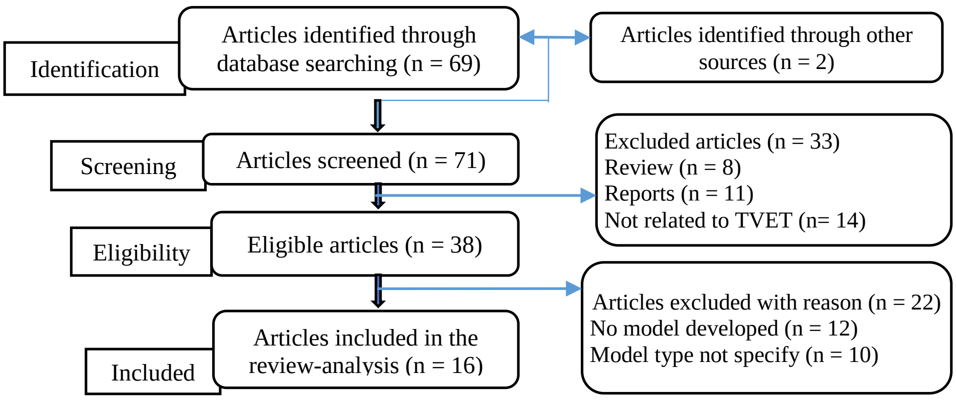


Fig. 1: Schematic diagram of the article selection analysis. Derived from the PRISMA method of reporting items for systematic reviews or meta-analyses (Moher et al., 2009)

RESULTS

Characteristics of Included Studies

The final review involved sixteen published studies out of which 7 were teaching models and 9 learning models. 4 of the included studies were empirical while, the remaining 12 were qualitative articles. In terms of steps, 3 studies had four steps design, 3 had five steps design, 4 had six steps design, 3 had seven steps design, 1 had eight steps design, 1 had nine steps design and 1is made up of eleven steps. In all, the search identified 71 articles and 54 were excluded after a thorough screening process and for reasons as stated in Fig. 1 above. However, all the articles use in the study tend to develop a procedural system to address the problem of teaching and learning technical skills in TVET and all met the conditions for inclusion in this review analysis.

Quality of the Methods

We test for selection, detection, performance and exclusion. These are biases known to have one influence or the other in the results of a review study. These biases have been demonstrated in methodological criteria and empirically tested (J. Higgins & Wells, 2011). No one study met all criteria in the instructional model criteria assessment. Randomization minimizes the systematic differences between baseline characteristics in treatment and control groups, detection bias is the systematic differences on how outcomes are assessed between the treatment and control groups, blinding is protected against performance bias while, the performance bias refers to the systematic difference in the treatment and control groups with exposure other than the intervention (J. Higgins & Wells, 2011; Vesterinen et al., 2010). Most of the study shows weak risk of bais such as (Albuainain, Abdulaziz, Nouby, & Alajab, 2012; Allery, 2009; Ayonmike, Chijioke, & Okeke, 2014; Chiu, Lai, Fan, & Cheng, 2015; Deba, 2015; Hidayat, Herawati, Syahmaidi, Hidayati, & Ardi, 2018; Ismail, Samsudi, Widjanarko, Joyce, & Stearns, 2018; Vong & Kaewurai, 2017), some were at moderate risk of bais (Hidayat et al., 2018; Idris, Rajuddin, & Rufai, 2014; Nicholls, Sweet, Muller, & Hyett, 2016). All the articles reported the outcome as we assessed if the study was free from selection checking bais. In all, we found three common risks of bias across selection, performance and detection.

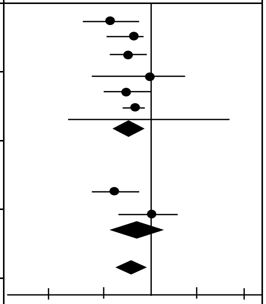
Interventions Effect

The effect of instructional models was examined based on procedural steps as common to all the design reviewed and students test scores. Time of the interventions varies among the studies due to the procedural steps. The intervention uses two studies with 8steps and above (Hidayat, 2015; Nicholls et al., 2016), which lasted for 1hr:45minutes each, five studies having above 5 to 7steps (Albuainain et al., 2012; Ayonmike et al., 2014; Chiu et al., 2015; Hidayat et al., 2018; Vong & Kaewurai, 2017) for 1hr:30miniutes each and three studies having below 5steps (Allery, 2009; Idris et al., 2014; Ismail et al., 2018) for up to 1hour each. In all, ten articles were used involving 200 students in the experimental group and 250 in the control group. The interventions were done in a workshop during metalwork practical class. To avoid experimental bias, technology teachers used to give the intervention were trained and this helps in familiarizing them with the models to be able to differ the approach to the experimental teachers from that of the control in teaching both the experimental and control group. In addition, we avoided the test effect, maturation; novelty effect and mortality were also controlled in the study. Eight studies revealed test differences in students' technical skills between the experimental and control group but two studies showed no statistical mean differences in test scores between the two groups. Table 1, present the meta-analysis for the study.

Table 1, present the results of our meta-analysis in which we find a significant difference in test scores in favour of the experimental group when compared to the control group. With the high heterogeneity of (I2 = 94%, $p < .00011$), we used the random effect model. We found out that the pooled effect size of (SMD =1.52, at 95%, CI = 3.34 – 8.67, $p < .00001$) was significantly different from the test scores favouring the experimental group. However, we had (SMD = 1.13, at 95%, CI = 2.56 – 5.88, $p < .00001$) when we applied the fixe effect model to pool the data generated. This result also showed a significantly positive large pooled effect in favour of the experimental group.

TABLE 1: META-ANALYSIS SCORES

Study or subgroup	Experimental	Control	Weight	Std. Mean Difference	Mean Difference

	Mean	SD	Total	Mean	SD	Total		IV, Random, 95% CI	IV, Random, 95% CI
Hidayat, et'al 2015	31.13	2.10	20	28.09	2.02	23	10.3%	3.04[2.88, 1.54]	
Nicholls, et'al, 2016	48.39	3.03	15	47.70	2.11	28	6.0%	0.69[7.42, 13. 48]	
Vong, et'al 2017	37.54	2.44	22	32.06	3.88	25	10.0%	6.84[3.86, 22. 01]	
Albuainain, 2015	28.87	2.56	20	28.22	2.47	26	15.2%	0.65[5.33, 11. 02]	
Hidayat , et'al, 2018	19.85	3.23	23	21.01	3.01	25	10.3%	-1.16[3.31, 8.08]	
Chiu, et'al, 2015	17.98	2.76	15	19.77	2.92	25	5.6%	-1.79[2.54, 4.76]	
Ayonmike, 2014	20.31	2.78	20	20.45	2.67	30	13.4%	-0.14[0.12, 3.66]	
Allery, 2009	24.90	3.77	25	22.11	3.85	20	6.2%	2.79[5.02, 9.88]	
Idris, et'al, 2014	16.85	2.37	20	15.02	2.63	25	16.0%	1.83[2.66, 7.56]	
Ismail, et'al, 2018	18.22	2.12	20	15.76	3.02	23	7.4%	2.46[0.83, 4.66]	
Total (95% CI)			**200**			**250**	**100.0 %**	**1.52 [3.34, 8.67]**	

Heterogeneity: $Tau^2 = 0.08$; $Chi^2 = 11.03$, df = 9, ($p < .00011$), $I^2 = 94\%$

-2 -1 0 1 2

Test for overall effect: Z = 3.22 ($p < .00011$) Favours {Experimental} Favours {Control}

Table. 1: Meta-analysis and forest plot summary of the test scores after using the instructional models.

Table 2: Pooled Effect Size of the Scales Measured

Skills Item	Sample size Exp/ Control	Analysis Mode	WMD 95% CI	p value effect	Heterogeneity		
					χ^2	df	p
I^2							
Weld metal surfaces using 88% oxyacetylene flame	200/250	Random	1.87[1.03, 3.89]	<.00001	4.01	9	.33
Operate lathe machine correctly to part-off work pieces 63%	200/250	Fixed	2.01[0.78,2.90]	<.00001	2.76	9	.19
Produce simple engineering components by forging 68%	200/250	Fixed	1.26[1.34,4.22]	<.00001	5.88	9	.42
Transfer measurements to metal surfaces using dividers 74%	200/250	Random	1.94[2.12,4.83]	<.00001	4.73	9	.28

Produce simple metal components and tools on the bench 86%	200/250	Fixed	2.17[1.75,3.94]	<.00001	6.11	9	.23

In Table 2, we examined the sub-items achievement test scores of the included studies to determine the pooled effect sizes for each category. The result reveals significantly positive difference in all category tested as (WMD 1.87, 95% CI 1.03 - 3.89 at p < 0.0001), (WMD 2.01, 95%, CI 0.78 - 2.90 at p < 0.0001), (WMD 1.26, 95% CI 1.34 - 4.22 at p < 0.00001), (WMD 1.94, 95%, CI 2.12- 4.83 at p < 0.00001) and (WMD 1.17, 95%, CI = 1.75 -3.94 at p < 0.00001) in favour of the experimental (treatment) group as against the control for weld metal surfaces using oxyacetylene flame, operate lathe machine correctly to part-off workpiece, produce simple engineering components by forging, transfer measurements to metal surfaces using dividers and produce simple metal components and tools on the bench respectively.

Sensitivity Analysis

We applied the fixed-effect statistical model, which observes attributes as though they were being treated as non-random against the random-effects model and handles exploratory variables as arising from random causes gives a high heterogeneity. Due to the heterogeneity in studies reporting test scores, we conducted a sensitivity test on individual studies by separating nine articles from seven studies (Albuainain et al., 2012; Allery, 2009; Ayonmike et al., 2014; Chiu et al., 2015; Hidayat, 2015; Ismail et al., 2018; Nicholls et al., 2016) to vary the reliability of the result. The pooled effect size of recorded SMD = 3.98 at 95%, CI = 1.33 – 3.28 at p = .00001 reveals that instructional models have a significant effect on students' practical skills acquisition in TVET.

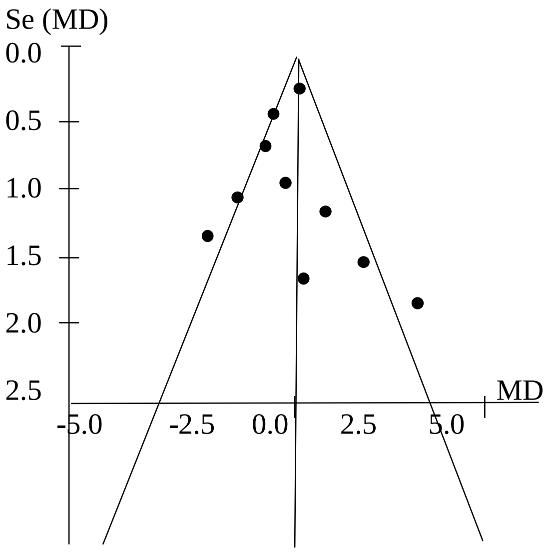


Figure 2: Publication bias of funnel plot analysis of test scores
Se = Standard Error, MD = Mean Difference

We used a symmetrical funnel plot shape as shown in Fig. 2 to report the analysis of the test scores of the ten included articles in the meta-analysis to ascertain whether there existed any publication bias. The result (SMD = 7.39, 95%, CI = 4.87 – 6.39 at p < .00001) shows that there was no negative effect of treatment on students' achievement scores. This implies that the pooled effect is in favour of the experimental group using Egger's bias indicator statistical scale {t = 1.74, p = 0.157}. However, the result did not change the effect of the primary analysis when we subjected it to the Begg-Mazumdar bias indicator test {Z = 1.32, p = 0.260}.

DISCUSSION

The contents of 10 out of 16 articles were investigated in our meta-analysis to ascertain the effectiveness of these models using test scores in practical examinations. It was observed that utilizing instructional models as a guide in practical lessons had a significantly positive effect on technical students' achievement in practical courses. The result obtained was expected because learners taught with systematic approaches (procedure) were actively engaged in the learning process since teachers allowed manipulation of materials. This might have stuck the lesson in them and stimulated their inquisitiveness to learn faster and remember easily, which agreed with the earlier studies of (Akano & Akpokiere, 2006; Dochy, Segers, Van den Bossche, & Gijbels, 2003). A challenge most teacher face is the ability to organize practical lessons in a manner that will enable students to approach problem-solving and critical thinking exercises easily. This is why instructional model seeks to provide opportunities that guide learners through the process of organizing information that will foster complex learning skills (Lim & Morris, 2009; Van Merriënboer, 2007). We observed that when teaching technical skills teachers need to be aware that certain principles inform what constitute the pedagogy of procedural skills. For instance, in learning skills, students must i) be made to know the importance ii) see the skill iii) discuss the skill iv) perform the skill and v) provide feedback (Allery, 2009; Mayer, 2002) and this is where the factor of teaching experience plays a vital role. We allow teachers to follow the sequence in the models to teach students in different classes (ST1, 2 & 3). The challenges encountered were due to disparity in teachers' qualifications and the steps involved in each of the designed model and activities to be performed. These indices might have caused variation in the achievement test scores recorded and by extension, variations between the two groups. Just as we observed these inconsistencies, the meta-analysis across all studies gave evidence that although both the experimental and control group manifested similar skills competency with reference to their test scores during the initial training, the instructional model group had higher test scores after the treatment. However, utilizing instructional models has the following advantages i) learners are being trained to carry out activities of observing, trying out, communicating and being able to produce products, which contain elements of technology ii) learners are facilitated to think creatively, analyze and be innovative.

CONCLUSION

This study present several implications. Prominent of them is the fact that we limited our inclusion criteria on articles published in English only. It is possible that some articles published in other languages will have missed. Our electronic search and consultation with the UTM Liberian suggest that the search was comprehensive although some items might have been omitted. In addition, the quantitative evidence of this review did not include the interaction effect of instructional models and lesson duration on students' achievement test scores. Second, the interactive effect of instructional models and teachers qualifications on students' achievement test scores. These are aspects relevant for further research studies. Despite these limitations, the study provides empirical research evidence that may be useful to TVET teachers to make them crave to employ scientific procedural teaching guides in teaching practical skills. Although we adopted some precautionary methods interpreting the meta-analysis owing to the risk of bias, this meta-analysis shows that instructional models contributed significantly positive variation in students' achievement test scores.

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CONFLICT OF INTEREST
There was no conflict of interest identified.

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