EVALUATING THE EFFECT OF LEARNING FLUID MECHANICS THROUGH THE CCAILM LEARNING APPROACH IN SOME SOUTH AFRICAN UNIVERSITIES

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ABSTRACT

The need to increase the number of quality engineering graduates, graduating from South African Universities, informed this study. Based on the findings from the baseline study, conducted prior to the present study, this research seeks to evaluate (using a static, non-equivalent, group design) the effect of Constructionist Computer-Aided Instructional Learning Model (CCAILM) approach, used in some South African Universities, for studying fluid mechanics in mechanical engineering classes. This new learning model is derived from constructionist learning theory, media-affects-learning hypothesis and multiple representation principle. The results of the data analysis indicate that CCAILM learning approach enhances the learning of fluid mechanics in mechanical engineering classes.

Keywords: engineering education, undergraduate, fluid mechanics, teaching approach, mechanical engineering

1. INTRODUCTION

Engineering education has been facing serious challenges in recent years (Li, McCoach, Swaminathan & Tang, 2008). On one hand, the problem seems to stem from the low student enrolment figures in engineering courses. Apparently, poor learner performance in mathematics, results in low enrolment in engineering studies, since mathematics undergirds such studies. In fact, the teaching/learning of mathematics in schools is problematic and the annual pass rate has been declining (Felder & Brent, 2005).

On the other hand, in the case of South Africa, the brain drain, the country has experienced over the years, is another factor that has contributed considerably to the skills' shortage problem occurring on a national scale. In fact, a considerable number of professionals, including engineers, have left South Africa. Whatever the reasons for this, the country desperately needs these professionals, particularly engineers, in order for the economy to expand and, in the process; raise the infrastructure to an acceptable standard (National Science Foundation - NSF, 2004; Li et al, 2008).

Joint Initiative for Priority Skills Acquisition (JIPSA) was launched on 27th March 2006 by South African government as an initiative to address the skill challenges facing the country (Apple, 2008). The organisation was saddled with the responsibility of supporting the Further Education & Training (FET) colleges and Higher Education institutions in their work to produce graduates who could meet the needs of employers in the public and private sectors. JIPSA realised that brain drain has brought about shortage of experienced engineering lecturers at higher institutions of learning and has impacted negatively on the teaching and learning of engineering modules at higher institutions of learning (Ibid).

A number of research studies have investigated the issues relating to skills' challenges in South Africa, particularly in the field of engineering. Brandon and Jennifer (2003) carried out research to determine, which factors influence learners to follow a career in engineering, with a view to increasing enrolment figures as well as the graduation rate at South African Universities. The duo suggests that focused interventions, concerning the factors, which influence learners to follow careers in engineering, could serve to encourage more learners to enter the engineering field. The findings of Brandon and Jennifer (2003) are similar to that of Jawitz and Case (1998), who investigated the reasons given by South African engineering students for studying engineering, with a view to attracting more learners into the engineering field.

However, the approach used in teaching is an important component. It influences students' performance at university level and determines which effective teaching approach is likely to improve students' performance (Ramsden, 1992; Trigwell, Prosser, Ramsden & Martin, 1999a; Trigwell, Prosser & Waterhouse, 1999b). Trigwell et al (1999a and 1999b) reported that students, who are taught through a student-centred teaching approach, adopt a deeper attitude to learning, compared to those, who are taught by a lecturer-centred teaching approach. Therefore, the researcher in the present study looked at the problem of skills' shortages in engineering fields in South Africa, from the perspective of how engineering modules are taught in South African Universities.

This study hopes to improve the learning of engineering modules in South Africa through a CCAILM learning approach and an in-house, tailor-made software, (ACIA), which was developed to address the kind of specific learning needs discovered in the baseline study (Faleye & Mogari, 2010) in terms of learning fluid mechanics in mechanical engineering classes.

2. CONCEPTUAL FRAMEWORK

Since the latter part of the twentieth century, numerous studies (for example, Ngo & Lai, 2001; Steif & Naples, 2003; Hall, Philpot & Hubing, 2006; Cleghorn & Dhariwal, 2010) have been undertaken to address the various challenges facing the learning taking place in engineering modules.

The teaching/learning of these modules is becoming increasingly more difficult owing to the following reasons:

- The growing number of students from varied cultural backgrounds;
- The necessity to move away from the abstract illustration of concepts; and
- The need for multidisciplinary teaching in order to minimise teaching duplication and cost (Dearn, Tsolakis, Magaritis & Walton, 2010).

Kyza, Erduran and Tiberghien (2009) as well as Barnes, Camburn, Holmstrong, and Han (2009) postulate that different kinds of learning styles require different instructional approaches and no single instructional method will be able to meet the learning needs of the large student numbers found in engineering classes nowadays. Indeed, many studies have presented various instructional approaches, which are deemed effective for facilitating learning in engineering classes, but none of these approaches is able to solve more than one of the problems manifesting in engineering classes. Hence, the quest for effective teaching strategies that facilitate learning in engineering classes remains on going.

The researcher in this study believes that the content of engineering modules should be taught in such a way that students would be able to connect theoretical concepts to engineering field practices. To achieve this, engineering students need to learn in a way whereby they gain a deep conceptual understanding (Taraban, Anderson, Definis, Brown, Weigold & Sharma, 2007). Nevertheless, fluid mechanics is currently studied through a traditional approach in South African Universities, (Gallagher, 2000; Faleye & Mogari, 2010).

However, one of the problems inherent in the traditional teaching/learning approach is that the lecturer devotes most of the effort to helping students acquire information, while only a small part of class time is utilized to help students make sense of the new information (Gallagher, 2000). The lecturer spends a great deal of time looking for information; while, in the lecture room, the students merely copy notes from the lecturer. Very little learning can be achieved in such a learning setting (McDowell, 1995). The students, who are able to pass examinations, using this learning approach probably, make it through memorisation. However, Reeder (2007) maintains that the ability to memorise facts, does not necessarily imply an understanding of content. Students lack the capacity to take the knowledge acquired and apply it appropriately to different settings, when they do not understand the concepts very well, (Brandt, 1993).

Accordingly, social interaction in the classroom is a fundamental aspect of cognitive activities (Borko & Putnam, 1998; Vygotsky, 1978). The lecturer's role is to support learners in making or discovering new ideas. Students need to learn for themselves, rather than shape their ideas based on some other authorities. Hence, learning should be learner-directed, not lecturer-directed, more especially in engineering modules, in which students are expected, to acquire technical knowledge. Constructionist learning theory postulates that learning is an active process; in which learners construct mental models and theories of the world in which they live. It holds that students learn best when they are in the active roles of designers and constructors of learning (Papert, 1991). Engineering students will develop deeper conceptual understanding when they are active in making objects in the real world tangible to complement mental knowledge construction (Ibid).

On the other hand, studies (for example, Ngo & Lai, 2001; Steif & Naples, 2003; Hall, Philpot & Hubing, 2006; Cleghorn & Dhariwal, 2010) have shown that the use of technology to aid learning has the potential to improve student performance. Furthermore, Mayer and Moreno (2002) note that a computer-based multimedia learning environment has the ability to improve student understanding. The researcher in this study notes that education researchers (Mayer, 2001; Moreno, 2004) have presented many learning theories on how technology can be utilized to guide the use of technology in the classroom, in order to enhance learning. Examples of these learning theories are the media affects learning hypothesis (Clark, 1999), which states that advanced instructional technologies promote deeper learning, and the multiple representation principle (Mayer & Moreno, 1998), which states that it is better to present an explanation through words and pictures, rather than just words.

In view of the constructionist learning approach, the media-affects-learning hypothesis and the multiple representation principle, the researcher in this study formulated and proposed a learning model called the 'Constructionist Computer-Animated Instructional Learning Model' (CCAILM) for the learning of fluid mechanics in mechanical engineering classes. Therefore, the present study evaluates the effect of learning fluid mechanics by CCAILM learning approach in mechanical engineering classes at four South African Universities.

3. PURPOSE OF THE STUDY

As noted, efforts are needed to promote engineering studies and to increase the qualifying rate of quality engineering students. Interventions are needed to retain students' interest and improve their understanding of key concepts, especially where fluid mechanics is concerned. The following hypothesis guides this study:

H_0:There is no statistical significant difference in the study participants' examination mean achievement score after following CCAILM approach to learning fluid mechanics, as compared to the examination mean achievement score in the control groups.

H_1: There is statistical significant difference in the study participants' examination mean achievement score after following CCAILM approach to learning fluid mechanics, as compared to the examination mean achievement score in the control groups.

The result of the hypothesis testing will be further supported by the outcomes of the analysis of the classroom observation data.

4. METHODOLOGY

4.1. Research design

A static, non-equivalent, group design (Washington, Parnianpour & Fraser, 1999) was used to carry out the study. It was made up of both experimental and control groups:

- The experimental group consisted of nonrandomised mechanical engineering students, who used ACIA in their fluid mechanics' classes in a CCAILM learning environment.

- The control group comprised two consecutive groups of mechanical engineering students, who were taught the same fluid mechanics content by means of the traditional lecturing method, which entailed static two-dimensional PowerPoint presentations, and a chalk-and-talk instructional approach.

The students in both control and experimental groups were taught by the same lecturer at each of the participating universities.

The researcher considered a static group design appropriate for this study, mainly because the study was based at universities and not ordinary schools. Each university is autonomous and has its own practices, culture, rules and processes as well as distinctive curriculum and administrative arrangements. Clustering universities that offer the theoretical and practical application of fluid mechanics, as part of a mechanical engineering degree, could not be incorporated into the control and treatment groups. Instead, each of these universities was looked at individually; hence, the researcher's referral terminology to these as “cases”.

4.2. Sampling

Eight universities in South Africa have built the theoretical and practical applications of fluid mechanics into their curriculum for a BEng. Degree in Mechanical Engineering. Since the study was intended to investigate the use of ACIA to teach and learn the theoretical and practical applications of fluid mechanics in a CCAILM learning environment, the researcher requested all the universities to participate in the study. Only four universities were willing to participate and later the number dwindled to three, because the fourth university did not keep up with the schedule and was unable to perform research activities on the prescribed dates. However, the minimal data collected on the fourth institution, which dropped out, are also reported in the baseline study. Nevertheless, the quality of the study was not compromised, given the type of design used, combined with the fact that sufficient necessary data could still be gathered from the three remaining universities.

4.3. Data analysis and presentation of results

Data were analysed through ANCOVA data analysis techniques. A classroom test, administered for fluid mechanics only, before the thermodynamics teaching began in both control and intervention groups, were used as covariate. Every study participant was given a code, for the researcher to identify and follow the performance of each. The hypothesis tested is as stated in Section 3.0. Before ANCOVA was used to carry out the test on the null hypothesis, it was ensured that the data set satisfied the ANCOVA assumptions test of homogeneity of the regression parallelism, and the test of linearity and significance of relationship between the covariate and the dependant variables, in each of the Case Studies. The presentation of the results begins with Case Study 1 and ends with Case Study 3.

4.3.1. Case study 1

The intervention of Case Study 1, took place in the second semester. The control groups comprised the students, who were offered the fluid mechanics that was used to carry out this study in the 2007 and 2008 academic years through a traditional approach. The intervention group (2009 academic year) comprised students, who were offered the fluid mechanics that was used to carry out this study through CCAILM approach.

Table 1: Summary of the ANCOVA test

Source	Type I Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	38001.720[a]	5	7600.344	60.254	.000
Intercept	927516.191	1	927516.191	7353.120	.000
Test	19773.339	1	19773.339	156.758	.000
Treatment	4070.295	2	2035.148	16.134	.000
Treatment * Test	14158.086	2	7079.043	56.121	.000
Error	30904.088	245	126.139		
Total	996422.000	251			
Corrected Total	68905.809	250			

a. R Squared = .552 (Adjusted R Squared = .542)

Table 1, illustrates that the intervention, as the main effect, is significant on the study participants' achievement, in the fluid mechanics under review, at 0.05 level. This is because the observed $F_{observed}$ (2, 245) = 16.134 and p = 0.000, where $p < 0.05$. Hence, the null hypothesis was rejected. It thus points out that CCAILM enhances the study participants' achievement in the learning of the fluid mechanics.

Table 2: Post Hoc Analysis: Multiple Comparisons of Means of examinations in the control and intervention groups in case study 1

(I) Year	(J) Year	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
2007	2008	3.42257	2.40428	.467	2.3722	9.2174
	2009	8.73375*	2.45756	.001	14.6570	2.8105
2008	2007	3.42257	2.40428	.467	9.2174	2.3722
	2009	12.15631*	2.47104	.000	18.1120	6.2006
2009	2007	8.73375	2.45756	.001	2.8105	14.6570
	2008	12.15631	2.47104	.000	6.2006	18.1120

*. The mean difference is significant at the 0.05 level.

Table 2, displays a significant difference when comparing the achievements in the 2008 (control) with the 2009 (intervention) groups, and the 2007 (control) with the 2009 (intervention) groups. However, there is no significant difference between the achievements of the 2007 (control) and the 2008 (control) groups.

Figure 1 below compares the achievement means across the groups.

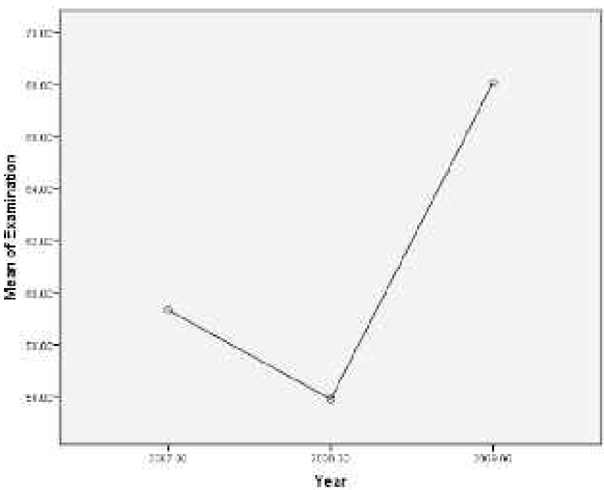

Figure 1: The mean plot of the examination performance

From figure 1, the researcher observes that the intervention group (2009) gained the highest achievement in fluid mechanics.

In view of the above results, the study participants who were exposed to a CCAILM approach performed better than those who were taught according to a traditional approach.

4.3.2. Case study 2

In this case study, the intervention was carried out in the first semester. The control groups comprised the students who were offered the fluid mechanics that was used to carry out this study in the 2008 and 2009 academic years in a traditional approach. The intervention group comprised students who were offered the fluid mechanics that was used to carry out this study in the 2010 academic year in CCAILM approach.

Table 3: Summary of the ANCOVA test

Source	Type I Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	28173.258[a]	5	5634.652	64.878	.000
Intercept	1047148.238	1	1047148.238	12056.951	.000
Test	15037.545	1	15037.545	173.144	.000
Treatment	6654.327	2	3327.164	38.309	.000
Treatment * Test	6481.386	2	3240.693	37.314	.000
Error	27531.504	317	86.850		
Total	1102853.000	323			
Corrected Total	55704.762	322			

a. R Squared = .506 (Adjusted R Squared = .498)

Table 3, reveals that the intervention, as the main effect is significant in terms of the study participants' achievement, in the fluid mechanics under review, at 0.05 level. This is because the observed $F_{observed}$ (2, 314) = 2.279 and p = 0.000, where p > 0.05. Hence, the null hypothesis is rejected. It, therefore, means that the CCAILM enhances study participants' achievement in the learning of the fluid mechanics under review.

Table 4: Post Hoc Analysis: Multiple Comparisons of Means of examinations in the control and intervention groups in case study *2*

(I) Year	(J) Year	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
2008	2009	.33916	1.43429	1.000	3.7909	3.1125
	2010	4.97957*	1.40052	.001	8.3500	1.6091
2009	2008	.33916	1.43429	1.000	3.1125	3.7909
	2010	4.64041*	1.43122	.004	8.0847	1.1961
2010	2008	4.97957	1.40052	.001	1.6091	8.3500
	2009	4.64041	1.43122	.004	1.1961	8.0847

*. The mean difference is significant at the 0.05 level.

Table 4, indicates there is a significant difference when comparing the achievements in the 2008 (control) with the 2010 (intervention), and the 2009 (control) with the 2010 (intervention) groups. However, there is no significant difference between the achievements of the 2008 (control) and 2009 (control) groups. Figure 2 below compares the achievement means across the groups.

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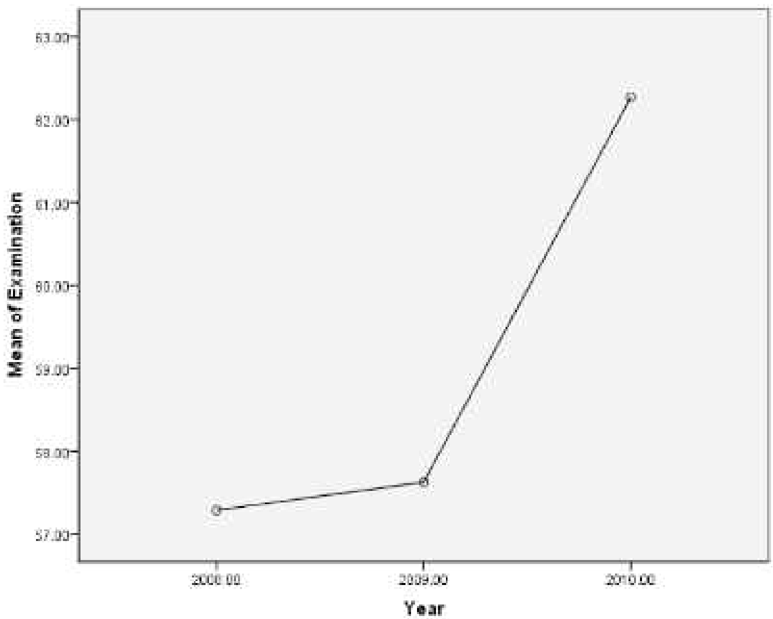

Figure 2: The mean plot of the examination performance

From Figure 2, the researcher observes that the intervention group (2010) gained the highest achievement in fluid mechanics.

In view of the above results, the study participants, who were exposed to CCAILM performed better than those, who were taught in the traditional approach.

4.3.3. Case Study 3

The intervention in Case Study 3 was undertaken in the first semester. The control groups comprised the students who were offered the fluid mechanics that was used to carry out this study in the 2008 and 2009 academic years in a traditional approach. The intervention group (2010 academic year) comprised the students, who were offered the fluid mechanics that was used to carry out this study through CCAILM approach.

Table 5: Summary of the ANCOVA test

Source	Type I Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	10122.065 [a]	5	2024.413	24.444	.000
Intercept	1111797.013	1	1111797.013	13424.545	.000
Test	5087.115	1	5087.115	61.425	.000
Treatment	377.475	2	188.738	2.279	.104
Treatment * Test	4657.474	2	2328.737	28.119	.000
Error	26004.923	314	82.818		
Total	1147924.000	320			
Corrected Total	1147924.000	319			

a. R Squared = .280 (Adjusted R Squared = .269)

Table 5, demonstrates that the intervention, as the main effect is not significant on the study participants' achievement, in the fluid mechanics under review, at 0.05 level of confidence. This is because the observed $F_{observed}$ (2, 314) = 28.119 and p = 0.104, where p > 0.05. Hence, the null hypothesis was accepted. Consequently, this means that the CCAILM enhances the study participants' achievement in the learning of the fluid mechanics.

Table 6: Post Hoc Analysis: Multiple Comparisons of Means of examinations in the control and intervention groups in case study 3

(I) Year	(J) Year	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
2008	2009	.00113	.09908	1.000	.2396	.2373
	2010	.08403	.09165	1.000	.1365	.3046
2009	2008	.00113	.09908	1.000	.2373	.2396
	2010	.08517	.09908	1.000	.1533	.3236
2010	2008	.08403	.09165	1.000	.3046	.1365
	2009	.08517	.09908	1.000	.3236	.1533

Table 6, expresses that there is no significant difference when comparing the achievements in the 2008 (control) with the 2010 (intervention), 2009 (control) with 2010 (intervention), and 2008 (control) with 2009 (control) groups. Figure 3 below compares the achievement means across the groups.

Figure 3 below compares the achievement means across the groups.

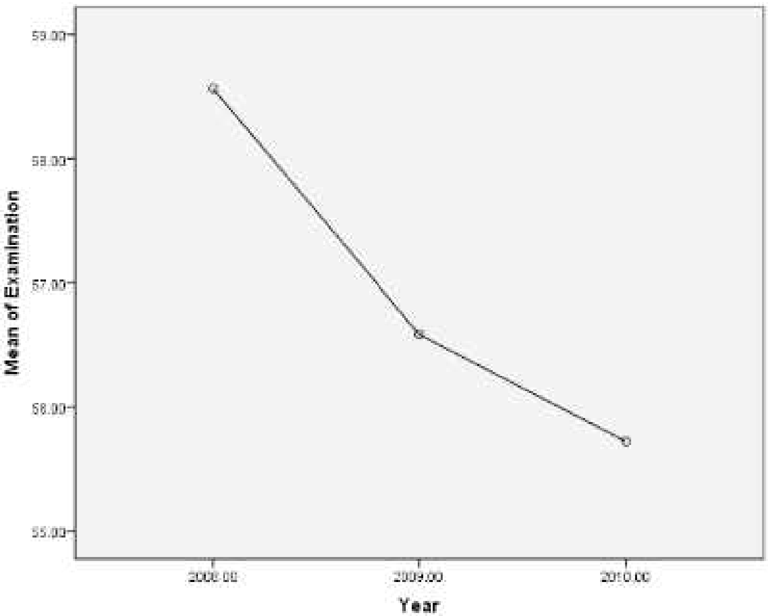

Figure 3: The mean plot of the examination performance

Figure 3, confirms that the intervention group did not perform quite as well, compared to the 2008 and 2009 groups, which were the control groups. The results from the classroom observation supported this result.

In summary, the above results suggest that the study participants, who were exposed to CCAILM, did not perform better than those, who were taught by means of the traditional approach.

5. DISCUSSION

One of the major results of this study was the findings that there were marked differences in achievements when comparing the marks obtained by the control groups and the marks obtained by the study participants in the intervention groups.

In Case Studies 1 and 2 the F-value of the test of the null hypothesis, which probed the achievement level, was statistically significant. The p-value in both cases was less than the 0.05 level as was given in Tables 1 and 3 respectively. This implies that there was a significant difference in the achievement level of the study participants, who learnt fluid mechanics with the aid ACIA in CCAILM approach, compared to the marks obtained by the students in the control group, who learnt the same fluid mechanics material according to a traditional approach and taught by the same lecturer. Thus, CCAILM has proved to enhance the study participants' achievement in the fluid mechanics that was used to carry out this study in Case Studies 1 and 2. Figure 1, in Case Study 1, depicts that the mean examination mark in the intervention group (2009) was about 69%, compared to about 59% and 56% mean mark for the 2007 and 2008 groups, respectively, which were the control groups. While in Case Study 2, Figure 2 illustrates that the mean examination mark in the intervention group (2010) was about 62.50%, compared to the control groups' mean mark of about 57.30% and 57.50% for the 2008 and 2009 groups respectively.

Furthermore, the results of the classroom observation data exposed that the study participants in Case Studies 1 and 2 were always very active in class, answering and asking questions, bringing materials to the lecture room to demonstrate fluid mechanics concepts physically, and generating new ideas. They proved that they understood fluid concepts and were very interested in them. These results conform to the principles of appetitive conditioning (Klein, 1974), that when a subject learns, responses increase and when unlearning occurs, the rate of responding falls. Skinner preferred this qualitative measure of learning to the quantitative results reported above because, according to Skinner, it provides an orderly and continuous record of behaviour change, free of arbitrary criteria (Skinner, 1950).

However, in Case Study 3, there was no statistical significant difference between the achievement level of the study participants, (Table 5 referred), who learnt fluid mechanics using the CCAILM approach and have used ACIA, with the control group, who learnt the same fluid mechanics material according to a traditional approach and who were taught by the same lecturer. In Case Study 3, learning fluid mechanics by means of CCAILM approach did not have any statistical significant effect on the study participants' achievement in fluid mechanics. In that, the mean examination mark for the intervention group (2010) was about 55.47%, compared to the 58.70% and 56.80% mean mark for the 2008 and 2009 groups respectively, as could be observed from Figure 3.

The results of the classroom observation data disclosed that the study participants in Case Study 3 were not very active in class; they asked more questions than they answered questions. The nature of the questions they sometimes asked proved that they did not understand fluid mechanics concepts; neither did they understand the illustrations on the ACIA CDs. Again, the researcher noted here that the study participants were not very active in class, which once again demonstrated the principles of appetitive conditioning. Their understanding could have been impaired because the ACIA CD was compiled in English. These sets of students were mainly Afrikaans speaking and the lectures were conducted mainly in Afrikaans, but interspersed with some English. However, the prescribed books for the fluid mechanics modules are written in English.

During one of the lectures, a group of students, seated close to the researcher, were recorded as saying that they were not enjoying the class, because they always wanted to copy and memorise the lecturer's note. The CCAILM approach, however, encourages students to construct or discover knowledge for themselves. Reeder (2007) notes that ability to memorise facts, does not necessarily imply understanding of content. Although the majority of these study participants passed very well in the class test, it is noted that they wrote the test while the intervention was still on. It might be that the study participants memorised the content in order to pass the classroom test and hence had a superficial understanding of the fluid mechanics concepts tested. In a classroom environment, where students understand the concepts taught, Reeder further remarks that, at some point, learners' grasp of concepts becomes deep or sophisticated enough to enable them to use their knowledge in a practical way. Perhaps, since the majority of the study participants in Case Study 3 could not gain a deeper understanding of the concepts, they were unable to solve new problems in the examination. The difference in the medium of instruction is indicted for the non-achievement results obtained in Case Study 3. These results, give further credibility to the outcomes of this study in that all the conditions in Case Studies 1, 2 and 3 were the same, except the medium of instruction.

In view of the above, it could be concluded that the CCAILM approach has enhanced the learning of the fluid mechanics module reviewed more than the traditional approach currently used for teaching fluid mechanics in South African Universities. These results conform with the remark made by Papert that deep, substantive learning and enduring understanding occurs when a public construct is added to a mental construct (Papert, 1993), or the remark made by Bandura, (1977) that learners perform best when they learn in a community of social practice, such as, found in CCAILM learning environment. The results also illustrate conformity with the principle of multiple representations, which implies that students learn better, when they are taught both through words and pictures (Mayer & Moreno, 1998). All these learning approaches were built into the CCAILM to create a learning model of significance to the study, in order to:

- Promote active learning,
- Improve the quality of graduating engineering students, and
- Encourage more learners into engineering fields stated in the purpose of the study in Section 3.0

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