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Balancing of Cognitive Abilities: A Challenge to Quality in Mathematical Achievement

Luckson Muganyizi Kaino

College of Education, University of South Africa (UNISA), South Africa 169 Ezra Road, Die Wilgers, 0184 Pretoria, South Africa
Telephone: +27 766 000 182; E-mail: kainolm@unisa.ac.za

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ABSTRACT In this paper, as a case study, the researcher looks at the performance of one mathematics module offered through Open distance learning (ODL) to student-teachers. The student-teachers' examination results for the past four years were analyzed and the set examination as well as performance for the year 2011 were analyzed in the six levels of the Bloom's taxonomy of the cognitive domain. The findings showed that the set paper reflected lower levels of the cognitive domain and the average performance in the past years was generally good. The findings also indicated that most students performed well in the lower levels indicating that they had not achieved adequate knowledge in higher levels important for critical thinking and problem solving. It was concluded that lower levels in the set examination and the poor performance in higher levels did not reflect quality in the module offered.

INTRODUCTION

The assessment of students' cognitive development has been addressed by various studies. One of the most prominent assessments was developed by Bloom (1956), called Bloom's taxonomy that provided six sequential levels of cognitive ability: knowledge, comprehension, application, analysis, synthesis, and evaluation. In recent years different taxonomies have been developed in cognitive levels for different mathematics activities. For example, these taxonomies categorize different level forms such as memorization, procedures without connections, procedures with connections, and doing mathematics (Stein et al. 2000). The report of *Adding It Up* (NRC 2001), categorized five components in mathematics proficiency: Conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition. In the study of assessing pre-service teachers' pedagogical content knowledge, California Mathematics Framework (2005) and Wu and An (2006) proposed a new cognitive model: Model-Strategy-Application (MSA) to balance mathematics learning in basic computational and procedural skills; conceptual understanding, and problem solving. Porter (2008) categorized the levels into memorization, performing procedures, communicating understanding, solving non-routine problems and conjecture, generalization and proof.

While the categorizations suit well in some of the mathematical examples illustrated by above researchers, the complexity in these levels is that some questions suit a particular level according to the argument set by the researcher in the solution process of the problem tackled and at the same time could also suit the other level with convincing arguments. It also becomes difficult to apply these developed taxonomies in the construction and evaluation of the mathematics examination because of the overlaps in developed levels. Some of the overlaps in developed taxonomies have also long been noted in the Bloom's taxonomy. Anderson et al.'s (2001) categorization of the cognitive levels as remembering, understanding, applying, analyzing, evaluating and creating makes it more similar to the Bloom's categorization though the two are different in the categorization of higher levels. Evaluation of the two categorizations in the lower cognitive levels would provide similar results but seemingly not in higher levels where overlaps would be encountered. The matching of Bloom's *evaluation* level to Anderson's *creating* level in the higher cognitive abilities could be equally tested by setting similar objectives in the two levels.

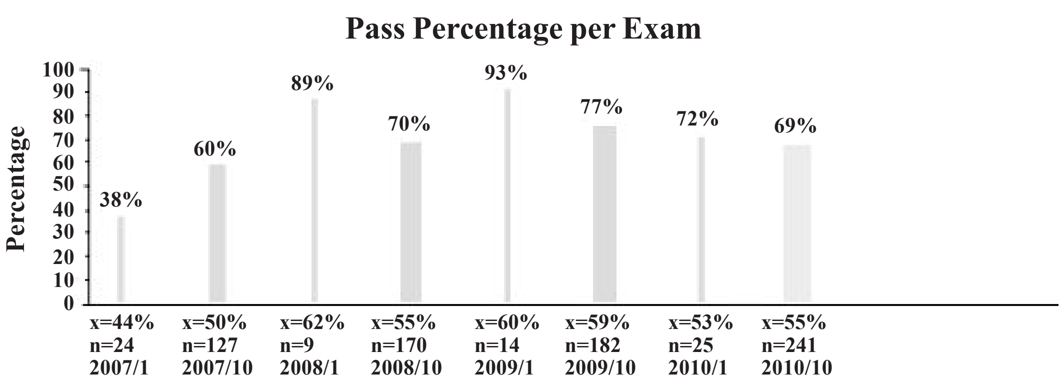
The module studied in this paper is offered through Open Distance Learning (ODL) and this mode of instruction has been debated whether it can offer quality instruction as has been believed in a face to face instruction. However, ODL has been regarded as a promising and practical strategy to address the challenge of widening access to education for many people. ODL was considered to offer the curricula appropriate for learners and addressing their needs and interests, accepted as a viable, cost effective means of expanding education provision without costly outlay in infrastructure (Pityana 2009). While in some other subjects, ODL modes like electronic texts have been reported to provide the opportunity for learners to establish communicative relationships among learners where they were able to reflectively co-construct their knowledge by engaging in open and critical discourse (Maor 1998, 1999; Taylor et al. 1999), very little research had shown such outputs in mathematics, science and technology (Mashharawi 2000; Gilmer 2002; Tobin 2002; Open University 2011). ODL has become known as a veritable vehicle of access to educational opportunities for a substantial proportion of the population all over the world and is evident that traditional educational systems are not capable of eradicating mass illiteracy on the African continent and in developing nations elsewhere (AGBELEKAWE 2010). The success of some ODL programmes was reported to be realized for many years where resources were made available to support these programmes (Perraton 2000). In this study, the analysis of performance in cognitive levels does not assume any disadvantage of teaching this module in ODL mode. The latter can be tackled in a further study.

Despite a general view that mathematics was failed in many places, this mathematics modes labeled "Y" for ethical purposes has shown good average performance for the last four years as indicated in Figure 1. These results indicated that most students were passing the module with an average of 50% and above. These good results put a picture that the module offered to student-teachers was of the quality expected. Despite these seemingly good results, there were concerns that teachers' knowledge in the subject was not adequate for effective teaching in schools and as a result many students failed the subject. It was then the intention of the researcher to investigate the performance in the subject by looking into the nature of the set examination and the performance of candidates at different levels of the cognitive.

The researcher decided to use the Bloom's taxonomy other than other developed taxonomies due to the nature of set questions and expectations. However, it would be important to apply Anderson et al.'s (2001) categorization in a further study using a similar or a different sample.

METHODOLOGY

A sample of 50 student-teachers' results in module "Y" were selected at random for study. This number was about 21% of students who wrote the paper and was considered to be representative sample of the module. The 2-hour examination had six questions and an evaluation of the exam in the six levels of the Bloom's cognitive domain, that is, knowledge, comprehension, application, analysis, synthesis and evaluation was done. Also the student-teachers' scores in these levels were analyzed. The premise made in this paper was that quality of the module was to be largely reflected by a balanced examination paper and good performance in all levels of the cognitive domain.



x: average final mark; n: number of students written
Percentage is the number of students passed per written.

Fig.1. Pass percentages for module Y

FINDINGS

The examination paper consisted of 6 questions and these were found to be in five out of six levels of the Bloom's taxonomy, that is, *knowledge, comprehension, application, synthesis and evaluation.* The *analysis* level was not included in the set exam. Constructed questions carried the following weightings: knowledge (21%), comprehension (48%), application (10%), synthesis (13%) and evaluation (8%) as indicated in Table 1 (in the first row). The weighting of the examination paper showed that the lower cognitive levels of *knowledge* and comprehension carried 69% of total examination weight and higher levels *(application, synthesis and evaluation)* carried only 31%. The overall average performance of 50 student-teachers was 47% and the average scores in the five levels were 54% (*knowledge), 55% (comprehension), 31% (application), 38% (synthesis) and 17% (evaluation),* (See Table 1 and Fig.2). These findings show that most students performed well in the two lower levels of *knowledge* and *comprehension* and performed poorly in the three higher levels of *application, synthesis* and *evaluation*. The analysis on *knowledge* and *comprehension* levels show almost normally distributed scores indicating that many candidates scored well in these levels, (Figs. 3a and 3b). However, the analysis on *application, synthesis* and evaluation showed positively skewed scores indicating that few students scored better in these levels, (Figs. 3c, 3d and 3e). A deeply skewed distribution score in *evaluation* level show that candidates performed very poorly in this area. These findings can be interpreted as student-teachers being more knowledgeable in the lower cognitive levels than in the higher ones.

DISCUSSION

The overall average score of 69% in the examination for all student-teachers in the year 2010 indicated that the candidates performed well in the subject. And with a recorded performance of 50% and above in the module for the past 4 years, it tended to portray the quality of the module offered. Furthermore, an average

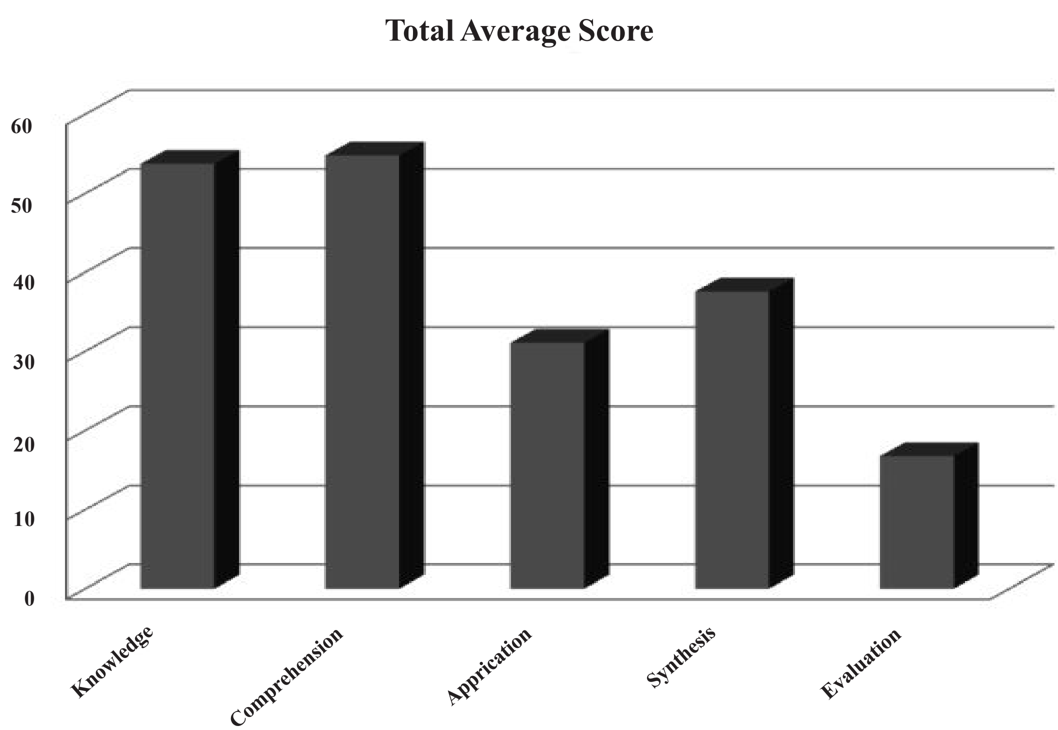


Fig. 2. ***Y*** **module scores in the 4 cognitive levels**

Table 1: Student-teachers' performance in module Y

Student	*Knowledge Q1.1,1.2, 3.1,5.2(21%)*	*Comprehension Q1.3, 2.1,2.2, 2.3,4.1,5.1, 5.3(48%)*	*Application Q3.2(10%)*	*Synthesis Q6.1,6.2(13%)*	*Evaluation* Q4.2(8%)	*Total score (%)*
1	18	44	9	9	1	81
2	17	40	8	10	0	75
3	6	5	2	1	1	15
4	9	44	5	4	1	63
5	10	40	1	0	0	51
6	11	41	2	2	1	57
7	8	37	3	3	0	51
8	13	36	4	5	0	58
9	10	9	3	3	1	26
10	9	4	1	0	2	16
11	10	43	3	1	1	58
12	8	37	4	2	0	51
13	16	40	9	10	1	76
14	2	3	3	2	1	11
15	11	46	3	2	0	62
16	3	5	5	3	1	17
17	19	27	9	10	1	66
18	15	27	4	6	0	52
19	6	25	1	0	0	32
20	14	8	8	10	6	46
21	15	44	5	4	8	76
22	9	37	1	0	0	47
23	10	42	6	5	1	64
24	8	41	5	5	1	60
25	3	33	1	1	1	39
26	18	32	1	0	1	52
27	17	25	9	10	8	69
28	19	43	8	10	1	81
29	18	5	5	5	8	41
30	13	8	2	1	2	26
31	9	9	1	1	2	22
32	16	45	4	8	8	81
33	17	42	3	2	1	65
34	5	2	2	1	0	10
35	5	8	1	0	0	14
36	17	3	1	0	0	21
37	8	31	2	0	0	41
38	9	11	8	10	0	38
39	16	45	9	10	0	80
40	9	8	5	3	0	25
41	14	29	4	2	0	49
42	8	7	1	0	0	16
43	7	45	1	1	0	54
44	16	43	8	10	2	79
45	8	44	1	0	0	53
46	17	9	7	5	1	39
47	15	43	6	5	1	70
48	10	2	1	0	1	14
49	6	9	5	5	1	26
50	7	9	2	1	1	20
Total Average Score	11.28	26.3	4.04	3.76	1.34	46.72
Total Ave.	0.537142857	0.547916667	0.31076923	0.376	0.1675	0.4672
Score (%)	53.71428571	54.79166667	31.0769231	37.6	16.75	**46.72**

score of 47% in the sample of 50 students used in this study was an indication of a fairly good score in the module. However, the analysis indicated that these students performed well in

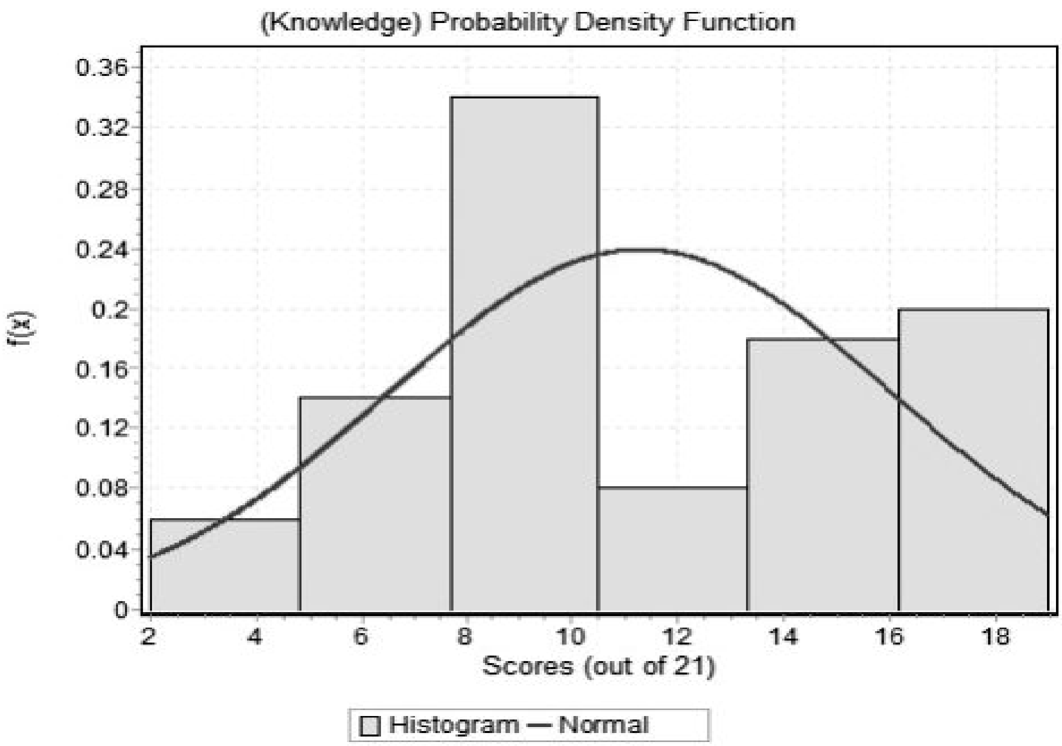


Fig. 3a. Distribution of scores in knowledge

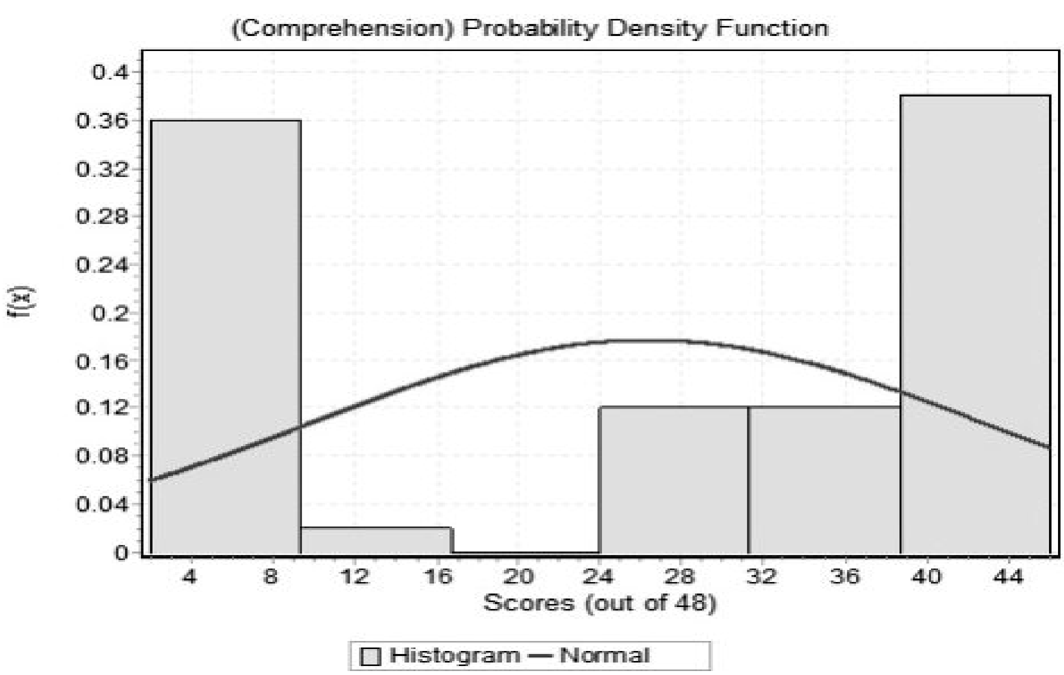


Fig. 3b. Distribution of scores in comprehension

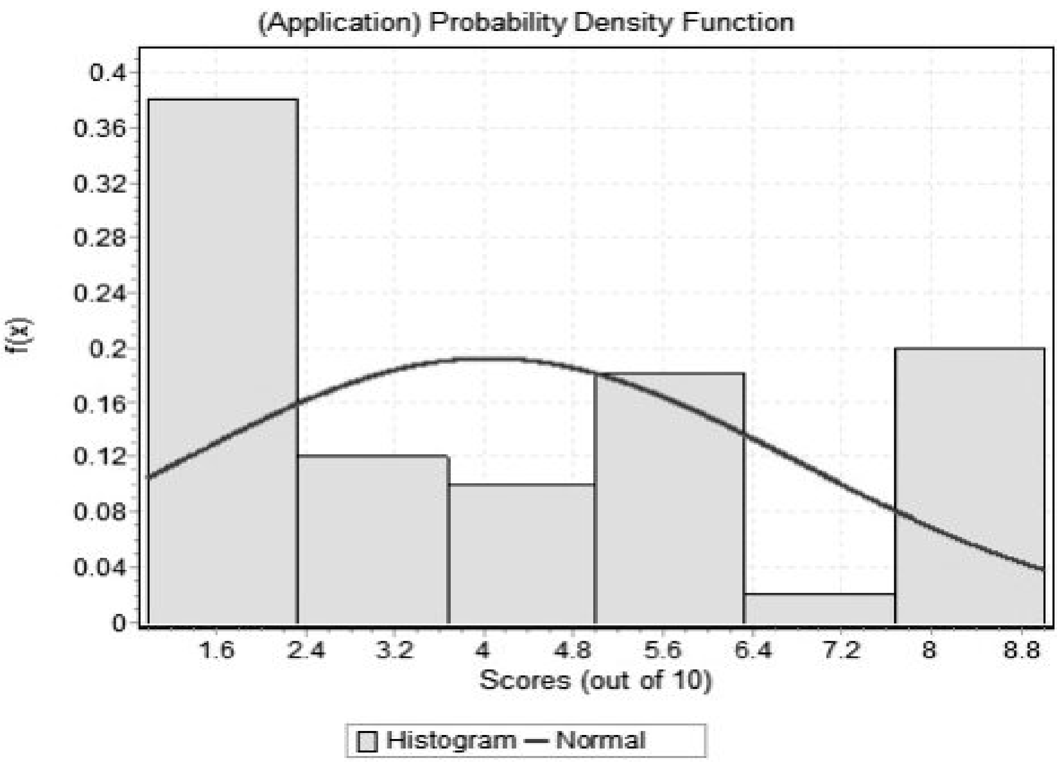


Fig. 3c. Distribution of scores in application

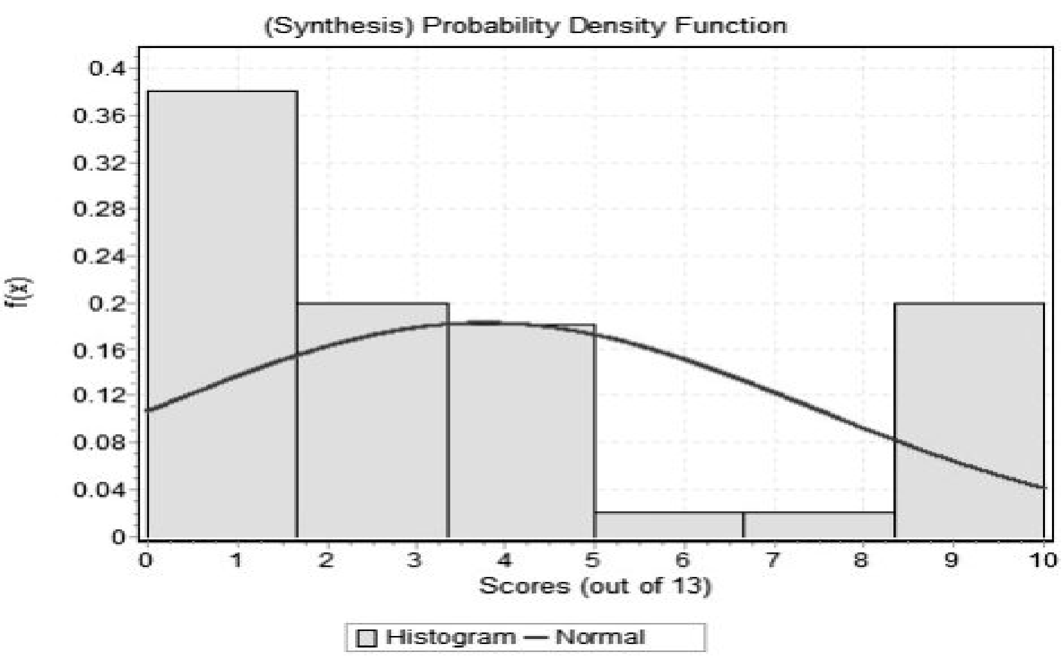


Fig. 3d. Distribution of scores in synthesis

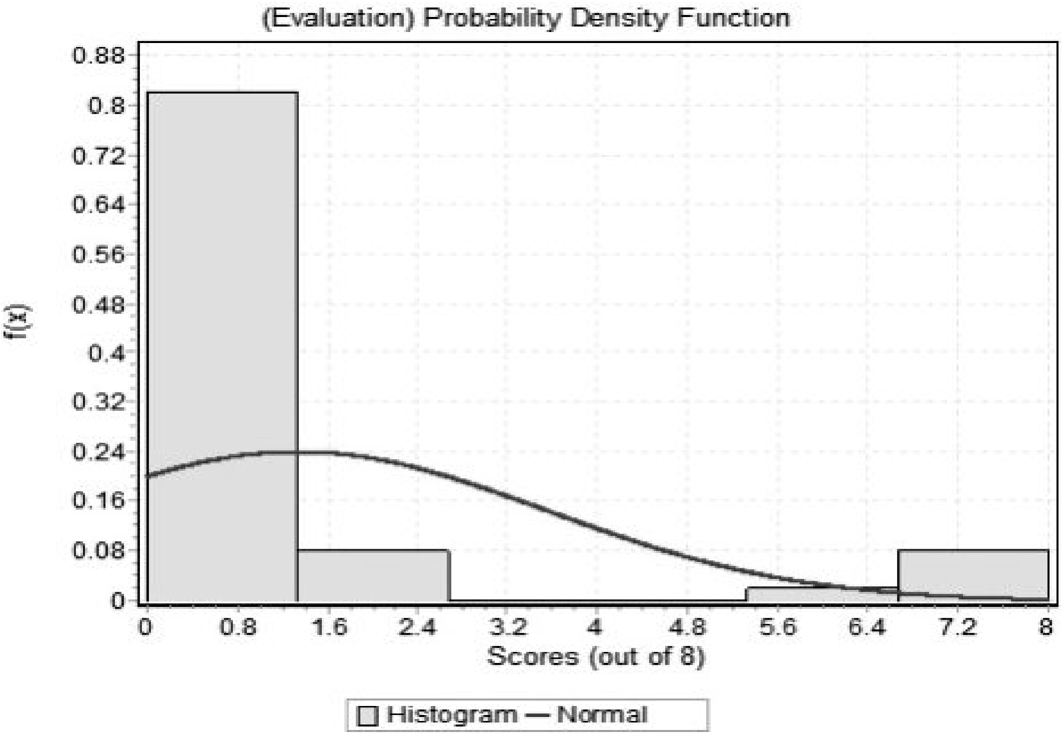


Fig. 3e. Distribution of scores in evaluation

the lower levels of the cognitive domain, that is, *knowledge* and *comprehension* and failed in higher levels of *application*, *synthesis* and *evaluation*. The analysis showed that fewer students performed well in the higher levels while many performed poorly. These findings indicated that student-teachers with such performance lacked critical and problem solving skills required by learners. The *knowledge* level enabled learners to recall mathematical rules, procedures, formulas and facts. From the study findings, the questions on *knowledge* level required student-teachers to state things like the importance and significance of doing mathematics as well as on how mathematical models could be used to develop particular concepts in mathematics. In the *comprehension* part, student-teachers were able to make descriptions of their understanding of conceptual and procedural knowledge in mathematics, and also why the traditional computation of maths were different from the 'doing' of maths. At the comprehension level, student-teachers were required to have knowledge of expressing mathematical knowledge from one form into the other and vice versa, and being able to make an interpretation of these. Knowledge in these two levels of *knowledge* and *comprehension* did not provide learners with critical and problem solving skills necessary to tackle mathematical problems in higher levels of cognitive domain. Student teachers' knowledge in these levels enabled them to translate and interpret information in comprehension problems but unable to move well into another level of *application* and above and present the solution process into appropriate component forms. The lack of knowledge in *application* was found in student-teachers' inability to solve the problem using Polya's (1957) four steps of problem solving technique. In Polya's solution process, the candidate was required to show an understanding of the problem by identifying the shaded quadrilateral of which the formula to calculate its area was non-existent, then devise a plan, carry out a plan and then look back to the process to determine the solution. All these steps needed the candidate to use the knowledge on triangles and rectangles to discover, plan and solve the problem; the knowledge essential in the *application* level.

The question in *synthesis* level that required the candidates to develop a mathematics lesson plan was performed better than the question in *application* level. In this question the candidates were to present assumed or previous knowledge in the area selected, develop anticipated outcomes of the lesson involving knowledge, skills and attitudes, introduction, conclusion and development of the worksheet. In this type of the question, the candidates were to plan, design, organize and propose different methods and strategies in developing the lesson plan, the knowledge that was essential in the *synthesis* level. The reasons for the candidates' good performance in this level than in *application* were not immediately known to the researcher though the assumption could be that many of the candidates might have been practicing in the schools (without teaching qualifications as many do) and were able to obtain the knowledge and skills of lesson planning through their daily activities in the classrooms.

Also the failure by the candidates in the *evaluation* level to identify assessment strategies in mathematics classrooms by displaying an understanding of why mathematical algorithms and different problem solving methods did not form a major part of classroom assessment was an indication that the candidates lacked knowledge in this level. In this level, the candidates were to display their arguments, make a justification of these and then defend their arguments. Poor performance in these higher levels was an indication that that learners lacked critical and problem solving skills (obtained in higher cognitive levels) necessary to solve real life problems and lack of these does not indicate quality in the module offered. Though the evaluation of exam paper written by the candidates found that the *analysis* level was not included in the questions set, there was little possibility that candidates would have done any far better in this level compared to performance in the lower levels. The candidates' performance in the *analysis* level was thus comparable to the lower performance in the higher levels analyzed.

Poor performance of mathematics teachers (related to poor performance of students for many years) in many countries prompted teacher training institutions to evaluate their student subject matter and pedagogical knowledge as well as methods of training in these institutions (Bukova-Güzel 2010). The findings of this study clearly indicated the need to make a deeper analysis of student-teachers knowledge during the preparation period.

CONCLUSION

Despite an overall good performance in the module studied, as also reflected in the past 4 years, student-teachers performed poorly in the higher levels of the cognitive domain indicating that critical thinking and problem solving skills were not attained by these candidates for effective teaching of the mathematics subject in schools. It was concluded that the set examination (in lower levels of the cognitive domain) and the poor performance in higher levels did not reflect quality in the module offered. However, the author acknowledges that quality cannot be only measured through good performance but provides clues on the quality of instruction used.

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