ORIGINAL ARTICLE

Assessment of Students' Mathematical Competency, a case Study in Dire-Dawa University

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Abstract

Nowadays, no nation can make any significant economic development without technological advancement. In Ethiopia increased attention is given to strengthen science and technology education (Federal Ministry of Education, 2010). On top of this, an adequate supply of young people with strong mathematical skills is needed to effectively exploit advances in science and technology. Mathematics provides people with powerful theoretical and computational techniques to capture the complexity of real life problems which is very essential for individuals and countries to gain a competitive edge in many fields of today's global economy. The assessment of students mathematical competency in Dire-Dawa University indicates that the majority of the students have been joining the university with poor mathematical background. Regarding their attitude, many students are not happy to study mathematics and do not believe in the uses of mathematics. On the other hand, only 14.96% of the students scored above 55% in the achievement test which indicates that many students have poor current performance in mathematics.

INTRODUCTION

Background of the Study

Mathematics in the real sense is a science of space, quantity and change that helps in solving the problems of life needing numeration and calculation. It also provides opportunities for the intellectual gymnastic of the man's inherent powers (Ravanan**,** 2004).

Mathematics is crucial to all aspects of science and technology; the design of many of the technologies that we use today developed from the results of mathematical research. Scientific theories are always expressed in mathematical language.

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Mathematical competency refers to the ability to understand, judge, do, and use mathematics in a variety of contexts and situations in which Mathematics plays or could play a role (Niss, 2002). In this study paper, "mathematical Competency" shall mean student's knowledge of mathematical facts (like definitions, theorems, techniques, principles, and formulas), and student's skill in using the facts to formulate and prove relations and to solve problems in Mathematics or in other sciences.

Much of the information in the physical and social world is mathematical in nature and so it is necessary to be mathematically competent to effectively analyze the information. People without this mathematical competency will be at a great disadvantage in dealing with this information to make reasonable decisions affecting their work, their life and their society (Spannberg, 2011). In particular, students who are not competent in mathematics have a difficult time in understanding their major discipline. Moreover, the competition and the opportunities in the career world become a serious problem for those students who are not competent in mathematics, because then they are excluding themselves from the many career paths that need mathematical competency.

As to Dermott (2006) dividing by fractions, solving for x, and calculating sines and cosines are just some of the requirements of substantial mathematics. Unfortunately, too few American students can solve these problems today. He also suggested that if the future employees are math- or science-deprived, the American high-tech competitiveness as a nation will continue to be eroded.

As to Abu-Hilal (2000) students' perceptions regarding the importance of mathematics exerted a significant effect on achievement. However, many Ethiopian students do not like mathematics and others consider it difficult (Education Quality Assurance and Examination Agency, 2007).

The peoples and government of Ethiopia are now struggling to escape out of poverty through accessing to higher education, in particular to science and technology (Federal Ministry of Education, 2010). Dire-Dawa University is one of the public universities endorsing the new science and technology focused training policy. The university has been admitting undergraduate students with majority of them enrolled in the Institute of Technology and in the School of Natural and Computational Sciences; these students have been taking different mathematics courses as an essential tool to study Engineering, Computer Science, Chemistry, Mathematics, Physics, and Statistics. Unless the university mathematical competency of these students reaches the desired level, any effort to implement science and technology focused training in the university will not be successful. Thus it becomes necessary to assess the mathematical competency of the students in relation to the new science and technology focused on training program of the university. Since no adequate studies have been conducted on the mathematical competency of students, this research project was designed in order to answer the following key research questions:

- What is the mathematical background of students joining the university?
- What is the attitude of students towards mathematics?

- How is the current mathematical achievement of students looks like?
- What are the areas of mathematics for which many students fail to achieve?

Objectives of the Study

This study was conducted in order to achieve the following general and specific objectives.

General Objective

The general objective of this study is to assess the mathematical competency of students in the case of Dire-Dawa University.

Specific Objectives

The specific objectives of the study were the following:

- Analyzing students' mathematical background;
- Investigating the attitude of students towards Mathematics;
- Assessing the current level of students' university mathematical achievement;
- Identifying the areas of mathematics for which the students fail to achieve.

Significance of the Study

The result of this study is believed to have remarkable significance to students, course instructors and curriculum designers as summarized in the table below.

Table 1.1 Out puts, Benefits and Beneficiaries of the study

Out Puts	Benefits	Beneficiaries
Areas of Mathematics in which students fails to be competent were identified;	Students will get additional training on the identified areas;	➢ Students ➢ Instructors ➢ The University
The attitude of students towards mathematics was determined;	Seminar on the uses of mathematics will be arranged;	
Solution/strategies were identified.	Course instructors and curriculum designers will find relevant information to make all the possible improvements in their strategies and practices.	

Hence among other things, the results of this study will contribute for improving the mathematical competency of students leading to successful implementation of science and technology focused education policy in Ethiopian universities. The study will also serve as a spring board for similar studies.

METHODS OF THE STUDY

Study Design

The study was conducted in Dire-Dawa University from January–August 2012. Both cross-sectional survey and experimental methods were employed in the study. The dependent variable of this study was students' mathematical competency. On the other hand the independent variables were students' mathematical background and students' attitude towards mathematics. The target populations of the study were students and instructors in the following departments: Chemical Engineering, Chemistry, Civil Engineering, Computer Science, Construction Technology Management, Electrical Engineering, Industrial Engineering, Mathematics, Mechanical Engineering, Physics, Statistics, and Surveying.

Sampling Procedures

There were 138 instructors, 2368 second year and above students, and 1757 first year students in the above Institute and departments. In order to get better representation of students' population, a stratified random sampling based on students department followed by simple random sampling technique was used. However, all the available 138 instructors were considered without sampling. The sample population sizes of first year students; and second year and above students were determined separately by using the following formula:

$$n = \frac{n_0}{1+\frac{n_0-1}{N}} \text{ for } \frac{n_0}{N} > 0.05 \text{ where } n_0 = \frac{Z^2P(1-P)}{d^2} \text{ (Cochran,1977)}$$

where ***N*** is the number of target population, that is, N=2368 and N=1757, *n* is the required sample size ***P***= 0.5 is the expected proportion of students that are competent in university mathematics and Z =1.96 is the standard normal distribution at 95% level of confidence and $d = 0.04$ is the tolerance error. Substituting the values in the above formula, we find the following sample sizes: From the total of 1757 first year students a sample of 315 and from the total of 2368 second year and above students a sample of 331 were taken. The number of sampled survey group in each department was allocated proportionally by using the relation: $n_i = \frac{n}{N} N_i$ where N_i is the number of students in each department; and n_i is the required sample size in each department of the students.

Data Source and Instrument

To gather relevant information upon students' mathematical competency, the following data sources and data collection instruments were utilized:

1. Students' University Entrance Examination, UEE score (2008-2011) were obtained from the university registrar office; and the diagnostic test of first year students (2011/12) were considered to analyze their mathematical background;
2. Two sets of well-structured and self-administered questionnaires were used; one for students to assess their attitude towards mathematics; and the other is for the instructors to know their day to day class room challenges in relation to students' mathematical competency.
3. Discussions made at Mathematics Department Assembly and Natural and Computational Sciences school council of the university were also important inputs for the study.
4. Achievement test was also prepared for 2nd year and above students to assess their current level of mathematical achievement and to

investigate the areas of mathematics in which many of them fail to achieve;

To ensure the standard of the achievement test and the reliability of its result the following efforts were made by the researcher:

- ✓ The conceptual areas in Linear Algebra I, Calculus I, and Calculus II, were carefully selected form the courses' syllabus; and table of specification were prepared to fairly distribute the test items over the course objectives;
- ✓ The test items were then commented and reviewed by senior staffs of the target departments;
- ✓ In order to create better awareness of the test by the students, they were informed via their respective school dean and the institute director; also a promise was made by the researcher to reward the high achievers.
- ✓ In order to minimize students' work load stress, the test and the questionnaire were administered together the first week of class begin.

Ethical Considerations

Since the study was conducted in the university the researcher has been working, the university officials, the students and the academic staffs were easily communicated on the objectives of the study and they were willing to provide information relevant to the study. Moreover, confidentiality of the information was assured and privacy was maintained.

Methods of Data Analysis

The collected quantitative data were organized and presented in tables, pi-charts, scatter diagram and line diagrams. On the other hand, the qualitative data obtained from open-ended questions were recorded by considering the most relevant and the most frequently forwarded once. Statistical tools such as average, percentage, t-test, ANOVA and Chi-square test of association were used to analyze the data.

Results

The results of the study can be classified mainly as the mathematical background of students, the attitude of the students towards mathematics, the mathematical achievement of students, the dependency of students' current mathematical achievement on their mathematical background and attitude towards mathematics, and the areas of basic mathematics for which many students fail to achieve.

Mathematical Background of Students

The mathematical background of the students can be determined from their mathematics scores of both Ethiopian Universities Entrance Examination (EUEE) and the diagnostic test of the university as discussed below:

Students' University Entrance Examination Score in Mathematics

At the end of preparatory school, Ethiopian students always take university entrance examination of different subjects including Mathematics. Universities have been admitting those students passing the UEE without giving due attention for the individual subject score of the students. Thus this study attempts to analyze the UEE score of students in mathematics.

The following line graph presents the average mathematics UEE scores of

students joining Dire Dawa University in each of the past four years.

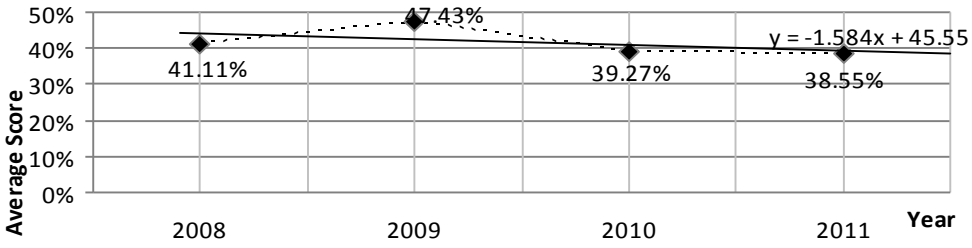

Fig. 3.1 Students' Average Mathematics UEE Score (2008-2011)

Moreover, since the cut off points for joining universities do not consider students' score of individual subjects, it becomes necessary to investigate whether the proportion of students' mathematics score to the corresponding total score of the students is as required. Since students took five subjects in the years 2008 and 2009 and seven subjects in the years 2010 and 2011, the expected proportionalities and the determined proportionalities are shown in the table below:

Tab. 3.1 Proportion of Students' Mathematics score to their Total Score

Year	Number of Subjects	Required Proportion	Average Proportion =Mathematics Score/Total Score
2008	5	0.2	0.2
2009	5	0.2	0.193
2010	7	0.143	0.122
2011	7	0.143	0.121

To categorize students' mathematics UEE score in three levels: relatively high, relatively medium, and relatively low; the relation *average* $\pm$ *standard deviation* is used to determining the cut of points; that is, since the average and the standard deviation of students' score in the four years is 41.59 and 11.41 respectively, we have 53 and 30 as the two required cut off points by which the following three levels of achievement are observed below:

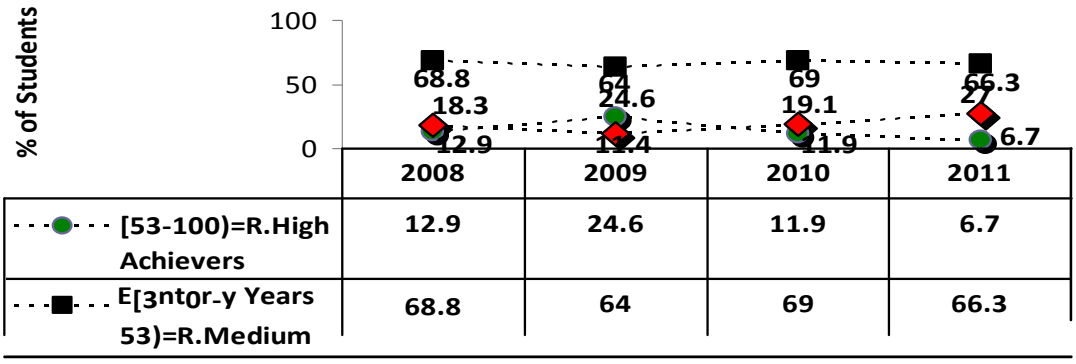

Fig 3.2 UEE Achievement Levels of students in each of the past four years

Generally, we can have the following pi-chart presentation to see the total students' level of achievement.

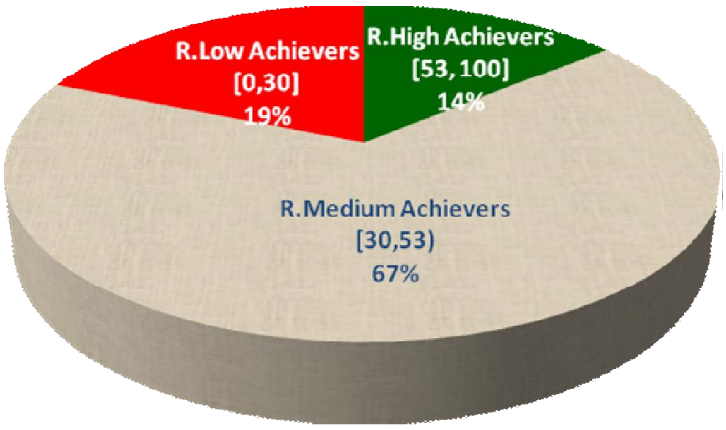

Fig. 3.3 *UEE Achievement Levels of students in the past four years*

Students' Diagnostic Test in Mathematics (2011/12 Academic Year)

Since it is impossible to determine the specific areas of weakness and/or strength just from the UEE record of students, and it is the university's good experience in providing diagnostic test to first year students, it becomes necessary to analyze this test. To this end, the Mathematics Diagnostic Test of 2011/12 academic year was considered and the achievement of students is presented in the table below:

Table 3.2 Students' Diagnostic Test Result in Mathematics (2012)

	Relatively High Achievers [50-100]	Relatively Medium Achievers [25-50)	Relatively Low Achievers [0, 25)
Percentage of Students	**13.11**	**33.33**	**53.56**

Moreover, the average score of these students in this test was found to be 24.36%.

To see the relationship of students' diagnostic test achievement and their University Entrance Examination (UEE) achievement in mathematics we use the following scatter diagram:

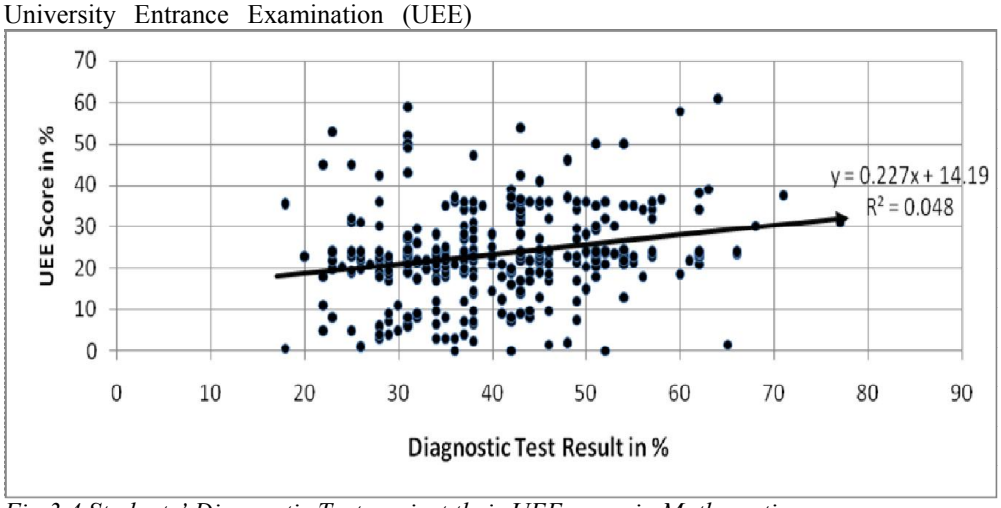

Fig 3.4 Students' Diagnostic Test against their UEE score in Mathematics

Based on the discussions made at department assembly and school council, the low achievement of students in the diagnostic test is due to one or many of the following causes:

i. Lack of awareness among students about the uses of diagnostic test; some of the students consider that the result of the diagnostic test has nothing to do with their survival or promotion. So they did not take it seriously;
ii. Lack of awareness among instructors and administrators in preparing and administering the diagnostic tests; that is, some of the test questions are either so elementary that they have no future use or they are so advanced that they will be discussed in the forthcoming courses. Students were also be given many test questions of more than one subject to complete in short period of time by which they get exhausted to go through;
iii. Since there are about 3 months between the end of students' preparatory education and the beginning of university education, they are likely to forget many of the mathematical facts and skills; and

iv. Some portions in preparatory mathematics are uncovered or covered in adequately.

In providing corresponding remedial actions challenges like shortage of time and classrooms were repeatedly forwarded by the instructors; moreover, lack of interest by the instructors was also observed as there were no incentive mechanisms when the instructors give the remedial actions beyond their full load.

The Attitude of Students towards Mathematics

The two dimensions of attitude, namely enjoy studying mathematics and believe on the uses of mathematics of the students, were investigated and the result is presented below:

Table 3.4 Students' Attitude towards Mathematics before and after joining DDU

	Before joining DDU			After joining DDU		
Response	Very Much	Some what	Least	Very Much	Some what	Least
Enjoy studying Mathematics	26.24%	28.72%	45.04%	23.05%	29.43%	47.52%
Believe in the uses of Mathematics	29.43%	33.69	36.88%	33.33%	26.95%	39.72%

Students' Current Mathematical Achievement

Many of the scientific theories are always expressed in mathematical language and understanding the theoretical and computational techniques in mathematics is the best way to develop the ability to analyze and simplify complex problems precisely and accurately for making further decisions. To this end, after joining the university, students have been taking different mathematics courses to support their undergraduate studies and to equip them with the necessary mathematical skills in their future careers. So a well designed achievement test was given for 2nd year and above students to know their current achievement and to identify the areas of mathematics in which many students fail to achieve.

Fig 3.5 Students taking the Achievement Test (Partially), Feb 2012

Students' achievement test result was summarized and presented in the table below:

Table 3.5 *Students' Mathematical Achievement Test Result Feb, 2012*

	Relatively High Achievers [55-100]	**Relatively Medium Achievers [27-55)**	**Relatively Low Achievers [0, 27)**
Percentage of Students	**14.96**	**47.86**	**37.18**

Moreover, the average score of these students was found to be 39.34%.

Areas of Mathematics in which Students have Poor Achievement

In addition to the score analysis of the achievement test attempts were also made to identify the main areas of mathematics in which students fails to achieve. This includes the following main categorical areas:

- Applications of Derivative
- Partial Derivatives
- Matrix Operations
- Solving system of Linear Equations

Many Students also fail to recall simple facts. For instance, only 6% of the respondents were able to state the Geometric Series Theorem.

Instructors of the target departments were also given the opportunity to express any of their ideas on the impact of their students' mathematical competency in their class room teaching learning process. They respond as follows:

- My students get difficulties to easily understand concepts that involve mathematical principles.
- I waste my time in teaching mathematical techniques instead of the course objective; this significantly affects the flow of the course I have been teaching.
- It affects the learning style of fast learners; it forces them to wait for until others understand that mathematics.

Students' suggestions to improve mathematical competency of students is presented below:

- Tutorial should be given to students with poor academic performance.
- Rewarding students who score best in Mathematics.
- Since practice makes perfect, students should continuously read and do exercises from different books and internet.
- Increase the number and quality of reference materials in the libraries
- Mathematics instructors should give examples related to students' field of study.
- I think teaching Mathematics effectively in lower grade level is the base for college Mathematics.
- For students to be happy, teachers must teach happily.
- Instructors' behavior should be attractive and they have to prepare before coming to class.

Instructors' suggestion to improve mathematical competency of students is pointed below:

- Establishing Mathematics Club.
- Since it is students' attitude that matters; and it is that we teachers should direct our students' learning, a lot is expected of teachers to build positive attitude towards Mathematics while teaching. To do this, Mathematics instructors should be aware of modern methods of teaching mathematics.
- Students should be aware of that Mathematics requires practice; they should maximize their effort for practice.
- Mathematical teaching should be highly student-centered and problem-based.
- A special type of teaching material should be prepared that could bridge high school and college Mathematics.

Discussions

We can see from Fig. 3.1 that except in 2009, the average mathematics UEE score of students joining the university is below 42% and it decreases from year to year. We also see from Table 3.2 that 86.89% (the majority) of the students scored below 50% in the diagnostic test and the average score of the students in the test is found to be 24.36% which can be regarded as poor achievement. Moreover, we see from Table 3.1 that except in 2008 the proportions of students' mathematics score to the total are below the required and decrease from year to year. This shows that students' total score is accumulated mainly from subjects other than mathematics. Thus we see that students have been joining the University with poor mathematical background.

As we can see from Fig. 3.4, there is no strong tendency of the points around the straight line. In particular, only 4.85% of the variation in diagnostic test result is determined by the variation in the UEE score. This shows that students' diagnostic

test result and UEE score in mathematics have no strong relationship to one another.

Regarding students attitude towards mathematics, we can see from Table 3.4 that only 26.24% of the students enjoyed very much while studying high school mathematics and only 23.05% of the students enjoy very much while studying university mathematics in DDU. Moreover, only 29.43% of the students strongly believed on the uses of Mathematics before joining DDU and only 33.33% of the students strongly believe in the uses of Mathematics after joining DDU.

As we can see from Fig. 3.2, students' score in the achievement test that range from 53-100% was decreased; and that range below 30% was increased from year to year. We see from Table 3.5 that the average score of the students is 39.34% which is less than 50%. Moreover, only 14.96% of the students are high achievers scoring above 55% whereas 37.18% are low achievers in the test.

Now we use the Chi-square method to discuss the dependency of students' mathematical achievement on their mathematical background and attitude one by one.

As to Ibe (1994), prior achievement has a significant indirect effect on mathematics achievement, influencing not only students' participation in mathematics learning, but also their confidence in understanding mathematical concepts and time spent on mathematics homework.

Now let the null hypothesis be given by:
H0: Students' current achievements do not depend on their prior achievement.

The following contingency table is used to verify this dependency at 3% level of significance.

Current Achievement	**Prior Achievement**			**Total**
	High	**Medium**	**Low**	
High	O_{11}=31	O_{12}=34	O_{13}=27	O^1=92
Medium	O_{21} =32	O_{22}=48	O_{23}=38	O^2=118
Low	O_{31}=19	O_{32}=37	O_{33}=65	O^3=121
Total	O_1=82	O_2=119	O_3=130	N=331

So if $E_{ij} = \frac{(o^i)(o_j)}{N}$, then the test statistic becomes

$$\chi^2 = \sum_{i=1}^{m} \sum_{j}^{n} \left[\frac{(O_{ij} - E_{ij})^2}{E_{ij}} \right] = 19.21$$

Since the critical value $\chi^2_{\alpha,(m-1)x(n-1)} = \chi^2_{0.03,4} = 13.27 < 19.21 = \chi^2$, it follows that the data provide us evidence against the null hypothesis, that is, students' current achievements depend on their prior achievement.

Next, the test for population correlation coefficient can be used as follows:

Let x and y be students' UEE Mathematics score and students' Mathematics achievement score respectively; if $n = 331$ is the number of students, then using the data we find the following:

$\sum x = 14649; \sum y = 13874.5;$
$\sum x^2 = 699979;$
$\sum y^2 = 671502.25;$
$\sum xy = 620956.5$ then the sample correlation r coefficient becomes

$$r = \frac{\frac{1}{n}\sum xy - \bar{x}\bar{y}}{\sqrt{\left(\frac{1}{n}\sum x^2 - \bar{x}^2\right)}\sqrt{\frac{1}{n}\sum y^2 - \bar{y}^2}} = 0.412239$$

, so that the test statistic t is given by $t = \frac{r}{\sqrt{1-r^2}}\sqrt{n-2} = 8.1995992$

If α=0.05, then

$|t| = 8.1995992 > 2.58 = t_{\alpha,n-2}$,

so that the correlation coefficient between the two scores is not equal to zero at 5% level of significance.

Similar procedure can be used to discuss the dependency of students' current mathematical achievement on students' attitude towards mathematics at 3% level of significance as indicated below:

Let H_0: Students' current achievements do not depend on their attitude towards mathematics.

Current Achievement	**Attitude**			**Total**
	Good	Somewhat	Bad	
High	45	34	22	101
Medium	28	46	41	115
Low	34	38	43	115
Total	107	118	106	331

So if $E_{ij} = \frac{(o^i)(o_j)}{N}$, then the test statistic becomes

$$\chi^2 = \sum_{i=1}^{m}\sum_{j}^{n}\left[\frac{(o_{ij}-E_{ij})^2}{E_{ij}}\right] = 12.96$$

Since the critical value $\chi^2_{\alpha,(m-1)\times(n-1)} = \chi^2_{0.03,4} = 11.14 < 12.96 = \chi^2$,

it follows that the data provide us evidence against the null hypothesis, that is, students' current achievement depends on students' attitude towards mathematics. This result is also demonstrated by other researchers and scholars (Papanastasiou, 2002; Schreiber, 2000).

CONCLUSIONS AND RECOMMENDATION

- Since many students have been joining the University with poor mathematical background, as revealed in both their University Entrance Examination and the university's diagnostic test, efforts should be made by the university to provide sound remedial actions based on a well-prepared diagnostic test to a well-informed first year students; a lot is also expected of academicians to identify the root causes of the problem. Effort should also be made to well prepare preparatory school students for further mathematical and hence scientific studies.
- The attitude of students towards Mathematics was one of the main concerns of the study and founded out that many students do not like Mathematics and others consider it useless. Thus, unless the attitude of the students is positive towards Mathematics, an ideal learning situation alone may not bring the desired Mathematical competency of the students. So we should improve the attitude of the students through seminars, workshops and individual instructor's effort to bring attitudinal change among his learners.
- Regarding the achievement test, many students were found to score low in the test. So unless the mathematical achievement of such students reaches the desired level, they may face a serious challenge to understand their major disciplines in their undergraduate studies. So adequate training on the identified areas of mathematics should be given. Moreover, students should be continuously assessed and be supported through a well-organized tutorial and cooperative learning methods should be strongly enhanced.

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