Analysis of Students' Difficulties in Transferring Calculus Knowledge to Physics: The Case of Mettu University

Lamessa Abebe[1], Gebeyehu Dirbeba[2]

[1]**Department of Physics**, **Mettu University**, Ethiopia
[2]**Department of Physics**, **Mettu University**, Ethiopia

Abstract: *This research investigated students' transfer of learning from calculus courses knowledge to an introductory physics course. In this study we used interviews and questionnaires methods to assess the extent to which students transfer their calculus knowledge when solving problems in a physics course. Difficulty problems present interviewees with an intermediate step in the form of a mathematical integration and ask students to come up with a physical scenario relevant to the integral provided. Results indicate that students often had difficulty taking apart the given problem and they needed prompting to connect the calculus knowledge with the physics problem. We also observe the result from pre-test to interviews of the students' background and knowledge of calculus, which is very poor. Generally, from all tests, quiz and final exam of students result almost 45% of them transfer calculus knowledge to introductory physics courses whereas 55% of them are still with confusion of identifying the derivatives and integrands. This is proven by questioning their calculus instructors and introductory physics instructors. Both department instructors are satisfied very deeply 28.6% to students calculus background, 42.9% medium,14.3% deep and shallow satisfaction calculus respectively.*

Keywords-*Calculus, calculus instructor, physics course, , Students' difficulties, Transferring knowledge*

I. Introduction

"...it is impossible to explain honestly the beauties of the laws of nature in a way that people can feel, without their having some deep understanding of mathematics." (Feynman, 1992)

There are many other physicists emphasizing like Feynman the deep interrelation between mathematics and physics. It is not the technical toolbox mathematics provides but rather the creative aspect producing new insights into physical structures that hints at a deep conceptual relation between both sciences. Einstein for example states that *"Our previous experience justifies the belief that nature is the realization of the most basic mathematical thoughts. […] Experience remains certainly the sole criterion of usefulness of a mathematical structure for physics. But the truly creative principle is in mathematics"* (Einstein, 1956).

Calculus is the "language of change" and has been considered one of the fundamental courses for engineering and science majors. The calculus reform movement began because of mathematicians' dissatisfactions with undergraduate calculus education. The calculus reform movement suggested changes in calculus instruction that emphasized deep understanding of calculus concepts and their applications in problem situations. In spite of the advances of the calculus reform movement, multiple-choice and short-answer questions still appear to be the dominant tools to assess students' learning in calculus. Since the ancient times, mathematics played a major part in the study of nature. Today, most physics instructors would agree that mathematics is the language of physics. Thus, it is imperative for students to have a solid mathematical background in order to succeed in physics courses. Research has reported that students are unable to explain their own solutions to physics problems within a mathematical context.

Today the fundamentals of calculus and classical physics are taught at the high school, college and university level throughout the world. Yet these two subjects are so closely related that may be important to investigate how this century students see the connection between calculus and physics. Unlike few countries, in Ethiopia, these classes are typically taught sequentially, calculus followed by physics, it is also relevant to investigate, and how students apply or transfer the knowledge they learned in their calculus courses in to physics courses. Many researches are made in different countries in a similar perspective.

Most science and engineering majors are required to take calculus-based physics. Students are usually required to concurrently take both their first calculus and physics courses, or take at least one calculus course prior to taking physics. To understand how students apply what they have earned in a calculus course to a physics course, it is essential to investigate their transfer of learning. Transfer of learning as (Byrnes, 1996), has often been referred to as the ultimate goal of education and is defined as the ability to apply what has been learned in one context to a new context. In most cases, students were unable to apply a principle or schema extracted from a particular learning situation to a new target situation.

Throughout our experience of teaching we have often see some physics teachers claiming that their students lack the pre-requisite calculus knowledge that could help them to solve the physics problems. Many students also perform poorly in introductory calculus-based physics courses. In addition, only few students are willing to join the physics department. Therefore it is essential to investigate the real problem entrenched behind all these by researching their transferring ability of calculus knowledge to physics. In this research then it was attempted to explore the problem in Mettu University, in the undergraduate physics students. Therefore, investigating transfer of learning from calculus to physics is the central focus of this study.

Statement of the problem

Most physics students, in Ethiopian universities, have seen refusing to study physics by their first, second, or third choice. They even do not like it; however, they obliged to study physics by their last choice. As a result, most instructors had seen complaining by assuming that they did not have mathematics and physics background in preparatory level as well as at the university level. In our teaching experience, most students have focused on the mathematics than the physical concepts; that is they have gotten the answer of the problems by calculating but they cannot explain what does the physical meaning of the result. Moreover, they have seen facing difficulties to interpret the physical meaning in to mathematical meaning and solve the physics problems. Therefore, the researchers believed that students have difficulties in transferring the knowledge they had acquired from calculus in to the introductory physics courses.

To investigate the transfer of knowledge from calculus to physics, the following research questions were raised and answered by this research.

1. To what extent do students retain and transfer their calculus knowledge when solving problems in the introductory physics courses?
2. What are the main difficulties of students not to capture the knowledge and transfer what they have learned in calculus to introductory physics?
3. What strategies may facilitate students' transfer of knowledge from calculus to physics?

Objective of the study

The main objective: The main aim of this study is to explore and suggest ways of solving the difficulties of the Mettu University physics students transferring ability of calculus knowledge to physics.

The specific objectives

The specific objectives are:

- To investigate to what extent students retain and transfer the calculus knowledge in to physics.
- To sort out the main difficulties of students to transfer knowledge of calculus to physics
- To indicate the strategies that help students to transfer the calculus knowledge to physics.
- To indicate the strategies that help instructors how to teach calculus and physics.

Significance of the study

Both instructors and students were benefited from the result of this study. Since most instructors have applied science backgrounds, pinpointing the difficulties and the strategies of transferring knowledge of calculus in to physics will have an immense use to teach calculus and introductory physics. In addition, it will serve as springboard to young researchers who are interested in this field of study for further investigation.

Population of the study and sampling technique

In this study, the population was all first year applied physics majors students who took electromagnetism in the second semester of 2012/13 academic year. Seven instructors who taught calculus course and eight instructors who taught electromagnetism in the previous semesters and those offered these courses during the second semester of the academic year were also participated.

II. RESEARCH DESIGN AND METHODS

A grounded theory approach was used at the beginning of this study to understand the problem deeply and then descriptive survey study was employed to collect and analyze data from a wide range of sources. Interviews were designed for sevenvolunteer students and questionnaires for seven calculus and eight physics instructors who offered/ offering the course. The information gathered from different sources was analyzed qualitatively and quantitatively.

Research methods

Grounded theory approach was used at the beginning of this study to excavate the data carefully. Descriptive survey was then employed to see the existing relationship between calculus and physics and the practice of instructors that exists. Descriptive research, according to (Best, 1970), is concerned with conditions or relationships that exist, practices that prevail, beliefs, points of views, or attitudes that are held, processes that are going on, effects that are being felt, or trends that are developing. Descriptive research is also concerned with how *what is* or *what exists* is related to some preceding event that has influenced or affected a present condition or event.

Materials and methods

The following primary data gathering instruments were used in order to collect the sufficient information.

Questionnaire

A questionnaire is the most popular type of data gathering instrument, which used to collect appropriate information easily. The questionnaires for eight physics instructors who offered the course electricity and magnetism and those mathematics instructors who offered calculus courses were participated. The questionnaire contained both close-ended and open-ended items. The close-ended items were comprised of options while the open-ended items have a space to suggest their idea.

Interview: The interview was conducted for volunteer 4 female and 3 male students and was paid to compensate the time they spent.

Tests and Exams

The tests and exams, which were administered to the students, were taken from Lilli Cui's (2006) research and their reliability was tested. Such tests were similar to the chapter end problems and they were calculus based.

Data sources and data analysis techniques

Source of Data

The information from calculus and electromagnetism instructors was gathered with the questionnaires, the necessary information was also gathered with in depth interview of seven volunteer students. The information from tests and exams was also gathered to get all the essential information.

Method of data analysis

The data, which were collected through questionnaires: the closed ended questions, were analyzed quantitatively using mean and percentage. However, the data gathered from the open-ended questions, the interview, tests and exams were analyzed qualitatively using the descriptive analysis technique and the grounded theory analysis techniques as Strauss and Corbin (1998): open coding, analysis of axial coding and selective coding.

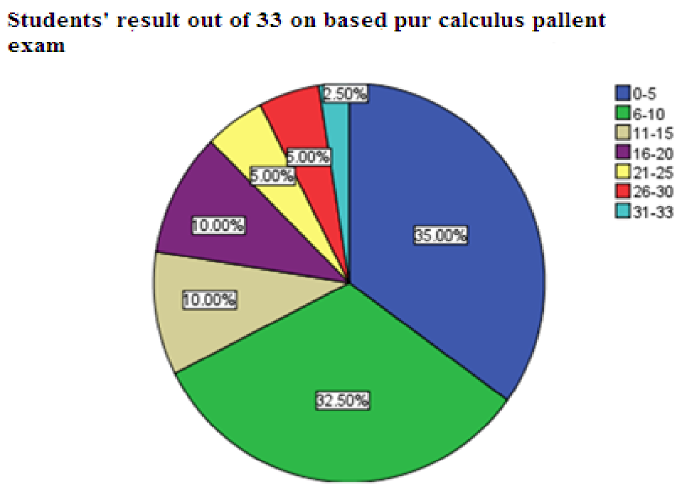
III. MAJOR FINDINGS

The information gathered from Test1 (T1), interviews (I), Test2 (T2), questionnaires and final exams were presented and analyzed qualitatively and quantitatively and interpreted accordingly.

Pre- test: Before starting the entire research, each participant was assigned a written test, which was comprised of pure calculus questions to investigate students existing status of calculus knowledge. A brief summary of the result was presented in table-1 below.

Table 1. A Pre- test: Students' result on pure *calculus* question.

Values	Frequency	Percent	Valid Percent	Cumulative Percent
0-5	14	35.0	35.0	35.0
6-10	13	32.5	32.5	67.5
11-15	4	10.0	10.0	77.5
16-20	4	10.0	10.0	87.5
21-25	2	5.0	5.0	92.5
26-30	2	5.0	5.0	97.5
31-33	1	2.5	2.5	100.0
Total	40	100.0	100.0	



Pie chart 1: Students result out of 33 on based research pallet exam.

Interpretation: From the above table and pie chart, it is possible to say that 67.5% of the respondents didn't have deep, background knowledge in calculus. Majority of the respondents, 77.5%, who were enrolled to study applied physics in the year 2011/12 have scored less than 50% in pure calculus test.

In a similar way students were interviewed in this respect. It was summarized as followed: students have learned calculus in preparatory schools. However, they have difficulties to understand the concept of calculus though they can solve the problems using similar contexts as the example given in the chapter end questions.

From the analysis of written pre-test provided one of students' difficulties was confusion between derivatives and integral. However, for the majority of responses, it was not clear whether or not the students had an in-depth understanding of the definite integral concepts because most of the responses provided by the students lacked detail.

Analysis of students' responses from tests and exams

Table 2.(Test 1). Students' result out of six on calculus based physics test

Students' score using SPSS analysis

Value	Frequency	Percent	Valid Percent	Cumulative Percent
0-0.9	21	52.5	52.5	52.5

1-2	7	17.5	17.5	70.0
2-3	8	20.0	20.0	90.0
3.1- 4.5	3	7.5	7.5	97.5
4.6- 6	1	2.5	2.5	100.0
Total	40	100.0	100.0	

From table 2 we observe that the percentage result of scoring students between 0 – 0.9 is 52.5%, between 1 – 2 is 17.5%, between 2 – 3 is 20%, between 3.1 – 4.5 is 7.5% and between 4.6 -6 is 2.5%. This implies that almost student have less background calculus transfer to physics.

Table 3. (Test 2) Students' result out of 6 on calculus based physics test

Students' score -6%

Value	Frequency	Percent	Valid Percent	Cumulative Percent
0	18	45.0	45.0	45.0
0.5	2	5.0	5.0	50.0
1-1.9	4	10.0	10.0	60.0
2-2.9	4	10.0	10.0	70.0
3-4.5	9	22.5	22.5	92.5
4.6-6	3	7.5	7.5	100.0
Total	40	100.0	100.0	

The above table reveal that 45% of the respondents score zero out of 6 and 70% of them were scored less than half, whereas, 30% of the respondents score more than half in this test. From students result basic difficulty in determining of the limit of integration calculus concept in physics can be observed.

Table 4. (Final exam). The respondents' result on final exam out of 17%

Value	Frequency	Percent	Valid Percent	Cumulative Percent
0-0.9	10	25.0	25.0	25.0
1-2.4	7	17.5	17.5	42.5
2.5-3.9	6	15.0	15.0	57.5
4-4.9	2	5.0	5.0	62.5
5-6.5	5	12.5	12.5	75.0
6.6-8	3	7.5	7.5	82.5
9-9.5	2	5.0	5.0	87.5
10-13	4	10.0	10.0	97.5
13.5-17	1	2.5	2.5	100.0
Total	40	100.0	100.0	

From table 4, the numbers of students scored out of 17 between 13.5-17 and 0-0.9 are 1 and 10 respectively. The percentage of respondents getting marks between 0-0.9 and 13.5-17 is 25% and 2.5% respectively and most of the students scored less than one, therefore, we can conclude that applied physics students have poor performance on calculus based physics exams.

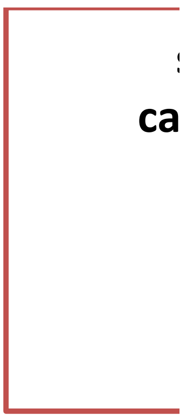
Analysis of the responses from calculus and physics instructors

Information was gathered through questionnaires from both calculus and physics instructors and was analyzed and interpreted as follow.

a) Analysis of the responses from calculus instructors

Table5. Instructors' response about students' background of calculus knowledge.

value	Frequency	Percent	Cumulative Percent
Very deep	2	28.6	28.6
Deep	1	14.3	42.9
Medium	3	42.9	85.7
Shallow	1	14.3	100.0
Total	7	100.0	



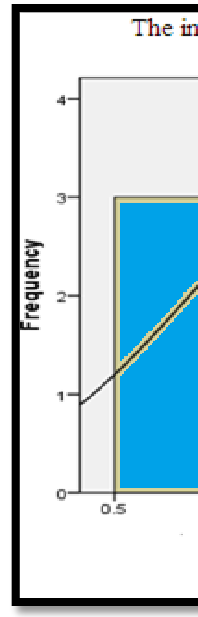
Pie chart 2 Instructors' response about students' background of calculus

From the above table and pie chart, students' background understanding in calculus, as viewed by instructors was medium (42.9%). However, 28.6 % of them said students have very deep understanding and 14.3% of them said they have deep understanding. So, majority of the instructors believe that students have medium understanding of the calculus concept however, in the preliminary calculus test it was revealed that majority students who were registered as physics major have little knowledge of calculus except few students that is 22.5 % of them scored above half.

As seen in the table 6 all participant instructors were taught calculus while the research was made or before one semester. So it is possible to say that all participants gave genuine and reliable information to this study.

Table 7. Calculus Instructors' response about their most instructional methods.

Description	Frequency	Percent	Valid Percent	Cumulative Percent
Lecture methods	3	42.9	42.9	42.9
Gapped lecture	2	28.6	28.6	71.4
group discussion	2	28.6	28.6	100.0
Tt total	7	100.0	100.0	



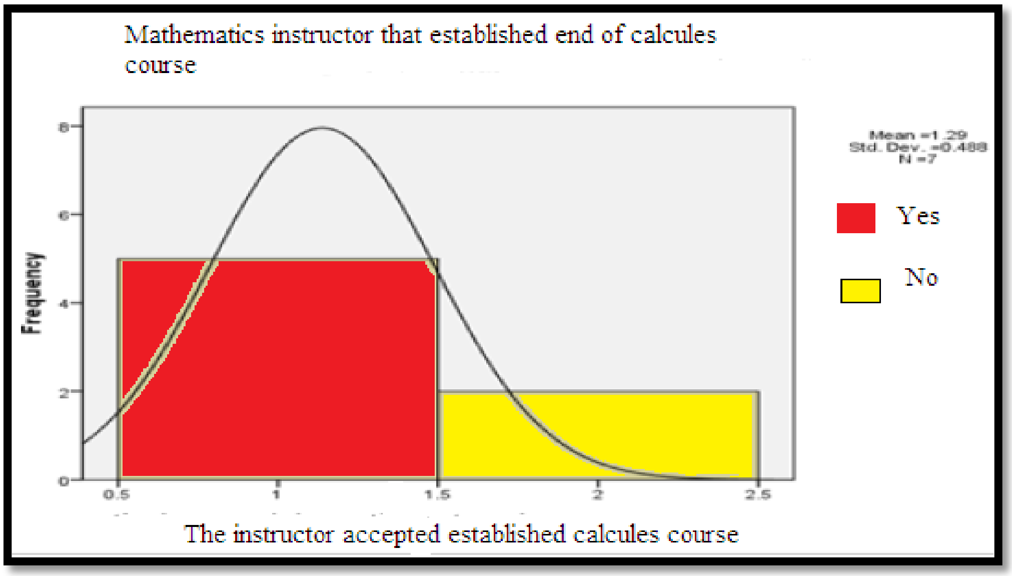
Bar graph 1: Calculus Instructors' response on use of instructional methods.

As above on the table most instructors use lecture methods and gapped lecture and group discussion when they believed appropriate to teach introductory calculus. This implies that the instructors were in a hurry to finish the course by simply lecturing the concepts mostly.

Table 8. Mathematics instructors' response about the calculus knowledge/skills that established by students after end course.

VALUE	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	5	71.4	71.4	71.4
No	2	28.6	28.6	100.0
Total	7	100.0	100.0	

Description	Frequency	Percent	Valid Percent	Cumulative Percent
2011/12 first semester	2	28.6	28.6	28.6
2012/13 first semester	1	14.3	14.3	42.9
2012 second semester	2	28.6	28.6	71.4
2013/ second semester	1	14.3	14.3	85.7
before 2011/12 first semester	1	14.3	14.3	100.0
Total	7	100.0	100.0	

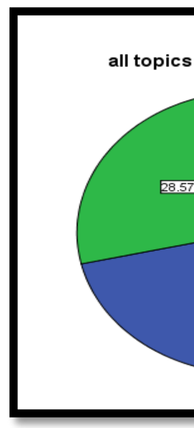


Bar graph 2: Mathematics instructors' response about calculus knowledge/skills

Table 8 and bar graph reveils that most mathematics instractor response calculus knowldge/skill that established to student after end of the calculus course. We suggest that the instructors' knowledge/skill were transformed efficiently to maximum potential so student will be capable of calcules consept.

Table 9. Calculus instructors response concerning the belief that calculus knowledge/skills that established by their students are useful for other subjects.

		Frequency	Percent	Valid Percent	Cumulative Percent
Value	Yes	5	71.4	71.4	71.4
	No	2	28.6	28.6	100.0
	Total	7	100.0	100.0	



Pie chart 3: Calculus instructor coursecoverage for given academic semester.

As seen from chart 3 majority of the calculus instructors, that is 71.43% of them, covered all of the topics that must be covered with in the semester. On the other hand 28.4% of the instructors couldn't cover the topics. It has its own influence in the performance of calculus as well as physics.

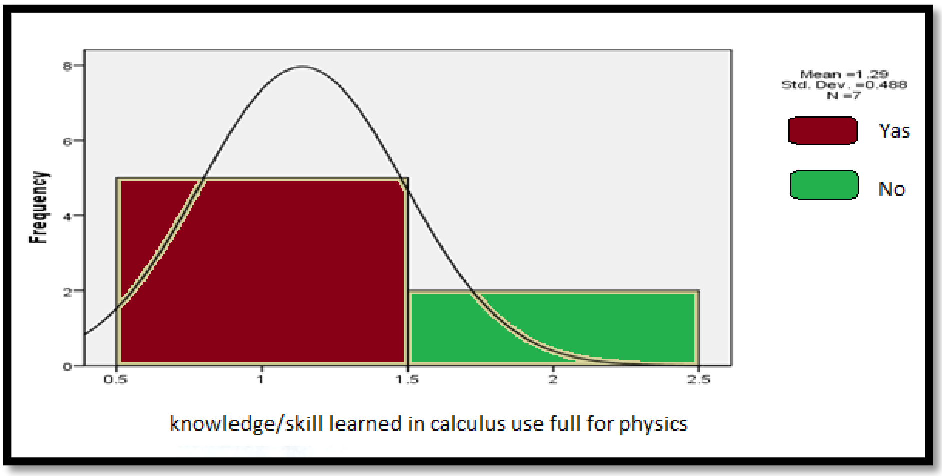


Table 10. Calculus Instructors response concerning the question whether students were adequately prepared in calculus or not.

		Frequency	Percent	Valid Percent	Cumulative Percent
Value	Yes	2	28.6	28.6	71.4
	No	5	71.4	71.4	100
	Total	7	100.0	100.0	

From the above table and graph we can see that majority of the instructors that is, 71.4% of them, agreed and have the belief the knowledge/skills learned in calculus class were useful for other subjects like physics. Surprisingly few of them, that is, 28.6% of them do not have such belief or they have other reason to believe. It is possible to say that 71.4% of the respondents agreed that students were not adequately prepared in calculus. Whereas 28.4% of them said that, students were adequately prepared in calculus.

Analysis of the responses from physics instructors

Table11). Physics instructors' response concerning the relation between calculus and physics

No.	Question	Response			
		Yes		No	
		No.	%	No.	%
1	Students learn all the necessary calculus topics previously, for the appropriate level	3	37.5	5	62.5
2	students were adequately prepared in calculus	2	25	6	75
3	I believe that the knowledge/skills learned in calculus class are useful for physics	7	87.5	1	12.5
4	They are able to apply their calculus knowledge to physics whenever necessary	3	37.5	5	62.5
5	They are able to apply their calculus knowledge to physics sometimes	2	25	6	75
6	They are able to apply their calculus knowledge to physics if the problem is familiar	7	87.5	1	12.5
7	They cannot apply their calculus knowledge to Physics although the problem is familiar.	-	-	-	-
8	They cannot apply their calculus knowledge to physics usually	-	-	-	-
9	I satisfied with the knowledge that established by the students when they finished the course	2	25	6	75

As seen in the above table, question number 1, 2and 3, although they all believe that the concept of calculus are very useful for physics learning, majority of the respondents, that is 62.5 % of them were agreed that students didn't learn all the necessary calculus concepts at appropriate level. In addition 75% of them believe that students didn't have prepared well that would help them for further physics learning. So, it is possible to say that their background knowledge of calculus as well as physics was not as intended from the applied physics major students in Mettu University during this academic year.

In question number 4 to 8 we try to ask when students apply their calculus knowledge in physics. Accordingly, majority of the students, which is 87.5 % of them, said that students apply the knowledge of calculus when the problem is familiar, that is as examples provided in class. Some of them, 37.5% also said that they apply their calculus knowledge whenever necessary. As a result, most instructors, 75 % of them were not satisfied in the students' performance.

Table12) the association of calculus to physics

No.	Question		Response	
			No.	%
1	I associate calculus to physics:	Always	1	12.5
		sometimes	2	25
		Whenever necessary	4	50
		never	1	12.5
Total			8	100

In the above table it intended to see when the physics instructors associate their calculus knowledge to physics. However, only 50% of the respondents associate whenever necessary and 25% of them associate sometimes. 12.5% of them never tried to associate calculus concepts to physics while they taught electromagnetism.

In general, we investigated students' transfer of learning from calculus courses to an introductory physics course. We used interviews to assess the extent to which students transfer their calculus knowledge when solving problems in a physics course, because how students transfer the knowledge learned in their calculus course can be critical to their learning in physics. So, we conducted one-to-one think interviews to assess how students transfer their calculus knowledge in a physics context. We have chosen electricity andMagnetism (phys1013) for pilot test because it requires a significant application of differential and integral calculus and basic for all courses. Electricity and magnetism is a one semester, calculus-based physics course. Each participant was interviewed over two sessions, each lasting about half an hour. The interviewee was left alone to solve an assigned problem. Upon completion, we asked them to explain what they had written down on a pilot test and encouraged them to verbalize their thinking process. We also asked them to describe any difficulties they had when solving the problem. We asked general questions about their calculus background and application of their calculus knowledge in physics at the end of the interview.
We were asked interviewees to solve physics problems that were similar to their homework or exam problems and required use of simple integration or differentiation. The four physics problems we used were: (1) E-field caused by a half-circle charge distribution, (2) electric potential caused by changing E-field, (3) B-field caused by a non-uniform current distribution and (4) current induced in a wire loop when the loop is moved through the field produced by a straight current-carrying wire. We will discuss the students' responses to each of these follow-up interview questions as the following manner.

Realization that calculus is required in physics

All of the students realized that physics and mathematics were inextricably linked. As one student commented: *"Physics talks about why to solve it, mathtalks about how to solve it."* They also realized that they needed calculus knowledge to solve the physics problems. Six out of seven interviewees thought their calculus knowledge was insufficient for them to use in physics class. But, students were evenly split when asked whether it would be possible to set up the physics problems without calculus. Furthermore, when asked to compare the calculus and physics problems, only the students who successfully solved the physics problem could see the similarities in the problems. Solving the calculus problem did not help interviewees solve the physics problem.

Confidence in setting up physics problems

All of the students had previously seen physics problems similar to the interview question. We rise for the students about their confidence on transferring the calculus knowledge to physics problems. Some of them were confident of their physics solution strategy by using their previous calculus knowledge. But for most of them it was particularly unclear about the criteria that determined whether calculus should be applied in a given problem.

Situations in which students use integration in physics

One out of eight interviewees appropriately used integration and derivatives to solve the physics problems, while seven students did not use calculus even after being given several hints. When a student that used calculus were asked about the criteria he applied to decide why calculus was applicable to the problem, the interviewees said the problems were similar to the examples he had seen in the text; however, he could not explain why he used integration. Two out of seven interviewees had a rough idea as to why they needed to use integration in terms of adding up the infinitesimally small elements: *"...you can notadd up an infinite number…then I used integral…"*

Difficulties when applying integrals in physics

When the question 'do you feel the need to use your math knowledge to solve physics problems?' asked, their responses about difficulties in applying integrals was:

- Determining the variable of integration:

Generally all interviewees complained that they had difficulty in figuring out the "real" variable that needed to be integrated or differentiated.

- Deciding the limits of integration.

Most interviewees had difficulties in setting up the limits of integration. About half approved the difficulties to the physics class. One remarked that it has*"…not really to do withmy math class…I know how to integrate it, but it is justfiguring out what to integrate."*

When the students were asked about their satisfaction of in transferring calculus knowledge to physics problems, most interviewees tended to use pre-derived formulae rather than using calculus to derive the formula from integration, not being clear about the criteria which determine whether calculus is applicable in a given physics problem; and they tended to use oversimplified algebraic relationships to avoid using calculus because they do not understand the underlying assumptions of the relationships.

VI. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

From the students result the researchers concluded that transferring calculus knowledge to physics introductory courses is very poor. This is due to the lack of background knowledge of calculus and the lack of relating calculus application to physics courses. In the other words, from the SPSS statistical data of the students result on pure calculus tests and calculus based physics tests almost 75% of the students have confused in the use of proper integral and derivations.

In general, in this study, we observe the difference between students' knowledge, based on pure calculus courses and calculus based physics courses. The result indicated the students are less in calculus based tests and they performed 45% to solve calculus tests. Based on physics questions they performed 50% but due to the lack of their calculus knowledge they don't perform as well as they asked and confused with the mathematical formulas they apply in physics. From the interview result of mathematics instructors and physics instructors, it is obtained both department instructors are not satisfied to the student's calculus background knowledge and according to their views, 28.6% of the students have very deep calculus background, 42.9% of the students have medium calculus knowledge and the rest of 14.3% of the students have deep and shallow calculus background respectively. So, majority of the instructors believe that students have medium understanding of the calculus concept however, in the preliminary calculus test it was revealed that majority students who were registered as physics major have little knowledge of calculus except few students that is 22.5 % of them scored above half.

Conclusions

This research attempted to investigate if the difficulties with the physics concepts are indeed due to the difficulties with the conceptual understanding of the definite integral and derivatives itself. These difficulties include deciding the appropriate variable and limits of integration and derivations, clear about the criteria which determine whether calculus is applicable in a given physics problems; and they tended to use oversimplified algebraic relationships to avoid using calculus because they do not understand the underlying assumptions of the relationships. Students also seem to believe that focus on conceptual understanding and concurrent teaching of calculus and physics would facilitate their application of calculus in physics. Our interview result represented a small portion of students taking these courses, but was helpful in identifying the aforementioned issues. One important reason for student difficulties with the physics concept that involve definite integrals and derivatives might be due to lack of coherence between the math and physics instruction. Overall, these findings strongly indicate that students have specific difficulties with definite integrals and derivatives, particularly, with negative integrals and derivatives that have physical significance. The results in this study also suggested that students understand some integrals and derivatives better when they are able to link the mathematical concepts of integrals to some physical meaning. Several physics instructors have started to introduce basic calculus for a few weeks in their classes. The researchers considered this as a good practice because it gives students an opportunity to learn the basic calculus required for the course. They also learn about notation and representational inconsistencies, if there are any, between physics and calculus. Instructors should help students recognize definite integral and derivative ideas when they come up in physics and tie the physics concept explicitly to prior math instruction.

Recommendations

There should be some sort of consistency in notation and representations between physics and calculus in order to prevent student confusion. The researchers found students inappropriate use of ideas related to derivatives to deal with integrals. In order to deal with this issue, the calculus curriculum should focus towards distinguishing between relating the two concepts derivative and integral. This could be achieved by designing problems that prompt the students to deal simultaneously with derivative and integral. For example, one could ask the students to determine both the signs of the slope and the sign of the integral, and then tell the difference between the two. This could be done by reviewing the distinction between when the second concept is taught to help and keep the ideas incomplete.

Integrated curricula and textbooks should be developed to teach calculus and physics concurrently to maximize the possibility that students can apply their knowledge in calculus to learn of physics.

Sequence of physics courses and calculus courses could be restructured to enhance students' achievement. This means, calculus courses could be come first before introductory physics courses for students and additional mathematical courses should be given for students to minimize their calculus knowledge gap because of their background of calculus.

References

Allbaugh, A. (2003). 'The Problem Context Dependence of Students' Application of Newton's Second Law. Physics.'Manhattan, KS, Kansas State University.

Byrnes, J. P. (1996). Cognitive Development and Learning in Instructional Contexts. Boston,MA, Allyn and Bacon.

Bascones, J. and J. D. Novak (1985). "Alternative instructional systems and the developmentof problem solving skills in physics." European Journal of Science Education7: 253–261.

Beichner, R. (1994). "Testing student interpretation of kinematics graphs." AmericanJournal of Physics

Bransford, J. D. and D. Schwartz (1999). "Rethinking transfer: A simple proposal with multiple implications." Review of Research in Education

Broudy, H. S. (1977). Types of knowledge and purposes of education.Schooling and theacquisition of knowledge. C. Anderson, R. J. Spiro and W. E. Montague.Hillsdale,NJ, Erlbaum.

Karplus, R. J. (1974). "Science teaching and development of reasoning." Journal forResearch in Science Teaching 12: 213-218.182

Maloney, D. P. (1993).Research on problem solving: Physics. Handbook of Research on Science Teaching and Learning. New York, NY, MacMillan Publishing Company.

Maloney, D. P., T. L. O'Kuma, et al. (2001). "Surveying students' conceptual knowledge of electricity and magnetism." American Journal of Physics 69(7): S12-S23.

Lili Cui, et al. (2007). Transfer of learning in problem solving in the context of mathematicsand physics. Learning to solve complex, scientific problems. D. H. Jonassen. Mahwah, NJ, Lawrence Earlbaum Associates.

Redish, E. F., J. M. Saul, et al. (1998). "Students expectations in introductory physics."American Journal of Physics 66(212-224).

Tucker, A., Leitzel, J. (1995).Assessing Calculus Reform Efforts: A Report to theCommunity. Washington, DC, the Mathematical Association of America.

Van Heuvelen, A. (1991). "Learning to think like a physicist: A review of research-basedinstructional strategies." American Journal of Physics 59: 891–897.187

Yeatts, F. R. and J. R.Hundhausen (1992). "Calculus and physics: Challenges at theinterface." American Journal of Physics 60: 716.

Anderson, J. R., Reder, L. M., & Simon, H. A. (1996).Situated learning and education.Educational Researcher, *25*(4), 5-11.

TesfayeSemela (2010). Who is joining physics and why? Factors influencing the choice of physics among Ethiopian university students.*International Journal of Environmental &Science Education* Vol. 5, No. 3, July 2010, 319-340

Granger Meador (2010). Inquiry Physics a Modified Learning Cycle Curriculum.University of klahoma.

Hall, Jr., W.L. (2010). Student Misconceptions of the Language of Calculus: Definite and IndefiniteIntegrals. In *Proceedings of the 13th Annual Conference on Research in UndergraduateMathematics Education* (Mathematical Association of America).

Meltzer, D.E. (2002). The relationship between mathematics preparation and conceptual learning gains in physics: a possible 'hidden variable' in diagnostic pretest scores. *American Journal of Physics*, 70, 1259-1268.

Rebello, N.S., Cui, L., Bennett, A.G., Zollman, D.A. and Ozimek, D.J. (2007). Transfer of Learning in Problem Solving in the Context of Mathematics & Physics. In *Learning to Solve Complex Scientific Problems,* David Jonassen, ed., Lawrence Earlbaum Associates, New York, 2007.

Redish, E. F. (2006). Problem Solving and the Use of Math in Physics Courses. In *Proceedings of the Conference, World View on Physics Education in 2005: Focusing on Change*, Delhi, ugust 21-26, 2005.

Vinner, S. (1989).The avoidance of visual considerations in calculus students.*Journal of Mathematical Behavior,* 11, 149-156.

Rebello, N. S., and Zollman, D. A. (2002). The effect of distracters on student performance on the Force Concept Inventory.*American Journal of Physics – PER Supplement, 70*(7).

Reed, S. K. (1993). "A schema-based theory of transfer". In D. K. Detterman and R. J. Sternberg (Eds.), *Transfer on Trial: Intelligence, Cognition, and Instruction*. Norwood, NJ: Ablex Publishing Corporation. Pp. 39-67

Resnick, L. B., and Ford, W. W. (1981). The Psychology of Mathematics for Instruction. Hillsdale, NJ: Erlbaum.

Rebello, N.S., &Zollman, D.A., et al. 2004. Dynamic Transfer: A Perspective from Physics Education Research. In: Mestre, Jose P. (ed), Transfer of Learning: Research and Perspectives. Greenwich: Information Age Publishing.

Brown, J. S., Collins, A., &Duguid, P. (1989). Situated Cognition and the Culture of Learning. Education Researcher, 18(1), 32 – 42

Feynman, R. (1992). The character of physical law. London: Penguin Press Science

Lederman, N.G. (1992). Student's and teacher's conceptions of the nature of science: A review of the research.

Redish, E. F. (2005). Problem solving and the use of math in physics courses. Proceedings of the Conference, World View on Physics Education in 2005: Focusing on Change, Delhi, India, August 21–26.

Sherin, B. (2001). How students understand physics equations. Cognition and Instruction, 19 (4), 479-541

Skemp, R. R. (1976). Relational understanding and instrumental understanding.Mathematics Teacher, 77, 20-26.

Lobato, J. E. (2003). How design experiments can inform a rethinking of transfer and vice versa. *Educational Researcher, 32(1),* (pp.17-20)

Ministry of Education [MoE]. (2008). Annual intake and enrollment growth and professional and program mix of Ethiopian public higher education: strategy and conversion plan, 2001-2005 E.C. Ministry of Education, Addis Ababa, April 2008.

Ornek, F., Robinson, W. R. W., &Haugan, M. P. (2008). What makes Physics difficult? *International Journal of Environmental and Science Education*, *3*(1), 30-34

Osborne, J., Simon, S., & Collins, S. (2003). Attitude towards science: a review of the literature and its implications. *International Journal of Science Education*, *25*(9), 1049-1079.

Park, J., & Lee, L. (2004). Analyzing cognitive and non-cognitive factors involved in Physicsproblem solving in an everyday context. *International Journal of Science Education, 26*(13), 1577-1597.

Redish, E .F. (1994). The implications of cognitive studies for teaching physics.*The American Journal of Physics*, *62*(9), 796-803.

Tobias, S., &Birrer, F. A. J. (1999). Who will study Physics and why? *European Journal of Physics*, 20, 365-371.

Zewde, B. (2002). Pioneers of change in Ethiopia: the reformist intellectuals of the early twentieth century.Addis Ababa: Addis Ababa University Press.

Rasslan, S. & Tall, D. (2002).Definitions and images for the definite integral concept. In Anne

McKeough, R. E., Lupart, J., & Marini, A. (1995).Teaching for transfer: Fostering generalization in learning.Mahawah, NJ: Erlbaum.

Ozimek, D. J. (2004).Student Learning, Retention and Transfer from Trigonometry to Physics.Unpublished M.S. Thesis, Kansas State University, Manhattan, KS.

D., Bransford, J. D., & Sears, D. (2005).Efficiency and Innovation in Transfer. In J. P. Mestre (Ed.), Transfer of Learning from a Modern Multidisciplinary Perspective. Greenwich, CT: Information Age Publishing.

Yeatts, F. R., &Hundhausen, J. R. (1992). Calculus and physics: Challenges at the interface.*American Journal of Physics, 60,* 716