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# Exploring a Deep Learning Approach on the Teaching and Learning of Introductory Physics

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**Abstract**

The main goal of this paper is to explore the effectiveness of an experimental learning approach in an introductory physics course regarding to student's academic achievement. Research articles point out that learning difficulty about science basic concepts, impact both, the quality of the skills and knowledge learned and hinder students' retention in science basic courses. For this research, Bachelor's Degree students of Natural Sciences, Chemistry, Bio Medical, Biology, Computer Sciences, Medical and Engineering Technology programs were selected. The teaching methodology used was named Learning Two Time Strategy (LTTS). The methodology consisted in applying active learning strategies, but at the same time lowering considerably the time for the traditional teaching process. This strategy allowed students to dedicate more time for classroom learning by increasing in about two thirds the active learning periods. The period assigned for instructions was turned into active learning sessions. Active learning was based in different strategies like "Context-Rich Problems". The methodological concept used was causal comparative (or ex post facto). Seven hundred and sixty-seven (767) students from two private universities in Puerto Rico participated in the study. The students were divided in two groups. The base group of 407 students was not exposed to didactic strategy. Another group of 360 students was exposed to the strategy. The statistical test shed a significant difference in students' academic achievement (value of p = 0.007) measured by the score of their final grades in the course. As a result, the group that was submitted to the strategy showed positive results in the student's evaluation.

***Keywords:*** Deep Learning; Active Learning; Teaching and Learning of Physics; Puerto Rico.

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# 1. Introduction

## *1.1 Background*

There is a generalized perception among college professors about students' academic aptitudes. These aptitudes fall in the average or below average categories in science and mathematics fields. Academic aptitudes are defined as the capacity to achieve in a competent way in the academic tasks, (which include knowledge, reasoning and habits of studying. Authors like John Biggs attribute the situation to the "expansion, restructuration and financing of the university sector during the decade of the nineties which caused schools not to be only bigger, but more diverse in relation to the learning capacity, motivation and cultural base of the students" [1]. A second perception, also generalized among professors is about new generations and points to the lack of reading time and the little amount of time that students dedicate to learn a new subject. These facts have developed a particular dynamic among scholars, bringing on diverse consequences that could hinder curricular contents and the learning of a subject. A person could wonder, what do professors have in mind when preparing their classes? Perhaps they may think. Where is the school? Which textbook should I use? What would I include? How many exams should I give? [2]. Subjects planned under these questions promote a limited execution made by the students. That is so, due to the fact that these questions already bring up a fact: action is centered on what professors do and not on what students will do in the teaching-learning process required by the subject.

On the other hand, The Physics Education Research has revealed that students do not come to the classroom as blank slates, but full of many concepts a priory. These concepts are called by many researchers as misconceptions, preconceptions, alternative conceptions or common sense conceptions. Decades of research in science and engineering [3-11], have demonstrated that traditional introduction is frequently ineffective in promoting sizeable conceptual change. Addressing this issue requires a change of model in the teaching methods, from a model of teaching by telling to a model that directly engages students in a conceptual level that and allows them to build new meanings.

Another important factor to have in mind has a direct relationship with the institutionalization of the learning process. To institutionalize the learning process, according to Briggs [12], frequently emphasizes non essential things, to present a valid project before deadline is institutionally more important than spend time of excellence interacting actively in class. Because of that, despite of professors' best intentions, they are forced to create and keep a context that requires students to focus on form rather than substance, to comply with the requisites not with the excellence. Most of the researches of the last decade have showed that students who interact among them and with the instructor learn the concepts, keep them for more time and can apply them to other contexts better than those who listen to them passively, maybe just to take notes for an exam [13,14].

# 2. Literature Review

## *2.1 Some considerations about students' learning*

Teaching and learning related literature generally highlights the importance of knowledge's active building by the apprentices. Let us take the following quotes as an example [1]: "… qualitative beliefs, from students' common sense about movement and ... (its) … causes have a great effect on its performance in physics, but conventional education inducts only a small change on those beliefs" [2], considering the differences in teaching style from the four professors … (implied in the study) … the gain in basic knowledge under conventional instruction is essentially independent from the professor" [15].

However, other authors like John Dewey, in the decade of 1920, had already anticipated this fact, (when a particular situation is troubled), which is relevant nowadays. So, considering this fact we should make reference to a pair of strategies (just to mention some of them) that facilitate this building process: the art of questioning and investigation. Bain [9], points out that there is no radical importance in the learning style, being them mastery classes, (conferences only), animated discussions in the classroom, demonstrative classes, exercises based in problems, teaching based in discovery, teaching based in inquiry, case studies or Socratic dialogues. What should be emphasized is the fact of allowing some internalization time (of ideas and concepts) inside the classroom (and to come with means the help to this internalization out of the classroom). Some professors already use strategies that take their classes to be of a deep impact in the students' way of thinking, the way they act and the way they feel.

Also, Biggs [2] exposes that: "faculty finds important difficulties to keep the level (academic)". Students' academic level is determined by the development of high level skills, the building of knowledge and the total coverage of the content for the class. It can be said that the academic level does not depend solely on the professor, but also on the institutional resources (technological means, access to update libraries, among others), and of course from the direct action (practice and reflection) of the students about the content of the subject exposed. Redish [16], suggests that to understand how people learn science and how can we use science to learn about how people learn, we need to think about the nature of the knowledge we are learning, and adds, "we share the conviction that when we use the tools of science: observation, analysis and synthesis, we have a better understanding about how students learn and we can find ways to improve the way we teach as a result" (page 9).

Retaking the matter of the two strategies previously mentioned, particularly inquiring. Authors like Finkel [17], speak about teaching based on inquiry, based, precisely on that basic idea from Dewey. The idea that exposes the way human beings are interested and move toward solving an issue. Therefore, inquiring processes are pertinent as means to reduce the time assigned for conferences, and allow time to didactic activities in the classroom. Now then, it is well known that some inquiring models instead of reducing the time assigned for the conference require more time, both in the preparation of the activity as in the execution of it. However, there are different modalities for inquiring. According to Finkel [17], in the book *Teaching with the mouth Shut,* inquiry is conceived as "the investigation of a certain matter or a problem". Investigation in the full extent of the word (to read, to write, to research, reports, exams, class discussions and classroom exercises among others). In Finkel [17] own words, to teach an inquiry based course, "the professor must have an issue, one that would be of interest for the students and also of interest for the professor. Once the professor has the issue, then the investigation

Can begin; and it would be from that investigation, from the attempt to solve the issue, that learning will flow.

If students are really interested in inquiring, they would want to learn everything that would be necessary to continue with it. Outward reasons should not be offered". (page 109). But Finkel [17] warns that if a student is not interested in inquiring, then there has not been any gain with this change. That is why for this project; those changes represent a significant challenge.

With regard to "the art of questioning" as a pedagogic strategy, worth noting that the question provokes a question, so that, "when we can stimulate our students successfully in a way that they could ask their own questions, we are just in the base of the learning process" [3]. This strategy, if executed adequately can become a valuable resource in the development of "meta cognition" (the capacity to react about what the person has learned and how does a person learn) within the students. The inquiring strategy has the advantage that can be used both by a conference minded faculty, as for those faculties that prefer pedagogical activities from a constructivist type. Whichever would be the strategy to use, the art of questioning, inquiring, or any other, the intentionality of learning should be considered. Every question, every available material, every learning activity should bring on an intention to pursue deep learning from the part of the apprentice. Furthermore, this intentionality should be aware of the social, cultural and generational context in which the students find themselves immersed. Bain [3] emphasizes that the best professors (begin their classes) with something that "matters to the students", something that they know about or they believe they know about. Not displaying a scheme, or a sketch, or a theory, or a story of the professor's own experience.

But among all that it has been mentioned previously it coexists an element of utter importance, the so called "preconceptions". These are defined as previous conceptions that students bring to class [3]. Many of these preconceptions obey to mental model already established ("old"), some of them even could be wrong. The thing is that there are always alternate conceptions that human beings use to interpret their reality. So, professors in their subjects should provide means for the building of new mental models that incorporate the "right" knowledge, validated by the correspondent subject. But to eliminate these models will not be an easy task. Then, it is critical for the students to master the proper language required for the subject. By doing this they will strengthen and expand not only the vocabulary but at the same time, the contexts under certain definitions and concepts typical for the subject to operate. Likewise, they will face certain situations in which the existing mental models will not work [3]. However, to change a wrong mental model for a right model of the reality is a gradual change that requires time, effort and dedication.

Now then, to "learn" something new brings the apprentice into two sequential processes. It will bring the apprentice into an emotional process, followed by a cognitive process [18]. This topic is important because aspects like: stereotypes [3], social desirability and the psychological sensibility of the students among others, will have to be considered in the planning of teaching and the learning of new concepts. Bain [3], points out that the process should begin with the students rather than the subject. As a consequence, the first link to have in consideration would be the psychosocial and cultural profiles of the students, ahead of the cognitive. This author suggests that in helping students to learn implies to influence substantially and continuously in the way they think, act and feel.

### *2.2 Active Learning*

Students learn much more from inquiry based activities and problem solving activities than from listening to conferences [19]. For this reason, two assumptions have been taken to conceive this study. The first one is widely known by the academic community, and it is related to the fact that learning is much more effective when it carries out an active role in this process (and the professor is only a guide). Some other results that support the efficiency of active participation methods are reported in the literature [5, 20]. These authors point out that the increases of the improvements to the learning process are due to the nature of the active participation and not to the time assigned to a given topic. Together, other research studies [21,22], provide considerable support to active participation methods, particularly to approach some of the students' basic erroneous concepts. The importance of approaching the erroneous concepts of the students has been recognized as an essential element of effective teaching [23,24].

The second assumption is related to what has been called as internal pedagogy and the language of the subject [25]. That is to say, each subject has a particular way for learning it (An axiomatic view of field and the reasoning of its content). In the light of these two assumptions, a didactic approach was experimented: Two Time Learning Strategy (TTLS) whereupon students find the adequate time in the classroom to make viable a student centered learning process [2,3,18,26,27]. The approach is conceived as a mean to promote among students an interest, of an intrinsic nature, to their own learning. This approach empowers an autodidact culture that reinforces the learning mechanisms to which students are exposed throughout their college studies. The acquisition and reinforcement of learning mechanisms should empower and make viable the obtaining of a deep learning by the students [2,3].

This strategy is conceived within other strategies that professors have been using [2]. But adding small changes based on the correspondent literature to human learning. These changes go from the way the students are seated in the classroom to changes in the order of content exposition. It is also assumed that if the lessons contain a significant percentage of learning activities in the classroom (opposite to merely explanatory classes), students will develop a better comprehension of the topics studied.

Reference [28] quotes numerous researches that suggest that a student's attention span during a conference is approximately fifteen minutes. After that time span, Harley and Davies [29] found out that the amount of students paying attention to the class decreases dramatically and as a consequence a loss in the retention of the material assigned for the conference. Besides, the conference method is a relative poor method to keep the student´s attention [22]. As a consequence, the findings of this type of research suggest that the concentration of the students during conferences begins to decrease after 10-15 minutes from the beginning [30]. A summary of the different types of evidence offered to support this assertion is provided by [30].

Then, it is conceived a transforming pedagogy that, as exposed by Bain [3], distinguishes between strategic learning (based exclusively on academic performance) and deep learning (transformation in the way of thinking, acting, or feeling of the students) [31]. For some didactics of this nature to happen, it is necessary the students will be exposed to diverse learning experiences [3]. It is suggested that every group of professors in charge of common subjects (or the same subject), develop pedagogic intervention protocols in the classrooms. In order to do this, it is required that the "expertise" of the professor both in the content of the subject as in the pedagogy of it (developed through years of teaching). And of course, a positive attitude, that will be coherent with the desire of teaching a transforming education.

## 3. Objective of the study

The objectives of the study are:

1. To explore the experimental teaching approach on student's achievement (academic performance), with major BS in Natural Sciences, BS in Chemistry, BS in Biology, BS in Bio Medical, BS in Medical Technology, BS in Computer Sciences, BA in Mathematic, and BS in Engineering, in courses of Physics.
2. To explore the experimental approach on students' final grade in the courses.
3. To explore the experimental approach on students' retention in the courses.

## 4. Hypotheses

The research hypotheses to be tested are as follows:

1. There is significantly difference between the experimental and base group respect to the students' final grade in a course which not utilized LTTS approach.
2. There is relevant difference between the experimental and Base group respect to the students' retention in a course which not utilized LTTS approach.

## 5. Research Methodology

This study seeks to investigate the effects of using an innovative teaching approach (LTTS) and compare it to the physics teaching without LTTS method with science and engineering students. The dependent variable was the academic achievement of the students, while the independent variable was the teaching strategy.

### *5.1 Design*

In this paper ex post fact or causal comparative study was used; the situation does not permit the manipulation and randomization of variables [32,33]. Specifically, we used the proactive ex post facto research design.

### *5.2 Sample*

The sample consisted of 767 sciences students at two private universities, 360 were in the experimental group and 407 were in the base group.

### *5.3 Research Instrument*

To measure academic performance, the course final grades were obtained for each student and also obtained the attendance in the course for each student. To measure the final grade of each group, several categories for all students were standardized. For both group, base and experimental, categories were: Partial Exam 1 (Midterm), Partial Exam 2, Partial Exam 3, Final Exam, and Laboratory. The students were from a diverse major: BS in Natural Sciences, BS in Chemistry, BS in Biology, BS in Bio Medical, BS in Medical Technology, BS in Computer Sciences, and BA in Mathematic, and BS in Engineering.

### *5.4 Base Group*

The materials used for the base group were the course syllabus, the textbook, exercises assigned by the instructor, four exams (a midterm, two partial exams a final exam). The midterm and partial exams were combined between multiple choices (60%) and problems solving (40%). Additionally, each student took the course in the classroom for a period of a trimester in a traditional classroom setting. However, for the second group of universities for the base group, the materials used were: the course syllabus, the textbook, homework problems, and four exams (40%) multiple choice and (60%) problem solving.

### *5.5 Experimental Group*

This group was exposed to an innovative teaching approach (LTTS). All the other aspects, like materials used for the base group were similar to the experimental group, such as the course syllabus, the textbook, exercises assigned by the instructor and four exams (a midterm, two partial exams a final exam).

For both universities in the experimental groups, the instructor's theoretical intervention, in the classroom, was for periods of time equivalent to one-third of the total period of the class (approximately 40 minutes for two-hour sections). There were held a series of activities during the course that allowed students to participate actively with their peers and with the professor.  Applying and assimilating the concepts taught.  Brief activities were introduced to the lecture. (Interactive lecture demonstrations, Peer discussion activities, Collaborative group activities and Take home experiments)

### *5.6 Teaching Strategy*

The didactic approach proposed for this research is Learning Two Time Strategy (LTTS) which is based on two ideas: the first idea is related to get an adequate proportion between the topics exposed through conferences and the topics exposed through didactic activities in the classroom.  This proportion must be at a level in which active learning time should be maximized, so that the students can internalize their knowledge in an active way with the aid of the professor.  This research study was worked within a fraction of the time assigned for the class.  Two thirds of the total time assigned for the class was assigned for students´ active learning.

The second idea linked to this approach is related to the strategies that professors have been using throughout their teaching careers up to the present.  Biggs [1], in his book Teaching for *Quality Learning at University* suggests that, “it is not about acquiring new learning techniques, but to take advantage of the great data base of knowledge, derived from the research, about teaching and learning that we have at our disposition”.  So, based on the strategy that each professor uses in the classroom and the peculiarity of the class, it is expected that throughout the professors´ academic reflections and “expertise”, they add teaching-learning mechanisms that allow space for didactic activities in their classroom. It is about making small changes that go from the way the classroom is physically configured to changes in the thematic order of the subject. In that way themes and concepts are exposed throughout the actions of the students and not solely by the action of the professor.

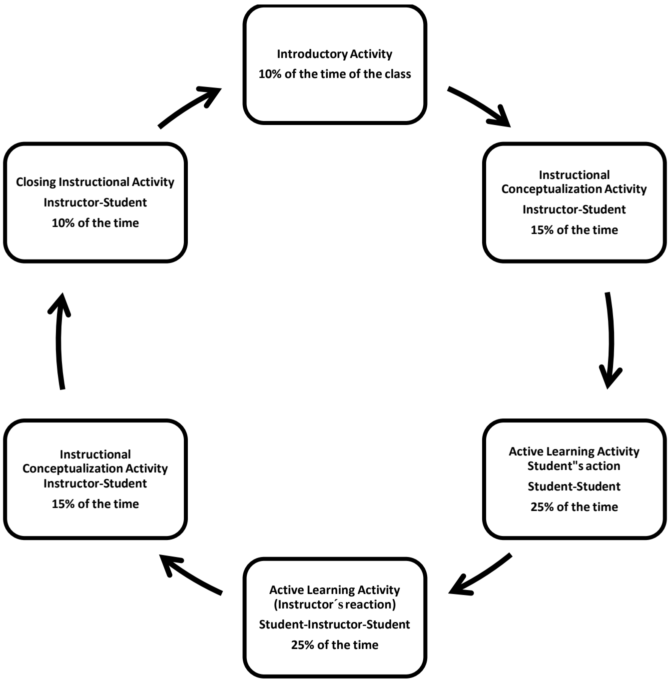


**Figure 1:** Distribution about time and learning activities based on a 100 minutes-cycle.

For this study, specifically, there were group activities selected such as: description and measures of physical quantities: kinematics; concurrent forces and dynamics; energy and momentum; not concurrent forces and stability; and heat. Sessions were prepared to conceptualize the contents and sessions to build content meaning by the means of active learning activities. The amount of session’s correspondent to active learning made up a 25% of the total amount of the class time. Figure 1, shows a diagram of the didactic cycle to which students were exposed. In this diagram, there was a beginning activity that took approximately 10% of the time of the class. There were two learning sessions. Each one took 25% of the time of the class. Also, there were two sessions of instructional conceptualization activities. Each one took 15% of the time of the class. To finish, there was a closing activity to resume the topic taught and to connect with the next learning topic.

The first step consisted in the selection of the totality of the topics (concepts) that are exposed throughout a traditional or contemporary conference. Certain amount of topics was exposed by the means of context didactic activities in the classroom. It should be noted, that these activities are not mean to support the comprehension of the magisterial class. It is about classroom activities by which, topics focused in the student will be brought and studied. This goes along with Finkel´s idea [17], which suggests to “using the subjects instead of covering them” (page. 107). There had to be asked for the planning of the class in the experimental group: which physics concepts, students can board by themselves and which ones not? from there it was determined the proportion of topics or concepts exposed at the conceptualization stage and which ones will be exposed through didactic activities of active learning in the classroom. It also helped for this selection what Biggs [1] pointed out, that "the key to reflect on the way we teach consists on basing our thinking in what we know about the way the students learn". Also by the expression that: "Learning is the result of its constructive activity in a way that teaching is efficient when it supports appropriate activities to achieve curricular objectives, therefore encouraging students who adopt a deep learning approach".

**6. Results**

Results from table 1 and table 2, show that data is not normally distributed. Both for the base group as for the experimental. So, it is justified the use of an inferential test, not a parametric one like Mann-Whitney´s to analyze the possible existence of a significant difference between both groups of study.

**Table 1:** Normality test for experimental group and for base group.

| | Kolmogorov-Smirnov[a] | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| Data | .197 | 767 | .000 | .873 | 767 | .000 |

a. Lilliefors Significance Correction

**Table 2:** Mann-Whitney Test

| | Data |
|---|---|
| Mann-Whitney U | 65191.500 |
| Wilcoxon W | 130171.500 |
| Z | -2.704 |
| Asymp. Sig. (2-tailed) | .007 |

The results of the final grades distribution, which can be found in Figure 2 also illustrated that 55.4% of the students who participated in the experimental group passed the course with grades of A, B or C as compared to 37.7% in the control group. In the experimental group, 44.6% obtained unsatisfactory grades of D and F and code of W as compared to 62.3% in the base group. The analysis showed that the experimental group had 4.1% more students with a grade of A, 1.9% more who obtained B, 11.7% more who obtained C, 0.2% less obtained D, 0.5% less obtained F and 16.9% less obtained a W. This indicates better performance of the experimental group in all measurable parameters. Regarding student retention, the retention was related to the number of W (students who dropped out of the course) and difference of around 17 percentage points was found between the two groups in favor of the experimental group. However, in this difference in the percentage of W, no statistically significant difference could be established due to the nature of the variable, but we find a relevant difference.

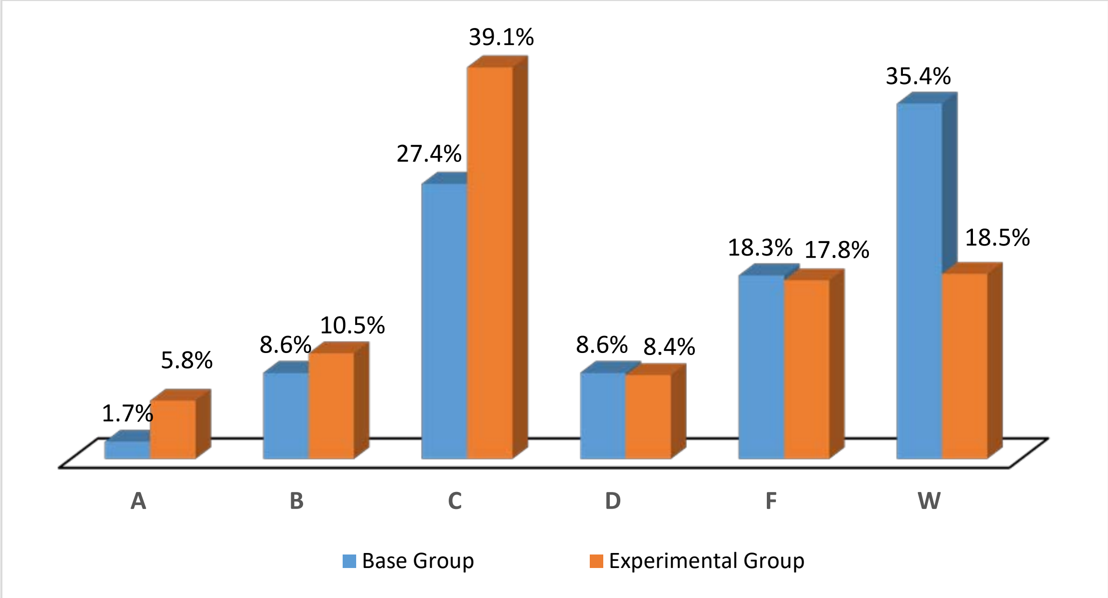


**Figure 2:** Distribution of final grades obtained by students in experimental group and control group

Thus, a significant difference was found in the academic performance of the students in the experimental group as compared to the base group, as the p-value was .007 and it is less than the Mann-Whitney. This shows the rejection that there was no difference between both means of both the control and experimental group. In other words, data confirmed that the p-value was 0.007 and it is less than the significance level of 0.01; hence, there is a significant difference between the two groups.

## 7. Conclusions

It is not intended that the evidence found in the research will work for all cases. However, it is possible to characterize, in general terms, aspects like: (1) the time for interaction from the students with the contents, which allows students to internalize concepts through action over the contents, (2) action in learning processes generates favorable results in terms of students' academic achievement and (3) when professors dedicate less time for verbal transmission of the contents, they can give feedback and correct possible conceptual mistakes filtered in students learning process. Regarding student retention, based on the number of students who left the course, the pedagogical strategy allowed to keep more students connected to the teaching-learning process. In such way, this strategy allows a teaching that is coherent with the new generations of students that are admitted to Science and Technology programs. These aspects should be present in the active learning approach to which students in the classroom are exposed. The results obtained in this research keep close coherence with the literature on the field which reports that what a student does (inside and outside the classroom) is more important to determine what they learn (the students) than what the professor does (in the classroom) [1-3,17,25,38].

## 8. Limitations and Recommendations

The results of this study appear to show that there are benefits to using of the particular teaching methodology

LTTS. However, there are limitations because this study was conducted in certain geographical area of Puerto Rico. Therefore, the results may not be generalizable to the other populations of Puerto Rico and other countries. Furthermore, the researchers recommend future studies which replicate this teaching methodology in other populations inside and outside of Puerto Rico to determine the replicability degree of the results and how much generalizable are.

Another two important recommendations for this study are: first, to consider other methodology design of research, for example the design experimental. Second, to consider other independent variables as the cultural or social aspect. Due that this study was carried out in a place with a specific culture and we did not measure the impact of the culture on the educational achievement and attainment. We would be interested known if this cultural differences among students have some impact on teaching methodology LTTS.

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