

# Learning by Teaching strategy to improve learning outcomes from undergraduate students

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**Abstract** — This paper describes the use of learning by teaching (LBT) as an instructional strategy to promote standards education in an undergraduate computer science course. The main objective of this instructional strategy is to make students understand how standards and computer network technologies are fundamental resources to create and use both internet infrastructure and services in a multitude of devices presented in daily activities. Such instructional strategy involves a distance learning platform with a sort of resources such videos, animations, class materials, online books and other resources, a set of equipment such as routers and switches to students make experiments, as well as librarian collaboration to provide access to technical standards and digital libraries. Preliminary results and observations indicate that learning by teaching is an effective approach to introduce technical standards in a computer science course compared to a traditional approach.

**Keywords** — standards education, learning by teaching, peer tutoring.

## I. INTRODUCTION

The study of computer networks technologies is vital to undergraduate students understand how to use the available resources from internet in order to create new systems and services. The standards are an essential source of information for the service and system high quality and proper design. Despite the importance of standards, several undergraduate academic programs seem do not incorporate the study of standards in the curricula, which create barriers for students to understand how a multitude of devices may interact to provide services or how to create systems using heterogeneous technologies. Computer Science students usually study software engineering standards, but not always have contact to IEEE standards or even with Request for Comments (RFC) from Internet Engineering Task Force (IETF).

The undergraduate students are considered digital natives and usually they do not realize (or do not think about) there is an infrastructure that need to have standards to provide devices interoperation and digital services such as instant messaging, video on demand or a simple web browsing. For them, learning standards do not seem an important issue.

In the proposed approach, students were introduced to all topics in classes when the teacher presents the main issues of each topic in the computer networks course syllabus and briefly do the relationship between them. The students were

also introduced to several types of resources, such as video, animations, reference sources and journal articles to create their own classes and had access to real computer networks equipment and computers to deeply test and check mechanisms defined in the standards. Such approach made the education of these concepts more interactive since it provides a dynamic and close relationship between standards and the services and systems that students use in daily activities.

This work aims to foster the discussion about how active teaching methodologies, like Learning By Teaching (LBT), can collaborate to encourage students of the Science, Technology, Engineering and Mathematics (STEM) courses [1] to study concepts presented in computer network standards and may be able to apply them into several scenarios. According to the case study carried out in [2], in which teachers indicated that the methodology based on LBT: "... supports life and career skills such as team work, flexibility, being enterprising, adaptability, self-management, responsibility and effective studying"; and those are fundamental skills to 21st century professionals. In order to improve students' abilities regarding to the subject of computer network standards, an instruction strategy will be discussed based on LBT methodology to teach critical IEEE and RFC standards related to computer networks in an undergraduate computer science course. These instructions are based on experimentation of the emerging effects of this method, in which 24 students participated in classes and activities according to the steps suggested by the Learning by Teaching methodology. The activities in the proposed approach was arranged according to revised Bloom's taxonomy [3] as a method to classify them according to the level of students' understanding about each course topic.

## II. LITERATURE REVIEW

In contrast to the traditional teaching methods based on lectures with few interactions between students, the active learning promotes the engagement of students in the learning process through class discussions, laboratories, projects and field experiences [4]. Several papers on the current literature presents topics about how students and teachers react with the adoption of active teaching methodologies and discuss the resistance of both students and teachers into adopt new learning methods. according to [5] the adoption of new teaching model has been slow, despite significant evidences of the efficiency of the method. The empirical results in [5] indicate that the

instructors have great influence to diminish the resistance of students in the use of the new methodology.

Learning by teaching and peer tutoring are not a new trend in education but in recent years several papers described application of this instruction strategy as a tool for active learning and a way to students improve their own learning [6], [7]. LBT presents relevant results in both higher education and middle school, making students to overcome their struggles and improve the retention of the topics studied as described in [6] and [8]. The complexity of the systems under development and the multitude of communication technologies presented in daily activities has an intrinsic demand for standards that not only guarantee the interoperation between systems and services, but also provide the principles to strategic planning of future infrastructures and services [9]. In [10] is discussed three categories of standards for complex projects such as smart city project: (i) the strategic standards to planning the infrastructure and basic requirements; (ii) process standards to structure process management and provide coherence between communication processes; (iii) technical standards with detailed definitions of processes, mechanisms and algorithms. In the study of Agayev and Mamedova [11] the main objective of higher education is the training of the skilled employee and standards are a fundamental knowledge to professional growth. However, a professional must be able to continuously learn by himself and he must be prepared to do so.

The LBT as an instruction strategy may incorporate the knowledge of computer network standards in an undergraduate computer network 101 course as a way to promote more dynamic classes with a deeper understanding of standards and technologies related to local area networks and internet routing issues.

#### *A. Learning by Teaching*

The active learning concepts may be applied using several methodologies, one of which is the LBT defined as a teaching strategy in which the student assumes a role of tutor and through the teachers' assistance teaches other colleagues about some subject. Studies indicate that the student in the role of tutor retains knowledge more efficiently when compared to other passive methods of teaching, such as traditional classroom when lectures are given with a teacher presenting all knowledge while the students taking notes. Recent researches based on the learning approach proposed by Jean-Pol Martin indicate the effectiveness of LBT in the development of students' abilities expected in the future professionals of XXI century [2].

There are three steps to apply LBT strategy [12]: (i) preparation for teaching; (ii) learning by teaching and (iii) recursive feedback. In preparation of teaching the students must gather pertinent contents to structure their reasoning about the subject. In this stage lies the expectation for teaching for the colleagues, which motivates the student to understand the topic as best as he can to teach. And such situation contributes to a deeply learning.

Once completed the preparation for teaching, the effective stage of learning by teaching begins, in which the tutor explains the content learned to the others. The tutor could be

stimulated to think about what he effectively learn throughout doubts that arise from the students that are learning with him.

The last stage of LBT is the recursive feedback, in which the tutor receives feedback that arises from the evaluate of the performance of his learners/pupils, that is, how the learner/pupil act using the taught content explained by the tutor, in this way, exercises could be applied to the learner/pupils to guarantee of what tutor taught is correct and was properly explained. Whether some student makes a mistake in an exercise, it may indicate that he did not understand some concept of the subject, both students may revise the concepts and work to achieve the right understanding. The teacher assistance may be required at any time. These steps generate an interactive and active work between students and between students and teacher. The expected result is a deeply understanding of the studied concepts [12].

A survey in [13] concluded there is no relevant differences in grades of an assignment applied after the class between a group of students that learn by traditional methods and two group of students: (i) a group of students that do the LBT and (ii) other group of students that just prepare themselves to teach, but did not. However, a second assignment after a week of the first test indicated that the group of students that effectively taught other students achieved a deeper degree of retention of knowledge that the other groups of students. In [14] the significant retention of content (memorization) and understanding were achieved in a group of 120 students (60 tutors and 60 receiving students). All those studies indicate benefits of LBT in several situations, but none of them were related to learning technological standards in an undergraduate course, or even detailed the complexity of the subject in which LBT were applied.

#### *B. Peer Tutoring*

Peer tutoring is also a learning strategy which can be defined as: "...people from similar social groupings who are not professional teachers helping each other to learn and learning themselves by teaching". Three issues can be associated with peer tutoring: (i) emotional satisfaction from tutors when they help learners and perceive his own learning development; (ii) personal responsibility related to tutor while engaging himself during the teaching activity; (iii) the interaction between learners and tutors [15]. Other Survey emphasizes the importance of encouraging student tutors in their preparation before leading study groups. The survey indicates that peer tutoring improves learning from both student - tutors and learners/pupils [16]. Peer tutoring has similar issues compared to LBT, and in this paper only LBT is taking into consideration. The next section is described how LBT was applied in a computer network class using IEEE and RFC standards as one of the reference materials of the course.

### III. TEACHING COMPUTER NETWORK USING LBT

The LBT was applied in computer network classes as the learning strategy to motivate students to study the technologies and standards used for communication in both local area networks and IP addressing related topics.

LBT activities in the classroom combined individual with group tasks, however the evaluation described in this work takes into consideration only the individual grades of students. The LBT learning strategy was applied in three topics of the course, and in the end of each class students answered questions about the studied topic. The LBT was applied in switch technologies and its mechanisms, VLAN (Virtual LAN) and STP (Spanning Tree Protocol), and IP (Internet Protocol). Students had text books to study and a set of videos, animation, reference sources and scientific and technical papers, and the standards and references related to standards. In each class, the group of four students were organized as follows: two as tutors and two as learners/pupils. If a student is tutor in one class, he would be learner in the next one.

In order to prepare students to work with LBT, teacher did a lecture about local area networks (LAN) topics to present the relevant technologies that will be studied in the LBT classes, including switch technologies, VLAN and STP. The most important mechanisms of each technology are presented in a real scenario of a LAN in order to help students to understanding the importance of each technology in the network operation and how such mechanisms are related. The objective is to give an overview of all topics to the students in order to help them during the preparation to explain to their colleagues about one of the proposed topics of the course (or to teach).

For any other class of LAN all students receive a set of questions to think about and engage tutors in the topic that will be taught in the next class (a week later). Such questions are also related with a typical scenario that students know, such as "how your computers exchange data using the Ethernet switch? How it may delivery all frames correctly to every machine?". In order to study and be prepared for the class, students have a distance learning environment with several videos, animations, online books and texts about each topic of the class, as well as have access of technical standards and physical reference books through the library subscription. Currently, students have access to full text access to standards from IEEE and IEEEExplore, and to other databases such as Elsevier and Springer.

As the majority of students have not been worked with standards prior in the computer science course, the teacher presents for each topic the standard that should be used in the class. For example, the IEEE 802.1Q standard for virtual lan (VLAN) class, the IEEE 802.1W for the spanning tree and the RFC 2474 and RFC6918 (among others) to IP. For each standard, the students should study some of the mechanisms and understand how they should be used in the proposed scenario for the class.

The students were organized into groups of four, and in each class, two students took on the role of tutors and the other two the learners (pupils). In the subsequent class students changed the roles. The students have access to switches and routers with respective tutorials to configure equipment and evaluate the effects of mechanism studied in a scenario described in the tutorial. The teacher could provide support for any question that the group could not solve by themselves during the class. The tutors had around 80 minutes to teach and

the group should to answer some questions in the distance learning system after the class (around 20 minutes). At the end of questionnaire, the student received a feedback about the results.

#### IV. RESULTS AND LEARNING OUTCOMES

Each LBT class had an individual assignment to students demonstrate their learning outcomes, and such results were compared to two evaluations that was done during the term. The teacher also took notes about the development of activities in the classroom. The objective was to register what happened in each class and compare it to the evaluation about the LBT methodology that students did in the end of the course.

##### A. Teacher evaluation about LBT approach

After the lecture in which students received an overview about the topics, they had one week to prepare themselves to teach each topic. During the preparation week (one week by topic), students usually did not looked for the teacher to solve doubts or to ask for assistance of any kind, even if teacher was available in his office, by email, or in distance learning environment. However, during the class students asked for help several times during all classes, which may indicate that other approaches of LBT could be used to make students more confident about the topics to teach.

Assignments in the end of class was an interesting tool to check the LBT effectiveness. Using the questionnaire tool of the distance learning environment, the teacher created several questions related with the relevant aspects of the studied topic, each one with a sort of feedbacks that was presented to students according to their answers. The learning environment also reports the success or failure of students in each question, and when a significant number of students did not understand some topic, teacher could provide an explanation in the beginning of the next class or even post some material to them to study online.

The teacher had to change its role to be also a tutor of each group of students, and needed to deal with each group of students work in their own pace. Although there was one topic with clear learning objectives for each class, each group develop their own strategy of presentation and discussion of the subject demanding sometimes more effort than expected by the teacher. Usually, students tried to deal with topics without asking for assistance. However, in issues related to standards such as algorithms, messages, response times of some mechanism, teacher was requested to help to understand the reason for the existence of certain mechanisms and how they are related with some situations of the proposed scenario under study.

The teacher also need to be aware of the discussions in each group and how students are using tools, because some concepts may be misunderstood. At these times, the teacher should interfere in the discussion of the issue and need to identify the misunderstandings and propose a question or emphasize some aspect of the scenario to bring the discussion back to the learning objectives. The LBT was an useful strategy because it was possible to closely follow the development of each group of students. The classroom had 24 students and it was possible

to identify that students could answer correctly direct questions about some technology of mechanism in most of times, after the class done by a colleague. However, they needed assistance to correlate concepts or apply some mechanisms described in the standards in a given scenario, even if a teacher had explained the scenario and briefly pointed those relationships in the first class of LAN or internetworking. Neither orientated questionnaire nor examples using the equipment in lab (tutorials) was quite enough to students make the connections between mechanisms in the given time, around 80 minutes in class or during their preparation for teach in the class. In both LAN and IP subjects the teacher needed to have an extra class to connect the concepts and explain the effects of the application of technologies described in the standards in a real network. The LBT was effective to students understand the mechanisms, but not their applications in a more complex scenario.

Although students were capable to do all the assignments and did all evaluations using LBT learning strategy as the same way as other students that did traditional lectures, the LBT class students asked for more assistance from teacher to work with standards and the concepts of computer network classes. It was not possible to assume those students had more difficulties to understand and correlate mechanisms and messages patterns presented in the standards, but they tried to go deeper in the concepts and that is the reason to request for assistance more frequently.

The first results indicate similar learning outcomes from students working in LBT compared to students of a traditional lecture. In the class using LBT there was 73.0% of students approved in the computer network courses and in class using traditional lecture 78% of students were approved. The two classes were given in the same term, with the same content and deadlines for the assignments.

Some students reported two reasons to disagree of the LBT approach: (i) they do not desire to interact with other students and prefer only a traditional lecture; (ii) they do not understand or not agree with the potential benefits of the LBT approach and prefer to study for regular assignments (in this course there is two assignments during the term).

#### B. Student evaluation about LBT approach

Students answered a survey with questions about students perceptions and evaluation about the application of LBT method in the course. The format of survey was direct questions with multiple choices and an open form when students could write any opinion about the method, the course outcomes, or other impressions.

Taking into consideration only the number of students approved, the dynamism of the classes and the possibility of the students work at their own pace had no effects. One possible reason for this result should be the impact of the new proposed learning method (LBT) which was new for all students. However, most students (92.0%) declared that the method and how to work with it was quite clear in the beginning of the course, and more than half students (58,3%) also declared that LBT made classes more interesting compared to traditional lecture, against 37,5% of them that

prefer the traditional lecture. Analyzing the anonymous posts from students it is clear that some students indicates learning by teaching as an innovative instruction strategies, however they declare themselves more adapted to the traditional instruction strategy when teacher guides students through all topics. Around 10.0% of students from LBT classes anonymously declare themselves uncomfortable to participate of this learning strategy and would only study by themselves as usually did for traditional lectures.

The students also anonymously declared that learned more when taught the colleagues compared to the traditional lecture (66,7%). However, several students (approx. 29.0%) declared that learnt more with a traditional lecture compared to that learned in LBT. Their comments indicate they were unsure about how to teach for a colleague, even if the teacher indicated all relevant points of each topic. And the reason of such concern was the feeling of responsibility to have a better understanding of the concepts in order to teach for someone else. Other pointed reason was they had many issues in a topic that they need to think about and understand how they was related to get a good explanation to the learners.

#### C. Results from evaluations

The contents and the evaluations were organized according to revised Bloom taxonomy [3] as a way to understand the results of the evaluation and also understand the learning outcomes. The evaluations were organized as depicted in table I, it is emphasized that there is no pre-requisite between revised Bloom's categories [17].

TABLE I. CONCEPTS CLASSIFICATION ACCORDING TO REVISED BLOOM'S TAXONOMY

	Switchs	VLAN/STP	IP1
Remember	x		
Understanding	x	x	
Apply		x	
Analise			
Evaluate			x
Criate			

Each topic demands from student more complex exercises and as consequence a deeper understanding of each topic. Such organization permits to evaluate how students were dealing with the LBT strategy and how deeply they were learning. The class about switch and related technologies had lots of new concepts such as switch learning process, concepts about what Ethernet (IEEE 802.3) technology is and its most important topics. However, students only needed to understand how components and mechanisms work together to create a layer two network and remember key features. In VLAN/STP topic students discussed the concepts, the mechanisms presented in the standards (802.1Q and 802.1D) and also applied the technologies in a case study. Because the complexity involved students should understand the concepts and also apply them. In this context, the recursive feedback [12] was relevant to motivate both tutors and learners in wok in one experiment to solve the case study. Tutors could actively review and consolidate their knowledge, and learners/pupils demonstrate to be more interested in learning the concepts to apply them. In

the third class about IP protocol (IP1) students needed to evaluate a scenario and work in a solution in order to apply a distribution of IP address in a scenario based on a real network.

For all classes, it was compared the results obtained by each student between the evaluation in the end of class and the score in an assignment about all three concepts (called P1). This last evaluation was done around a month after the switch class, three weeks after VLAN /STP class and only two weeks after IP class. The students were identified by their role in each class, and in P1 the same level of difficulty were applied to each topic; the question in P1 related to switch topic could be classified as remember and understanding according to revised Bloom's taxonomy [3], the VLAN and STP questions were classified as understanding and apply, and IP question the students should evaluate a scenario.

In figure 1 there was no difference between tutors and learners/pupils and all of them had a good score in both class evaluation and P1. This result demonstrate that students remembered and also understood, and there is no difference between student role. It may have happened because the question was not complex according Bloom's taxonomy; however, it is not possible to confirm improvements since it is unknown how much time students dedicated to prepare themselves to P1.

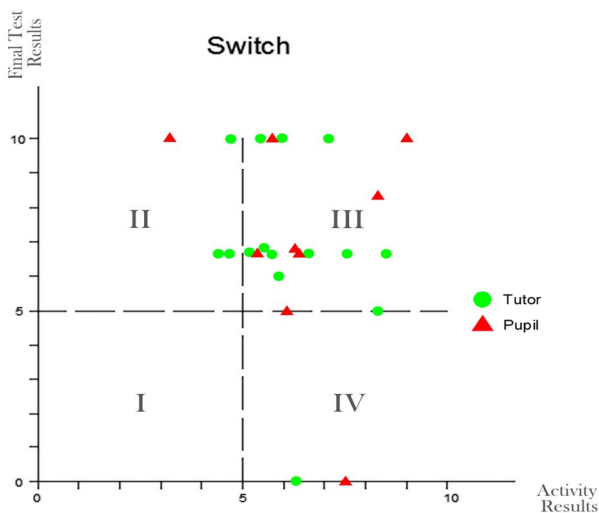


Fig. 1. Correlation between test and activity performance of Switch concept

The figure 2 presents some relationships between tutors and learners/pupils. Most students in area III in the figure II belongs to the same groups, which indicates that LBT could be effective. The students in area II could prepare themselves to the P1, since their results were not good in the class evaluation. And some students did not present a good result in the P1 compared to class evaluation (area IV). Although it is not possible to guarantee how much time each student studied to P1, those questions about VLAN and STP were more difficult compared to the question about switch technologies.

The difference in the distribution of students in figure 1 and 2 suggests that students of the same groups (area III) had a better understand of the topics and could apply such concepts

properly, which could indicate the LBT effectiveness regardless the individual study to P1. And students of area II and IV, which belongs to same groups as well could not repeat the results, and in some cases learners/pupils got better results in P1 compared to their tutors, which suggests LBT was not effective for those students.

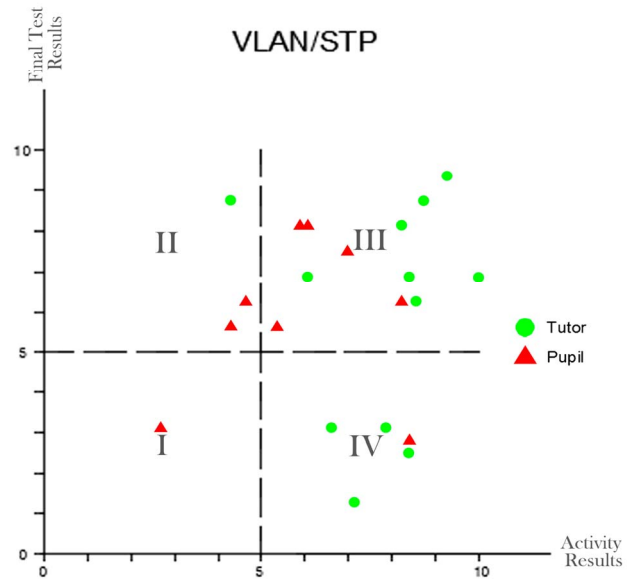


Fig. 2. Correlation between assignments (test) and activity performance of VLAN/STP concepts

The last concept was about IP protocol, its concepts, the application in real networks and the differences between IPv4 and IPv6. As students should work with a question about evaluation in revised Bloom's taxonomy, which can be considered more complex compared with previous questions. Again, the synergy of the group was significant in the results. In area III of figure 3 students of two groups got the best results in both class evaluation and P1 evaluation. However, due to the complexity of the subject the tutors had a better score compared to learners/pupils. Comparing the results of figure III with the average grade and with median grade of the past students of the same course that learnt in a traditional lecture, it can be observed a negative change in the P1 grades, because the median is 4.5 points in IP question. Using the LBT strategy it can be observed that a median was 3.75 and it happened because most learners/pupils did not reach good grades. Tutors had median in 9.37 which indicates that for more complex questions the tutors get better results, which is a similar result compared to the literature [14].

## V. CONCLUSION AND FUTURE WORK

The preliminary results and observations based in an anonymous survey identified some trends. First, students indicate their understanding of technical standards and technologies related to computer networks have increased after LBT classes, especially when they studied to teach a colleague. The initial analysis for the two global evaluations of the course indicated the students achieve better grades in the subjects they

taught compared to subjects they learn with the colleagues. The second trend is students prefer to use LBT instead of traditional lectures and the majority approved LBT learning strategy, however they need more assistance to correlate the mechanisms and algorithms presented in standards with proposed case studies.

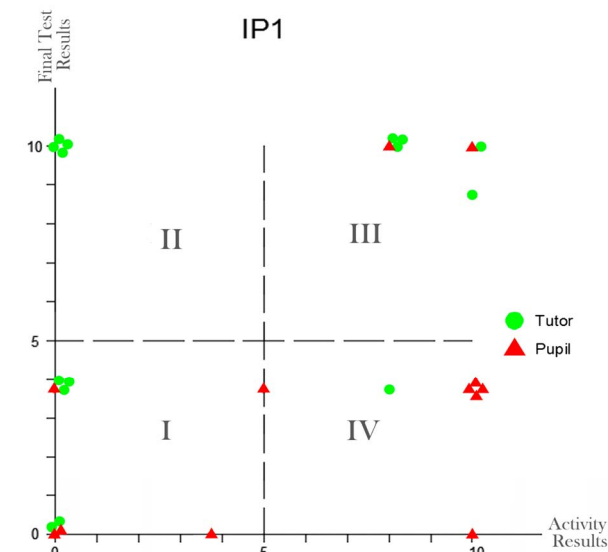


Fig. 3. Correlation between assignments and activity performance of IP1 concept

Based on answers provided in survey it was not possible to verify whether students became more confident to study by themselves or the discuss technologies related to computer networks or not. Students indicated that they enjoyed and prefer LBT, and at the same time requested more assistance in the future. It is not clear with they need assistance to relate what was studied with case studies or there is other difficulties not detected during this course.

The ability to teach is essential to the professionals of this century [2] and LBT could promote such skill development. The results obtained by learners/pupils in evaluation indicated that students are able to teach when LBT is applied, but some support from teacher is necessary to deal with students doubts or to advisory in several subjects related to teaching activity. The students changed their behavior during the experiments in the three classes and it was related with the complexity of the topic. The results suggested the groups that work better and did a richer discussion got better scores, and also suggested that the retention of groups that better work in LBT got better results as well.

Future work includes to plan continue improvements in the online materials to help students to identify the most relevant issues of each topic and better prepare themselves to teach. Some more detailed case studies could be developed to help students understanding about how mechanisms from standards work in real computer networks. Such case studies could be extensions of the current laboratory tutorials. Also, the authors plan to improve the support to students when they are preparing themselves to teach and after the LBT class for

topics that has some misunderstanding detected by evaluations. It is also necessary to explore other categories of Bloom taxonomy to identify the effectiveness of LBT in each category of cognitive skills in order to better prepare students for community.

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