# "Teaching is Learning": Pedagogical material created and evaluated by students

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***Abstract*—The action of teaching reinforces one's learning but requires some external quality control when done by non-professionals (e.g., a professor supervising teaching assistants). This quality control is costly and has limited the adoption of peer teaching in schools. Our solution to this problem is to ask students to create pedagogical material that will then be evaluated by the students themselves, where they evaluate a mix of new and already rated materials. One advantage of this technique is that it allows students to develop critical thinking skills, since they must judge if the presented material adequately covers a specific topic. We describe the "Teaching is Learning" project, that implements these ideas. We first discuss two pilot studies: 1) since 2009, engineering students from the University of Chile have been creating and validating pedagogical 3D animations; and 2) during 2015, seventh graders from the Blest Gana secondary school created and evaluated pedagogical videos using their cell phones, editing the videos during their Technology class. We then give an overview of existing work on measuring student learning, and discuss how we can evaluate the effectiveness of our technique. We conclude by describing our plans for implementing the "Teaching is Learning" project at a larger scale during 2016, both in Chile and in Brazil.**

## I. Introduction

A common intuition among instructors is that one deepens one's understanding of a topic when teaching it. There are at least two aspects of the teaching experience which can deepen this understanding: 1) preparing teaching material, and 2) reviewing and correcting students' answers. When preparing material, the instructor breaks down knowledge into smaller fragments and organizes it, which helps improve the memorization process. On the other hand, when reviewing answers, especially wrong ones, an instructor is pushed to explore the same knowledge from different points of view.

Given these benefits, it is tempting to generalize this practice from the small population of instructors to the large population of students. For example, if second year engineering students teach first year students, they can deepen their own understanding of the material while at the same time lightening the instructors' teaching load. The caveat, of course, is that generalizing from trusted instructors – who fact-check and prepare new material – to a general population of students – who may commit errors or mischievously introduce some – requires external quality control. This is more expensive than the traditional setting where the instructor simply teaches, since each interaction between the instructors and students, as well as between students, must be supervised and assessed.

Student teaching activities can be included on a larger scale if we can systematize their assessment. Inspired by collaborative quality control techniques introduced by systems such as Re-Captcha [1], Calibrated Peer Review, Amazon's Mechanical Turk [2] and others, we propose the "Teaching is Learning" (TiL) methodology. Here, students must: 1) create pedagogical material aimed at other students (as opposed to teaching those students directly), and 2) evaluate the pedagogical material produced by other students, according to some specific criteria defined by the instructor. In this step, students assess a random selection of both new pedagogical material and content that has already been validated by instructors. In addition to other more traditional objectives, we believe that this will help students in developing critical thinking skills, since they cannot assume a priori that all material is correct and/or complete.

We first describe two separate pilot studies that we carried out during 2009 - 2015. We then give an overview of how to measure student learning. We finally describe the studies that we will carry out during 2016, involving both secondary and tertiary students, and how we plan to evaluate the TiL methodology.

## II. Pilot Studies (2009 - 2015)

### A. "EI2001: Taller de Proyecto" course (2009 - 2015)

The "EI2001: Taller de Proyecto" course, taken by second year engineering students at the University of Chile (Santiago, Chile), aims to bridge the gap between theory and practice. Several sections are available, each one with a different theme, and students must register for one of these sections. For example, one section has students programming LEGO Mindstorm robots, while learning: 1) how to collaborate in small groups, 2) how to plan work under time restrictions, and 3) how to present the outcomes of their projects.

Another section of this course, called "Pedagogical Animations", created by J. Barbay in 2009, seeks to address the same pedagogical objectives via the creation of pedagogical videos using the Alice software, which is developed and distributed by Carnegie Mellon University. During the semester, students – in groups of 2 to 3 – must create five pedagogical animations. Each student is expected to spend 4.5 hours per week on these

videos (1.5 hours in class and 3 hours at home), and have 3 weeks to work on each video. Students are randomly assigned to a different group for each video. The general theme of these videos is common to all groups (e.g., Copyrights, Sorting algorithms, Comparing 2 sorting algorithms) and each group picks or is assigned a specific subtheme (e.g. creative commons, Google Image, sources for music "free of rights"). Students can also propose new themes, which must be approved by the instructor. The pedagogical videos are presented in class and evaluated collaboratively using a paper form. This section is taught every year, with cohorts ranging from 42 to 63 students.

The main observation from this long-running pilot is that students are more motivated: the students, both in class and in the teaching evaluations, express their appreciation for the possibility to express themselves creatively; and many students work more hours that they are supposed to. A second observation is that, while most students are reluctant to criticize their peers' work at the beginning of the semester, most are willing to do this by the end of the semester and have learned to do so in a constructive manner.

Along the years, we also administered questionnaires. Here we see that students show an increase in confidence about their ability to work in groups: at the beginning of the semester, asking them about their ideal group size yields an average of 1.2, while by the end of the semester, asking the same yields 1.8. We also attempted to measure how the creation of pedagogical videos reinforced knowledge, but failed because the question was poorly calibrated. We hope to perform a better measurement in 2016.

### *B. "Video Classes" project (2015)*

The "Video Classes" project[1] adapted the "Pedagogical Animations" experience (described in the previous subsection) in order to apply it at secondary schools. We carried out a pilot study at the Blest Gana secondary school (Santiago, Chile), where 82 eighth graders (ages ranging from 13 to 16) were asked to create two pedagogical videos during the semester, targeting students at the same level. These videos were created using the students' cell phones and basic desktop video editing software. Students spent 4 weeks working on each pedagogical videos in groups of 2-3, where they were randomly assigned to a different group for each video. Again, the general theme for these videos is the same for all groups (one Mathematics video, one History video), and the subtheme was assigned to or chosen by each group (e.g., Geometry, War of the Pacific, etc.). Students uploaded their videos to YouTube, submitting the video URL as well as the corresponding pedagogical question (e.g., "After seeing this video, what is the value of the inscribed angle of the circle?") to the TiL system, software developed specifically for this purpose. Students then used the TiL system to collaboratively evaluate three (video, question) pairs from other students.

The students at the Blest Gana school are divided into 3 sections, where two of these created pedagogical videos, and the remaining section served as a control group. In order to measure how this experience improved the students' learning experience, we analyzed the math test scores for all 3 sections. These tests evaluated more topics than those included in the "Video Classes" project, and were created by the math professor, who did not participate in this project. The 18 students that created math videos improved their marks by 1.8 points while the control group improved their marks by 0.6 points (out of 7.0).

This is a promising result, supporting our intuition that students learn more by teaching. However, overall there was a low level of participation in this study: only 3 (15) out of 42 (40) students created all the videos in section 1 (2). One possible explanation is that Blest Gana is a school for underserved students, who in Chile are historically harder to engage in educative experiences and drop out at higher levels than the rest of the population [3]. This is evidence by the large age range of the students. We need to address this issue in the next version of this project, as we believe that underserved students are the ones that can benefit the most from TiL.

## III. Measuring Student Learning

Some questions are quite common among educators and those who propose methods and ways of teaching, such as: are students learning what they are being taught? is what they learn proportional to the time and resources invested? is this effort sustainable? It is hard to answer these questions in a quantitative manner.

Different attempts have been made to quantify how much has been learned. They involve, among other points of learning, motivation [4], preparation and use of concepts [5], and the development of critical thinking skills [6]. These studies present possible ways of assessing student learning in relation to training, the use of concepts as well as critical thinking, and could be considered in future assessments of the "Video Classes" project, in addition to graded tests and activities that are customarily applied in formal education.

### *A. Evaluation*

Evaluation is not just the act of diagnosis, but also includes deciding what to do once a diagnosis has been made, and therefore consists of two inseparable processes: diagnosis and decision. The diagnosis is related to the pedagogical theory used in class [7], and translates into different educational practices. This means that in order to measure student learning, the data we collect must be consistent with the type of learning outcomes being assessed. For example, are we assessing student behaviors or skills? What course topics are being evaluated? What level of expressiveness and clarity are we expecting from our students? In other words, assessment tools need to be carefully thought out, as well as the actions need to be carried out given a result.

### *B. Evaluating concepts*

Pelizzari et al. [5] and Ausubel [6] discuss the significance of learning in the evaluation of concepts, reporting that this

[1] "Video Clases" in Spanish

is more efficient when students' knowledge, personal and past experiences are taken into account when presenting them with new knowledge. This can only happen when students are willing to learn, and it means something to her/him, both logically and psychologically. This means that teachers must carefully select evaluation tools, as well as the actions that they will apply for a given result. Typically, two classmates share more background and experiences than a student and an older professor. Peer teaching lets these students use this common experience to better communicate new ideas to their classmates. We also plan in later iterations to evaluate if guiding the students to include personal experiences in their videos leads to increased student learning.

### C. Development and analysis of critical thinking

Critical Thinking can be understood as an internal cognitive process, reshaped by the experiences and by analysis carried out by the individual, who questions and judges information that she/he receives [8]. It is hard to "measure" a person's critical thinking skills: not only are these skills constantly evolving, but these also change the person in the act. Based on Bloom's taxonomy of educational objectives [9], critical thinking is an open-minded process of discovery and understanding, analysis and application, and synthesis and evaluation. In TiL, students must first study the assigned topic and figure out what subtopic they want to focus on. They then need to work out an example for the video, figuring out how to present this information in smaller units so that viewers can follow the individual steps. They must also identify a pedagogical objective for this video, expressed as a multiple choice question. When evaluating the videos, viewers must be critical, as not all videos will be "good" videos. They are asked to directly evaluate the quality of the video, and to indirectly evaluate the contents of the video by answering the associated multiple-choice question.

In this section, we discuss two methodologies that help understand a student's level of critical thinking: the first establishes a series of criteria that can be used to understand a student's level of critical thinking, but does not necessarily involve the use of quantitative approaches; the second proposed a mixed assessment, with both quantitative and qualitative aspects.

*1) Criteria for evaluating critical thinking in general education:* Northeastern Illinois University established 10 criteria rubric for evaluating critical thinking [10] during oral and project presentations, or via self-reflections essays. During evaluation, the instructor must assess the student's level of proficiency for each criteria (no/limited, some, adequate, high). The criteria ask if the student can: identify and explain issues; distinguish types of claims; recognize stakeholders and contexts; frame personal responses; acknowledge other perspectives; reconstruct arguments; interpret content; evaluate assumptions; evaluate evidence; and evaluate implications, conclusions and consequences. This rubric must be applied by the instructor or a domain expert, so as to obtain a fair assessment of the student's proficiency levels for these criteria.

*2) Mixed Methodology Approach:* Garisson [11] argues that learning is validated by sharing personal interpretations with others. This inspired Rubino et al. [8] to propose the "Mixed Methodology Approach", where critical thinking skills are quantified by measuring certain interaction aspects between activity participants. They present an experience where they applied this methodology, opening chat windows during a video conference in order to measure and analyze the interactions that happened between participants, along with the participation rates (as measured by the number of posts in the chat). All this data was entered into an evaluation matrix, which includes participation rates per person, the number of participants, the types of comments (phrase, sentence, word combination, punctuation, symbol) and the types of participation (management, technical, social, content, combination/social). Rubino et al. linked these interactions with key indicators from the literature [11], finding that the following activities were related to critical thinking: the identification of problems during the presentation, as well as possible solutions, and the presentation of strategies for problem solving, operation and integration. After this check, the data was quantified and analyzed by category, and subjected to a cross-tabulation statistical analysis.

## IV. Current Implementation (2016)

### A. University of Chile

The experiment at the University of Chile described in Section II-A in the context of the course "EI2001: Taller de Proyecto" is continuing in 2016 with only minor changes. The biggest improvement for 2016 is that students will test and use the TiL software to submit their pedagogical material, thus systematizing the calibrated peer reviewing of the pedagogical videos by the student, in parallel with the more traditional, paper-based and in-class evaluations of videos by students. Other, smaller changes are: 1) we switched the order of the general themes of the videos; 2) we removed several lectures that focused on teaching the students to use Alice: as it was designed for use by children rather than university students, this time can be better spent on group work during class.

### B. Chilean Schools

During 2016, we plan to apply the TiL methodology at 4 to 5 Chilean schools. At each school, we will be working with 2 - 3 classes per grade, with an estimated participation of 50 - 90 students and 2 - 3 instructors per school (in total: 250 - 450 students and 10 - 15 instructors).

On July 27th, we will kickoff the current implementation of this initiative with a 1 day hands-on workshop for the instructors from the participating schools. There we will explain the concept of pedagogical videos/questions and iterative design. Instructors will then create in groups a video/question about a predefined topic, submitting them to the TiL system. They will then evaluate 3 videos from other groups using the TiL system, and we will wrap-up the workshop with a group discussion about techniques that instructors can use to improve the quality of pedagogical videos being created by their students.

Between August and October, students at participating schools will be asked to create 3 pedagogical videos, in groups of two to three students. As before, we have defined a general theme for each of the three videos: half of the students at each school will work on videos explaining mathematical concepts, the other half will focus on scientific concepts (students are randomly assigned to a theme). Students will have 4 weeks to create and evaluate each video. During the first 3 weeks, groups select a specific topic within the assigned theme, create a pedagogical video and define a corresponding pedagogical question, uploading them to the TiL system. In the remaining week, students will individually evaluate 3 videos on distinct subtopics created by other groups at the same school. We will measure student learning before and after each video by asking students to take multiple choice tests (half the questions will be about mathematics, the rest about science). We expect to see an improvement in learning based on the assigned theme.

In order to improve the low participation levels experienced during 2015, we will conclude this year's experience with an inter-school event during November, which will be held at the University of Chile. Students can participate in this event by submitting a new pedagogical video, this time about one of the event's challenge topics (e.g., sustainability, privacy and security). During the event, students will get a chance to watch and evaluate the submitted videos using the TiL system, as well as to attend talks on the challenge topics. The submitted videos will also be evaluated according to three objective criteria (format, duration, relevance) and three subjective criteria (clarity, pedagogy, originality) by a panel, and prizes will be awarded to the best videos per challenge topic. We are expecting 210 participants (40 students and 2 instructors per school).

### C. Brazilian College

In Brazil, we plan to apply the "Video Classes" project at the Federal University of ABC (UFABC). Students of the Bachelor of Science and Technology program can take the "BC0005 Bases Computacionais da Ciência" course, an introductory course about computational science. This course gives an overview of how computing can be used to understand and solve complex problems, and its application to the production of scientific knowledge. Some of the topics covered in this course are: the graphical representation of functions; statistical concepts like correlation and regression; databases; logic programming and computational modeling. This course is offered 3 times a year, and has approximately 30 students per offering.

During 2016, two of the three offering of this course will follow the methodology proposed by the "Video Classes" project, and the third offering will follow the traditional methodology, thus serving as a control group for the experience. Note that complete student and class profiles will be taken into account when comparing the groups and analyzing differences in results between groups. This profile includes the year in which students are enrolled in the course, course evaluations, failure rates, problems that the students may have and any other information that may help characterize the students. We will also apply questionnaires during the implementation of this project, in order to evaluate if students learned the concepts being taught, measure any changes in their critical thinking skills and determine if there are any educational gains from implementing this project in this sort of class.

## V. Discussion

Instructors deepen their understanding of a subject by preparing material and assessing student answers. In the "Teaching is Learning" project, students replicate part of this experience through the creation and evaluation of pedagogical material, but at the same time avoiding the supervision overhead that would be required in a traditional setting. The "EI2001: Taller de Proyecto" course has shown that this methodology has various positive effects: instructors are better equipped to detect misconceptions; students are more active and motivated, as they are in charge of their own education; both students and instructors are better equipped to detect and fill gaps in the curriculum; and students develop their critical thinking skills by reviewing material created by other students.

Further study is required: for instance, the increase in motivation might be merely due to the novelty of the technique, an effect that is destined to decrease over time if this methodology is adopted in a more general way. The most interesting effect might prove to be the development of critical thinking in students: in a society that is increasingly connected and promotes continuous learning, with so many sources of information, the need for such skills is stronger than ever. The techniques described in this paper are still quite rough, but form a first step towards a systematic development of critical thinking skills in secondary and tertiary level students.

## Data and Material Availability

The sources of the software used in this experiment are publicaly available and welcoming contributions at https://github.com/Videoclases/videoclases. The formal source of information on the project is available at http://teachingislearning.cl, while a more informal wiki is maintained at http://wiki.teachingislearning.cl/.

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