CATALYST: Technology-Assisted Collaborative and Experiential Learning for School Students

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Abstract. Advent of technology in the education domain has led to the emergence of new pedagogical models. However, there is very little study on the relevance of these models in developing regions. In this paper, we present a technology-enabled learning framework called CATALYST, which caters to technology-lean classroom environments particularly in developing regions such as India. The CATALYST framework combines concepts from experiential learning, collaborative and cooperative learning in education. The CATALYST framework is compared with the traditional classroom teaching in the context of teaching a 10th grade science concept of the Doppler Effect. Our user study on a set of 30 students demonstrates that CATALYST is more effective in improving students' understanding while generating higher student engagement as compared to the traditional approach. Additionally, the unique design of group activities in CATALYST leads to higher interaction among low and high performers as well as across the genders.

Keywords: Technology-lean environment · Experiential learning · Peer learning · Doppler Effect · Technology Enabled Learning (TEL)

1 Introduction

Education system in several developing economies faces acute shortage of qualified teachers [1, 2]. For instance, India currently needs 1.2 million additional school teachers [3], which is likely to grow to 5 million by 2020. Further, 20 % of currently employed teachers are untrained. Due to these problems, students often feel disengaged in the classrooms and often are not able to learn appropriately [2]. Extensive usage of technology in the educational domain in a past few years has led to the emergence of new methods of learning and some of these methods are being experimented in real-world. Massive Open Online Courses (MOOCs) is one such method that aims to broadcast video lectures on the Internet to a wide student audience [4]. MOOCs assume easy access to a personal computing device, high speed Internet connectivity for anytime anywhere access to e-learning content. However, most of the classrooms in developing countries do not have access to these technologies due to cost-constraints. There have been many efforts

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recently, which use MOOC content with classroom teaching in a blended learning environment [5]. Flipped Classrooms [6] and Blended Learning [7] methods which combine classroom learning with anytime anywhere learning are also being explored extensively.

Our team has been working to identify synergies between the various methods of technology-enabled learning and classroom teaching, particularly for technology-lean schools, which are typical of a developing region such as India. Technology-lean school refers to a school, which has only a select few ‘lab rooms’ that have computers and/or projector facilities to augment the traditional classrooms, which have no technology presence. Moreover, the computer in the ‘lab rooms’ is typically shared by 3-5 students. We are trying to identify the methods and frameworks promoting better learning environments in technology lean environments with additional challenges associated with inaccessibility to the well trained teachers.

The fact that lab rooms in our schools require 4-5 students to share a single computer also opens up opportunities for peer learning. Design methodologies for technology-enabled peer interactions and their impact on student performance and retention is an active area of research [8]. Authors in [9] show that peer learning also plays a key role in developing students’ social interactions and communication skills. Authors in [10] show that collaborative computer-game-based learning approach leads to improved learning, motivation, and achievements as compared to learning approaches based on either conventional collaborative learning or individual game-based learning. However, there is limited exploration of using online video content in classrooms in developing economies such as India. Moreover, by using video content in the classroom also opens up opportunity of enhancing the learning process by using concepts like gamification [11], adaptive learning [12], game based learning [13], experiential learning [14] and many more. We primarily focused on experiential learning where new concepts are learnt in relevance to the activities of everyday life by reflecting on our experiences. There are many questions surrounding the effectiveness of video based learning frameworks with limited no. of computers and technology-assisted experiential learning experience in classrooms in such technology-lean environments.

In this paper, we propose a learning framework called CATALYST that combines technology enhanced learning, peer learning, and classroom-based teaching in the context of teaching a tenth grade science concept of the Doppler Effect. We designed an experiential application, which uses real-world artifacts to create curiosity among students just before the actual classroom teaching. These applications are interactive and exploratory in nature and give the students an opportunity to try and understand new concepts themselves. We present our initial findings from an on-going user study where we compare the efficacy of the proposed CATALYST framework with the traditional classroom teaching. Specifically, we aim to answer following questions:

1. What is the impact of the CATALYST approach on students’ learning when compared to the traditional teaching, especially on the low performing students?
2. How does student engagement and curiosity vary across the two approaches?
3. What are the observed barriers in peer learning in an Indian classroom scenario and does the proposed CATALYST framework help in enhancing peer collaboration as well as learning?

2 Catalyst Framework

We present a technology-enabled learning framework called CATALYST, which caters to the technology-lean classroom environments predominantly present in developing regions such as India. CATALYST adheres to the following theoretical methods of learning: provide experiential learning where students can relate the learning to real life experiences [14]; adheres to the 'cycle of learning' which combines the three stages of situative, cognitive and associative learning [15]; provides peer-learning opportunity where collaboration and cooperation are combined (please refer [16] for details). It aims to enhance the learnability of the students, keeping them engaged and promoting them to interact among themselves. It also emphasizes on making students inquisitive in order to retain their interest in what they are learning.

An interactive and explorative application is a part of the proposed framework that gives the students an opportunity to explore and learn the concept themselves. For example: an experiential learning application for the Doppler Effect (Fig-2), left) gives the students flexibility to change the various parameters like velocity, frequency, wavelength and amplitude of the source, the velocity of the source and observer to get appropriate audio-visual feedback. CATALYST has following four important stages: (a) explore and learn: A group of three students explore the application collectively on a single device and change various parameters to get audio-visual feedback; (b) documentation: students discuss and write what they observe, this phase also help students to channelize their exploration of the application with clearly stated objectives. (c) Teaching: the teacher explains the scientific reasoning behind the concept, and (d) group activity: students perform a group activity with clearly stated individual subtasks and a final collaborative task.

3 Experiment Design

The experiment was designed to compare traditional and CATALYST approaches by teaching the Doppler Effect to two different groups of students. The Doppler Effect is a physics concept, which deals with the perceived change in frequency when either the sound source or the observer or both are in motion.

3.1 Participants

30 students of 9th grade from a public school in Delhi (India) participated in the study. The participants age range between 12-15 years. For the study, it was ensured that there is equal participation of high, average and low performing students (HP, AP and LP respectively) i.e. 10 students from each category. The categorization of HP, AP and LP students was based on cumulative grade achieved by them in their 8th grade. The HP students' cumulative grade is either A1 or A2, similarly for AP students it is B1 or B2, and for LP students it is C1 or C2. The study also had an equal participation of boys and girls. 30 students were randomly divided into two equal groups of 15 students each, the control and the experimental group. Each control and experimental group had equal

share of HP, AP and LP students. The control group had 7 girls and 8 boys, whereas experimental group had 8 girls and 7 boys.

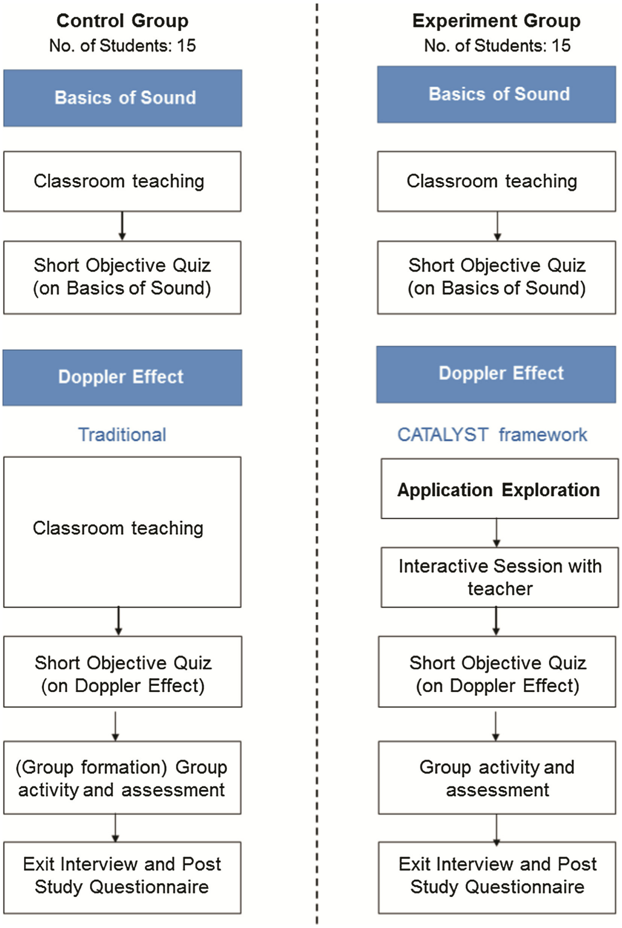

Fig. 1. Experiment design - Activities conducted in control and experimental group

3.2 Experimental Process

Thirty students participated in (a) pre-study discussion and questionnaire, (b) the actual learning experiment, and (c) post-study discussion and questionnaire. Students in control and experimental group were taught the Doppler Effect through traditional and CATALYST approaches respectively. In CATALYST, 15 students were further divided into 5 teams, each team having one HP, AP and LP student. Each team also had at least one girl and a boy. Each team in CATALYST framework was sharing a common laptop sitting together around it (Fig. 2). In the traditional approach, students were sitting like how they sit in their normal classes.

Figure 1 present the flow of the various activities conducted during the two approaches. ‘Basics of Sound’ a prerequisite to understand Doppler Effect was taught through traditional method, i.e. a lecture of approximately 15 min in both control and experiment groups. The lecture was followed by a short objective quiz (refer Fig. 1) of duration 15 min in both the approaches. The teacher and the material across both the approaches were also kept same. After the quiz a break of 10 min was given to the participants. After the break, students in the control group were given a lecture of duration 30-35 min by the teacher on the basics of Doppler Effect similar on the lines of traditional approach followed in normal classrooms. Where as in CATALYST framework, students started with exploring an application on a laptop in a team of 3 for 10 min. There were no pre stated objectives for the exploration and student took notes. After 10 min of exploration each student was given a documentation sheet to further help them in exploration and self-learning process. In the documentation students were asked to answer a few question, for ex. “Is there a change in the sound you hear when the observer starts to move towards or away from the source. How does it change?” After 10-15 min of objectified exploration of the application and documentation a short lecture was delivered by the teacher for approximately 10-15 min. The teacher also took the doubts of the students and discussed their observations. In both the approaches activities to teach Doppler Effect lasted for 30-35 min.

The application in CATALYST framework allowed student to control the velocity and frequency of the source (train), and the velocity of the observer (animated person) to receive live audio-visual feedback as shown in Fig. 2, thereby facilitating the experiential and explorative learning. Our hypothesis is that this kind of feedback would help them experience and understand the Doppler Effect in a much better way. After teaching the Doppler Effect, in both the approaches students were asked to solve an objective quiz (comprised of 10 questions) individually within 15 min. A short break of 10 min was given to all the participants. After the break students in the control group were also made to form teams of 3 comprising of one HP, AP and LP student similar to that in the experimental group. This change in the sitting arrangement of the students in the control group was done to conduct group activity. Under this group activity, a complex objective question was given in both the approaches to be solved in a team together. This group activity was followed by post study questionnaire and exit interviews.

3.3 Measuring Tools

A pre - study questionnaire was conducted before participants were finalized for the study and helped in ensuring that the students had no knowledge of the Doppler Effect. We conducted two different kinds of assessments: an individual-based short objective quiz on understanding of the basics of sound and Doppler Effect concepts and a group-based objective assessment on the Doppler Effect. Post-study questionnaire and an exit interview were also conducted for all the participants to understand their experience and preferences. Additionally, we observed and video recorded the in-class dynamics in both the approaches.

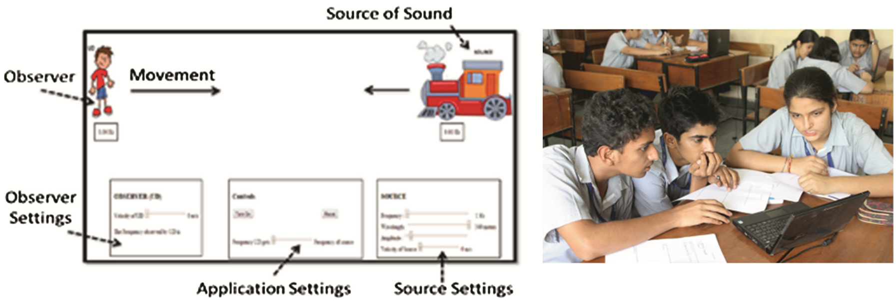

Fig. 2. Left – Screenshot of application used in CATALYST framework; Right – Student exploring application in a group.

4 Experimental Evaluation

The two approaches were compared quantitatively (using student performance on the assessments) and qualitatively (using student feedback and in-class observations).

4.1 Quantitative Comparison

Based on participants' performance in two individual short objective quizzes containing questions of basics of sound and the Doppler Effect, we try to answer some of the research questions raised above. We first wanted to determine whether there was any major bias in the results due to difference in participating students in two different approaches. It is important to note that participants in both the approaches were taught 'the basics of sound' in a similar manner and were subjected to almost identical experimental conditions. The teacher responsible for delivering the lecture component in both the approaches was also kept same. Participants in both the approaches were also assessed by the same objective quiz. Two tailed t-Test with 5 % alpha-level revealed that average marks of all participants in control group (traditional approach) was not significantly different from average marks of all participants in experiment group (CATALYST approach) ($p = 0.71$) (Table 1).

Table 1. Average score of students in Objective quiz 1 based on the basics of sound for both control and experimental group.

	$\bar{x}$ (Mean)	SD (Standard Deviation)	N (Sample Size)
Control Group (Traditional)	$\bar{x}_1 = 3.93$ (μ_1)	$S_1 = 1.43$	15
CATALYST (Experimental group)	$\bar{x}_2 = 4.00$ (μ_2)	$S_2 = 1.41$	15

The second question to answer is whether CATALYST framework helps in improving the learnability of the students as compared to traditional classroom teaching. To determine this average score of participants in objective quiz based on Doppler Effect was compared for both the approaches. Two tailed t-Test with 5 % alpha level revealed that the average scores of participants taught through CATALYST framework was significantly higher than average score of participants taught through traditional approach ($p = 0.013$) (Table 2).

Table 2. Average score of students in Objective quiz 2 based on the Doppler Effect for both control and experimental group.

	$\bar{x}$ (Mean)	S (Standard Deviation)	N (Sample Size)
Control Group (Traditional)	$\bar{x}_3 = 6.40$ (μ_3)	$S_3 = 1.88$	15
CATALYST (Experimental group)	$\bar{x}_4 = 8.06$ (μ_4)	$S_4 = 1.57$	15

The third question we would like to answer is whether the proposed CATALYST approach leads to uniform change in performance across all the students or if the change is dependent on the grade performance of the students. To answer this, Fig. 3 compares the average performance of HP, AP and LP students using the traditional classroom setup and the CATALYST set up on the basic of sound concept as well as to the Doppler Effect. Several interesting inferences can be drawn from this figure:

- The high-performers perform better than the low and average performers in both the approaches
- On the bases of the marks obtained by the students in the quiz the proposed CATALYST approach outperforms the traditional classroom setup
- The improvement in performance due to the proposed CATALYST approach is more pronounced for low-performers.
- This observation is consistent with the finding in [17] where the authors show that peer learning is most beneficial for complex cognitive tasks.

4.2 Qualitative Comparison

We use students' written feedback, oral feedback, and our in-class observations to qualitatively compare the two approaches in terms of student engagement and group dynamics. The 'explore and learn' phase of the CATALYST approach worked as an ice-breaker and got the students to talk to each other. Specifically, we observed that in the traditional approach, girls and boys within a team would largely work separately on the group problem, whereas in the CATALYST approach by the time the exploration phase was over, the group was already talking to each other. To quote one of the students: *"Group activity was good we would clear our doubts with others and helped each other"*. The structured group tasks in the CATALYST approach led to a clear division of labor, a sense of ownership, but at the same time encouraged each student to put forward his/her view in order to solve the group activity. This was also evident from the post-study survey, about 86.6 % of the CATALYST students agreed or strongly-agreed that they would be able to properly explain the Doppler Effect to their friend, whereas the corresponding number in the traditional approach was 46.6 %. Moreover, 91 % of CATALYST students agreed that the group task was helpful in understanding the Doppler Effect whereas the corresponding numbers for the other traditional approach were 42 %. The experiential aspect of the proposed CATALYST framework also triggered student engagement and enthusiasm and resulted in significantly improved classroom participation as observed by the researchers. In post study questionnaire, most of the students commented that the connection of the experiential web-application with the real life scenario helped them understand the concept and the underlying science in a better way. Also, in case of the CATALYST approach, students in a group interacted more frequently, irrespective of the gender or academic performance due to the collective exploration of an application on a single device. However, such interactions were missing in the conventional classroom teaching. In addition to the results above, 12/15 participants stated that CATALASY framework helped them learn the concept in a better way than traditional classroom approach.

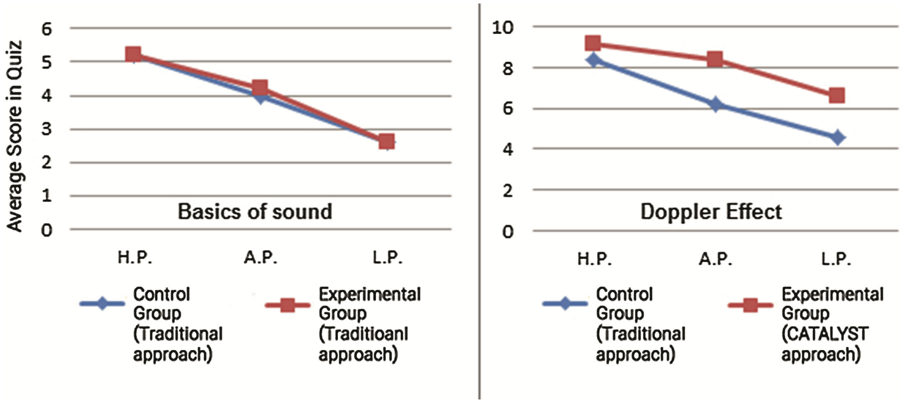

Fig. 3. For both control and experimental group, average score of high performing (HP), average performing (AP) and low performing (LP) students in quizzes based on the basics of sound (Left) and the Doppler Effect is compared.

5 Conclusion

In this work, we present our framework, called CATALYST, to create a learning environment, which combines concepts from experiential learning, collaborative and cooperative learning in education. In technology-lean learning environments, a single computing device is often simultaneously shared by multiple students. We use this constraint to our advantage by incorporating aspects of cooperative and collaborative learning in CATALYST to enhance peer-learning. We demonstrate the efficacy of the proposed framework in improving student understanding and engagement in the context of teaching the tenth grade science concept of the Doppler Effect. We are currently in discussions with the school to seek help from more teachers in better formulation of the framework and to recruit more students to conduct large scale experimentations. We have also formulated ways in which the proposed CATALYST design framework can be extended to other basic concepts such as 'resonance frequency' and 'constructive and destructive interference'. Our broad goal is to provide a stimulating environment in a typical technology-lean classroom so that learning is more experiential and loosely structured, which in turn will provide flexibility to the students on learning different concepts. We believe the proposed strategy will not only lead to increased learning outcomes along with sustained student engagement, but will also extend the recall duration. We are currently working on lesson planning strategies for an entire semester-long module of a tenth grade science course and subsequently measure its impact at a larger scale.

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