Engagement in Online STEM Learning: a Case Study of 3030-STEM

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1. BACKGROUND

The circumstances brought about by COVID-19 have compelled many schools and institutions to turn to either remote classes or at best a mix of remote and in-person classes depending on the situation. The pre-COVID era had already witnessed an explosion of online resources for education at large, ranging from MOOCs offered on platforms like Coursera and NPTEL, educational channels on YouTube such as MIT OpenCourseware, and various for-profit and nonprofit organizations like Unacademy, Khan Academy, and so forth. Courses relating to subjects in Computer Science, and specifically programming, have been especially popular owing to the large demand for such courses.

Despite the wide spectrum of resources available for self-learners, online courses have nonetheless had their fair share of challenges: fair and accurate assessments at scale, the credibility of certification in the online format, and retention of interest. There has been substantial research on the assessment aspects: some of these focus on methods for optimizing peer assessment strategies from a game-theoretic perspective[3], while others focus on interactive modes of assessment where the system intelligently learns about the state of the learner and adjusts the assessment mechanism appropriately [1].

The issue of credibility is somewhat intertwined with the problem of assessment at scale: the one thing that a traditional in-person university or school education can provide is relatively high attention to detail per student and consequently, more rigorous processes for assessment.

However, with the onset of the global pandemic in late 2019 and most schools and universities shutting down across the world, it was almost as if the tables were turned on the credibility front, and it was up to universities to demonstrate that they had the capabilities to run remote operations and maintain the same edge that came from the luxury of having the opportunity of interacting with students in a traditional classroom setting. Almost overnight, the traditional schools of education were facing the same challenges that have been fundamental issues in the growing space of online education: indeed, many universities invited much debate as they switched to binary

(pass/fail) modes of assessment[2], and teachers found themselves grappling with the new role of being live streamers to largely anonymous audiences.
As universities and schools aim to deliver on education in the new normal, teachers have to reinvent both the delivery of their content and evaluation. In this contribution, we focus on the former. Keeping a remotely connected audience actually engaged is clearly non-trivial. Apart from issues of logistics (such as some participants not having a steady internet connection, having the correct audio/video setup, and so on), talking to an empty room with either anonymous or no participants depending on whether the session is live or recorded, can be a jarring experience.

In this contribution, we address the issue of creating an engaging live session with the intent of communicating technical ideas through a case study of the 3030-STEM program. This is an hour-long program that is streamed live over YouTube and Vigyan Prasar's channel on JIO TV every Sunday to a large audience consisting largely of teachers and students. The series, which started mid-August, is created by the Center for Creative Learning at IIT Gandhinagar in collaboration with IISER Pune.

The analytics from Youtube reveals that these sessions have witnessed very significant engagement from the audience (which is typically in the tens of thousands). We hope that some of the ideas employed to keep these sessions engaging will be transferable, in principle, to regular classroom settings.

2 IMPLEMENTATION

The 3030-STEM program has already attracted more than 50 lakh[1] viewers on Youtube just within the first five weekly sessions. The audience is spread across all the Indian states and consists of teachers, students, their parents, and others with an interest in STEM topics. The first five live sessions of the program challenged the participants to explore some of the 'boring and hard' concepts of these subjects in an innovative and experiential way.

We summarize below the topics covered in these sessions:

1. Episode 1: **Adventures with an A4 Sheet.**[2] This narrative creatively explained how a paper could be used to understand mathematical concepts related to geometry and arithmetic. Activities ranged from cutting a surprisingly large hole from a single sheet to appreciating exponential growth with increasing folds, and also various patterns that emerge from cutting and folding the paper.

2. Episode 2: **Find Your Lung Capacity**.[3] Here, we used a plastic bag and a toy to elucidate Bernoulli's principle and concepts of Buoyancy.

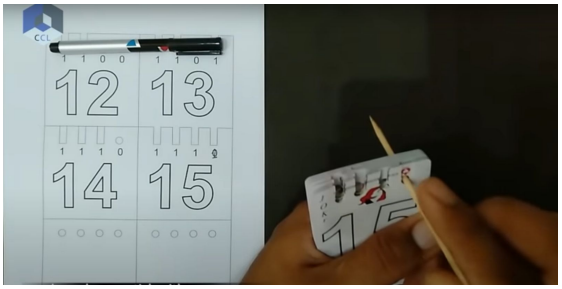
3. Episode 3: **The Wonder of Calendar.**[4] Here, we derived inspiration from calendars to help the participants grapple with a wide range of concepts, including tangents, magic squares, arithmetic progressions, and so on.

4. Episode 4: **The Science of Stars, Earth and Moon**.[5] This session

[1] This count includes the raw YouTube videos multiplied with the average number of people watching from each device or account, as determined from a poll conducted with the participants.
[2] https://youtu.be/41sdyOCxivs
[3] https://youtu.be/jMe_GKCMzsY
[4] https://youtu.be/ltxF3cpdwaU
[5] https://youtu.be/sQRlFb2DFhQ

covered several counterintuitive ideas, starting with "does the sun really rise from the east?". The audience went back to the basics as they pondered questions about why we have nights and days, why the seasons are the way they are, and why there are no solar or lunar eclipses every 27 days. We also put some astronomical scales in perspective with an activity that involved representing the sizes of the planets of our solar system using dough!

5. Episode 5: **Computational Thinking**.[6] In this session, the focus was on the "language of computers", i.e, the binary system. We went over several algorithmic concepts: including a physical manifestation of radix sort using a collection of punched cards - this demonstration was carried out in base two, to begin with, and became progressively more intricate with the numbers being represented in higher bases.



Card Sorting Activity[7]

There was also some thought-provoking discussion about the elementary but fundamental idea of long division and why it always works. A systematic way counting in binary using our fingers was also shown, and algorithms for multiplication were discussed as well.

Following table shows a summary of Video analytics for each episode.

#Ep	*#Total Views*	*#Expected Views*[8]	*#Concurr -ent Views*	*#Hour Count*
1	249 K	996 K	35.6 K	54 K
2	171 K	684 K	23.7 K	30 K
3	227 K	908 K	35 K	45 K
4	204 K	816 K	29.2 K	40 K
5	177 K	708 K	25.4 K	34 K

3 TECHNICAL DETAILS

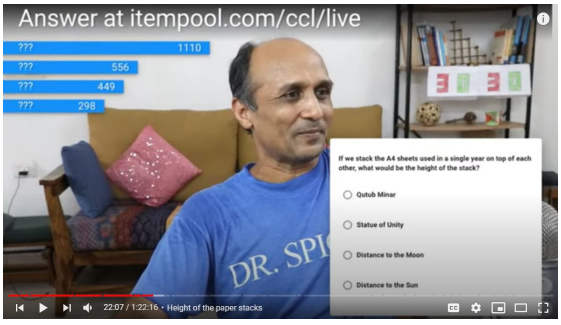
The hardware setup for these episodes include a computer, two cameras, two monitors, a stable internet connection, a condenser microphone, and appropriate connectors. The software used for the streaming is OBS, which allows the presenter to switch between different scenes and even overlay different layers of content: for example the video feed can be the background layer and an image, a file, or a screen can be an overlay that can be flexibly resized. This allows for the delivery of a richly interactive experience.

A key component of these live sessions is the use of Itempool, an online software solution for running live, interactive quizzes via

[6] https://youtu.be/0LdUew1OlqM
[7] https://youtu.be/0LdUew1OlqM?t=2672

[8] Expected number of view counts is derived by multiplying the recorded counts and multiplying it with the factor of 4. During the live session, we have surveyed how many people are watching with you. Average number of people watching together has been reported 4.

multiple choice questions. The way this works is that a series of questions can be created on itempool in advance, after which the quiz can be "administered live". This generates a link that the presenter can share with the audience. The audience can visit the link - even from a mobile device - to answer the questions live.



Interacting live with ItemPool[9]

A key feature of itempool is that it shows the presenter real-time data regarding which options were chosen by the participants, but *without* revealing which options were chosen by whom. For example, for a question with two choices, itempool might say that one of the options has received 40 responses while another has received 70, but it is not possible to view which is the more popular option. Therefore, these real-time statistics as offered by Itempool may be shared by the presenter with the audience without giving away anything that the audience may be biased by: indeed, the audience can see that there is a bandwagon to jump on, but they don't know where it is. Sharing the polling data live does create a sense of connectedness and suspense amongst an otherwise spread-out audience, and this is a central aspect of the engagement in these videos, given that it is quite impractical to interact over the live chat (although this may be feasible for classroom teachers with smaller numbers).

The heart of these sessions is the overall script of the narrative, and the manifestations of the individual concepts: these typically happen either through stories, written explanations, activities, or animations. While the individual manifestations do require substantial creative thought, the overall engagement is usually a function of the broader narrative and the intertwining of anecdotal sidenotes with the main narrative.

In the context of STEM topics, our experience has been that not confining ourselves to subject boundaries has allowed us to create more involved narratives that are not limited to a specific theme or a book chapter. While this may not be always feasible in a classroom context, whenever it is possible to make a cross-disciplinary connection, it is usually helpful to do so.

Questions, brought up either directly or using tools like Itempool, forces the audience to pause and ponder, and hopefully also compel them to ask questions of their own. These also punctuate the overall narrative and the breathers help the audience also assimilate the content that has been delivered up to the point in the best way possible - by applying their newly acquired knowledge to a problem.

Finally, whenever a topic can be related to a practical implementation or analogy, it is usually worth doing it. Discussing real-life examples, using day-to-day items that we typically don't think about explicitly, has turned out to have the effect of piquing a special kind of curiosity. The fact that the activities shown in our episodes make use of materials that can be easily found in a typical home has made them both relatable and accessible. This is also a frequent point in the feedback that we have received as well.

The demonstration of radix sort with punched cards is an illustration of turning an abstract idea into something physical: the members of the audience who choose to recreate the experience will find themselves developing a familiarity with the concept that is intuitive

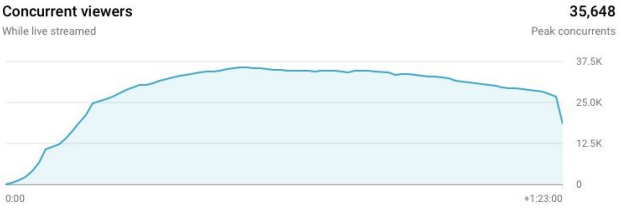
[9] https://itempool.com/

and this understanding is likely to be more robust when it comes to recall and application.

The analogies to everyday scenarios need not only emerge from activities: for example, when discussing sorting and searching, one might suggest that keeping the data sorted and searching fast is like having an organized cupboard that is an effort to maintain but easy to find things in; while keeping the data unsorted and searching slowly is like having a messy cupboard that takes no effort to maintain but painful to work with if one might be looking for something.

4 EVALUATION

The registration count at the time of this writing is 3.4+ lakhs. The graph of the concurrent participants during the live session shows 100% engagement and we have received 30,000 homework submissions by participants.



The next 25 weekly sessions will bring more interesting themes, topics, and puzzles such as combinatorics with playing cards; knowing our gut; how animals interact; 3D visualisation with vegetables you can find your fridge; using web-based software like GeoGebra to understand the concepts of geometry, algebra, statistics and calculus; geometry with dough and broom-sticks, and so on.

Many of our learnings align well with traditional wisdom in the context of classroom teaching: the significance of having a story, the importance of continuous interactions with the audience, the relevance of drawing up practical analogies, and so on. One might say that the quantitative data from YouTube analytics and the qualitative data from the feedback that we have received from the participants serves as an affirmation that these techniques are important and that they work. On the other hand, we believe that our data also goes against the grain on some modern wisdom: for instance, despite growing data showing that audiences today have attention spans lasting less than five minutes, our 60+ minute videos have received very consistent engagement even during the live streams. This case study demonstrates some ways of implementing the traditional wisdom in the remote setting. From using tools like OBS to mix and match different content types to Itempool for live engagement, and creating activities that are both virtual (simulations and animations) and physical (accessible experiments with everyday items like punched cards and dough), we believe that technology can truly enhance the overall teaching and learning experience in the remote setting if used alongside a careful plan and script.

5 LIMITATIONS

The format of the 3030-STEM sessions is mostly in the nature of a broadcast. While tools like itempool do allow for real-time interaction, the possibilities for serious assessment are limited in this format.

6 DEMONSTRATION

The videos in the 3030 STEM series are available for viewing on the YouTube channel[10] of the Center for Creative Learning.

7 Acknowledgment

[10]See https://www.youtube.com/c/IITGNCLI

Entire team of Center for Creative Learning, I.I.T. Gandhinagar is involved in successfully running this program. IISER Pune team is also participating in session delivery during the program. We also want to thank C.B.S.E and Vigyan Prasar for supporting us.

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