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Exploring Different Pedagogies to Teach Science More Effectively in an Online Environment

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Abstract: 75% of parents of children between 5-13 years report that their children learnt less online in comparison to the physical classroom setting. Children attending classes online can suffer from distractions and lower comprehension of class material due to ineffective teaching methods, leading to gaps in knowledge and a loss in motivation. The present research study aims to quantitatively and qualitatively analyse the most effective method of teaching Science online. It further aims to analyse the reasons for the effectiveness of certain methods, to propose improvements and solutions to the current methods employed in the Edtech industry and schools functioning online. The sample group consists of 28 students in Grade 4, from a Public school in Bareilly, India. The study consists of three unique teaching methods, traditional, through drama/storytelling and through arts and crafts, and Science topics aligned with the Class 4 CBSE curriculum. Three 45 minute online classes were conducted with a group of 30 children, followed by a monitored online test and an online survey. The results of this study clearly support that both retention of concepts and engagement within the class is higher in the drama/storytelling and arts and crafts condition as compared to traditional teaching methods. The results of this study can be utilized to improve the effectiveness of science education by Edtech companies and schools and NGOs using online resources.

Keywords: Online Education, Science Education, Teaching Pedagogy

1. Introduction

The COVID-19 pandemic has transformed the education sector all around the world, impacting 94% of the world's student population [1]. In India alone, around 250 million students were affected due to school closures at the onset of the pandemic. (KPMG, 2021). Indeed, nearly 75% of parents of children between 5-13 years reported that their children were learning less in comparison to the physical classroom setting due to the shift to online school (UNICEF, 2021). The pandemic also increased the number of school drop outs significantly; the proportion of 'out of school children' increased from 1.8% to 5.3% in the 6-10 age group between 2018 and 2020 [2]. Furthermore, according to a survey conducted by Oxfam India, over 80% of government school teachers in India received no training for online education as of September 2020 [3]. Thus, although an increasing number of schools have shifted onsite and the direct impacts by the COVID pandemic to education have reduced, the gaps in knowledge and education in the last 2 years continue to affect children's learning to a great extent.

Due to the pandemic, online classes and education have also become a popular model of teaching. This crisis led to a surge in online education and numerous government initiatives to increase the availability of technology and classroom resources, such as the 'Study Webs of Active-Learning for Young Aspiring Minds' and the Saubhagya Scheme. There has been research conducted to heighten access and quality of online education, specifically in science as well as other subjects. For example, the government of India initiated a programme called SWAYAM ('Study Webs of Active-Learning for Young Aspiring Minds') in 2017 which aims to achieve access, equity and quality in education. It is an interactive online learning platform which has free courses, assignments and quizzes for students. It further has an extension called SWAYAM Prabha which facilitates learning through a 24 x 7 educational programme available on 32 educational DTH channels [4]. Another notable initiative is the DIKSHA (Digital Infrastructure for School Education) platform by the 'National Council for Education Research and

Training, Ministry of Education. The initiative provides learning material in sync with school curriculums online for students as well as training content and online classroom resources for teachers [5].

Exploring online learning currently is still significant as it can directly be applied to the Edtech industry, which is poised to reach 30 billion US dollars in the next 10 years [6]. The pandemic brought to light the ease of conducting online lessons, and the results of this study can also be applied to online courses on websites and YouTube for children. Although this study was conducted in an online environment, it can be applied to the offline environment as well. In general, there are substantial benefits to be gained from meaningful science lessons for children because fostering their curiosity and connection to the real world at a young age can develop critical thinking skills and awareness for the world around them. Moreover, studies have shown that teaching science can benefit national development in the future [7].

Additionally, the pandemic introduced innovative approaches and pedagogies which brought out gaping and obvious problems within traditional pedagogies being used at a large scale within education. Traditional teaching pedagogy which emphasizes lectures and note taking presumes that all children learn at the same pace and does not take other learning styles into account. It also leads to lower retention as the students are passive [8]. Research has shown that there is a need for presenting science in a manner which helps students see relationships and make connections between what they are studying and the real world, which can be achieved through storytelling [9]. Moreover, a research study from Academia [10] has found out that the use of storytelling- and by extension, drama- to teach science is more coherent, memorable and meaningful. It can, seemingly, help children link cause and effect, and boost memory by raising glucose in the blood (due to exciting events and memories found in stories). The potential for kinaesthetic learning through drama activities has been found to increase information retention and engagement in the classroom [10].

Similarly, hands-on learning through arts and crafts has received a lot of attention in research recently. Experts believe that hand-on activities may be more effective than traditional pedagogy as critical thinking skills increase, students' motivation to learn increases and perception, creativity and logic are also supposed to be impacted beneficially [11]. This inquiry based hands on learning has shown to support the way children naturally learn and lead to children being more actively engaged, thus supposedly leading to higher retention and understanding. In contrast to the traditional style of pedagogy, research has supported that it accommodates a wider range of learning styles, increasing the opportunity for more students to succeed [12]. Additionally, the cognitive psychologist Jean Piaget has stressed the significance of using materials and physical experiences as a vehicle for learning, as it brings the real world into the classroom, consequently increasing excitement and motivation [13].

Based on previous research, this paper has identified 3 unique methods (traditional, through drama based storytelling and hands-on crafts) and strives to compare them and understand which one, or combination of which, should be implemented broadly. Although extensive research has been done in the field of educational pedagogies in an online environment, there is little clarity on what is the most effective method to teach science to children online. Many research studies have focused upon analysing a specific pedagogy, but do not compare traditional pedagogies directly with different ones. Moreover, previous research has pointed out that effective teaching can't be quantified simply through retention and academic achievement in students. Emotional involvement impacts meaningful learning, and enjoyment and engagement are critical motivational factors that can impact a student's retention and attitude to learning in the classroom [14, 15]. Therefore, this study aims to holistically assess the most effective method of teaching science, both quantitatively and qualitatively, which has not been covered in previous research either.

The research method included conducting 3 online lessons with different teaching methods to children in Grade 4. The results support that teaching through storytelling and arts and crafts is more effective than traditional pedagogies currently being used. A key novel result also points to the use of combining storytelling and arts/crafts for the most effective pedagogy in an online environment.

2. Methodology

2.1. Aim of the Study

The aim of this study was to analyze the most effective method of teaching science online, based upon both understanding/retention and enjoyment/confidence/motivation to children in Grade 4.

2.2. Research Design

To investigate which teaching pedagogy would be the most effective to teach Science in an online environment, an experimental study was conducted, using both quantitative and qualitative methods. The independent variable of this study was the type of teaching pedagogy applied in the class (traditional, storytelling or arts and crafts). The dependent variable of this study was the effectiveness of the pedagogy, which was measured through the quantitative factors understanding and retention, and the qualitative factors interest, confidence in understanding and enjoyment.

2.3. Consent and Ethical Issues

Ethical considerations were followed during the methodology of this study. Informed consent was given by the school and all participants had the right to withdraw at any point in the study. All personal details given by participants are confidential and were not shared with anyone other than the researcher during or after the study. Class teachers from the BBL Public School were present during the online class and test (on mute the entire time) to ensure that all participants were protected from harm and in the case of an emergency.

2.4. Sample

The study was conducted with 28 students in Grade 4 (between the ages of 9 and 10) at the Brij Bhushan Lal (BBL) Public School, Bareilly (over Zoom). All participants were from the same grade in this school and had all never formally learnt the topic 'Sound' before in class. Moreover, all students had been learning Science for the same amount of time within school prior to this, so it could be assumed that all students had comparable basic scientific knowledge. Out of the 50 students, three groups of around 15 students were created. Each group was divided based upon past exam results and had the same average overall scores, controlling for intelligence. During data analysis, data from 12 students in the first group (the storytelling condition), 6 students in the second group (the traditional condition) and 10 students in the third group (the arts and crafts condition) was analyzed.

2.5. Tools Used

This study was conducted using the online video conferencing platform 'Zoom'. This was chosen as it allowed for the creation of breakout rooms, to conduct all three lessons at the same time and also had screen sharing and whiteboard features which were utilized during the study. Through the course of the study, a general details and consent form, class test and online survey were given to participants through Google Forms. In the traditional condition, a class discussion, mind map and diagram drawing, small demonstration and video was utilized to teach the concepts. In the storytelling condition, a class discussion and story dramatically told were used. In the arts and crafts condition, a class discussion and 2 arts and crafts activities were done with participants.

2.6. Preliminary Investigation

The preliminary investigation, to foresee any possible challenges which may occur during the experiment, was conducted with a group of 15 students at a non-governmental organization, The Happy School. During the preliminary investigation, it was noted that many students dropped off the call due to Wi-Fi issues or low battery devices. At the end of the 45 minute class, only 2 students were logged in. Thus, preventative measures such as filling out forms later/before the class to reduce time actively online and a confirmation of a stable Wi-Fi connection with all participants was conducted prior to the main study.

2.7. Data Collection Procedure

Prior to the online class, a general details and consent form was filled by students in all 3 conditions. This asked students to fill in their general details (such as age, school, grade level and name), whether they had learnt science before (for how long and what topics covered) and whether they were interested in learning more Science.

Thereafter, the online 45-minute class and test were conducted. The same syllabus was followed by each condition, covering the topic 'Sound'. The syllabus included the key words sound, vibrations, vocal chords, ear drum, air particles, pitch, volume and energy. It covered 4 key concepts: What is sound?, How is sound created?, How does sound travel? and Variations in sound (pitch and volume). Also, all three teachers for each condition to teach the class had prior teaching experience. The traditional conditions, which had 6 students' data analysed, were taught the concepts with a short class discussion making a mind map on the whiteboard, diagram drawing using the whiteboard, a practical demonstration of vibrations using a rubber band and a short video and discussion. The arts and crafts condition, which had 10 students' data analysed, was taught using a short class discussion making a mind map on the whiteboard and 2 distinct arts and crafts activities. The first arts and crafts activity explained vibrations and energy transfer by asking students to wrap a bowl in plastic wrap, place uncooked rice on top of the plastic wrap and play loud sounds near the rice to see the rice move up and down (mimicking vibrations). The second arts and crafts activity connected to pitch and involved the students creating a reed using a straw. As they altered the straw's length using scissors, the pitch changed accordingly. The storytelling condition, which had 12 students' data analysed, was taught using a short class discussion making a mind map on the whiteboard and a handmade interactive story which was dramatically narrated to students. The story was about a magical drum that introduced sound to a city which had no sound prior, and explained the concepts laid out in the syllabus through its course. It is significant to note that all three classes had a 5 minute introduction icebreaker in the beginning of the class to make the participants feel more comfortable and at ease. Also, a trial class was conducted with the researcher after a highly detailed class plan was given to the teachers, in order to ensure that all concepts were being covered in each class and the specific pedagogy was mainly utilized during the duration of the class.

After the 45 minute class, an online monitored test worth 10 marks was conducted after the class to gauge understanding and retention (quantitative data). This test was done online using a google form and had a duration of 20 minutes. It involved multiple choice questions, true or false questions and short answer questions. Moreover, an online monitored five-minute survey through google forms was conducted 2-3 days after the online class and test to gather qualitative data regarding interest, confidence in understanding and enjoyment. This survey included free response questions, multiple choice questions and Likert scale based questions; 'What was your favourite/least favourite activity about the class?', 'How much do you think you understood the topic Sound?', 'How would you describe the class?', 'What activity would you want to be additionally added to this class (if any)?' and 'Are you interested in learning more science?'.

3. Results

3.1. Primary Findings

Based on the class test, an average score from each group

was calculated as a measure of understanding and retention. One can see that the traditional condition had a significantly lower average percentage of 51.7% on the class test as compared to both the storytelling and arts and crafts condition (which had average percentages of 62.5% and 59%, respectively), thus clearly supporting that teaching through this traditional pedagogical approach leads to lower understanding and retention (in the context of online science teaching to primary school students). In contrast, although the storytelling condition has a slightly higher average percentage as compared to the arts and crafts condition, this is not statistically significant.

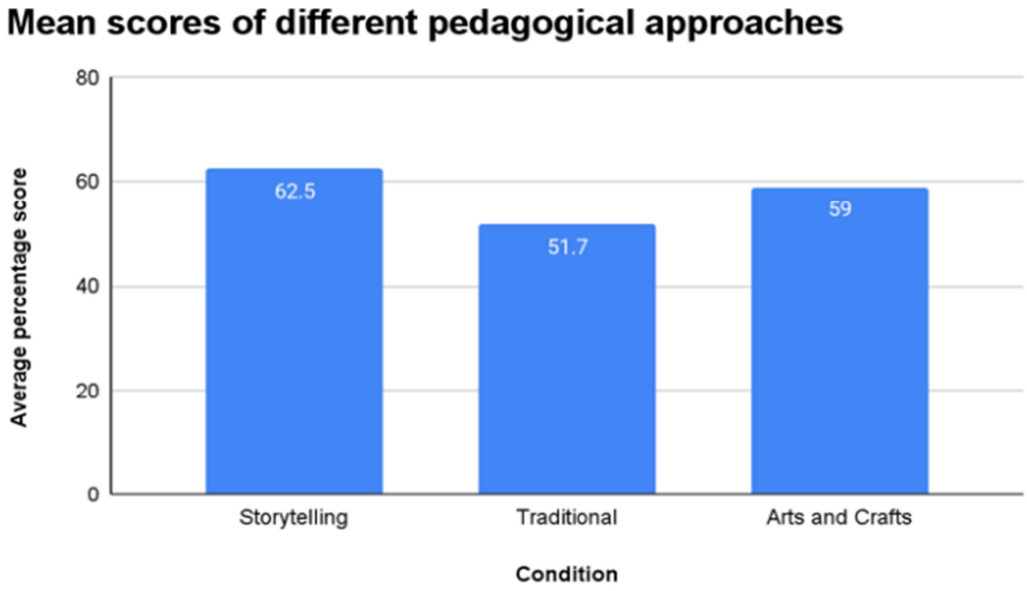

Figure 1. *Bar graph showing the quantitative comparison between test scores (N=28).*

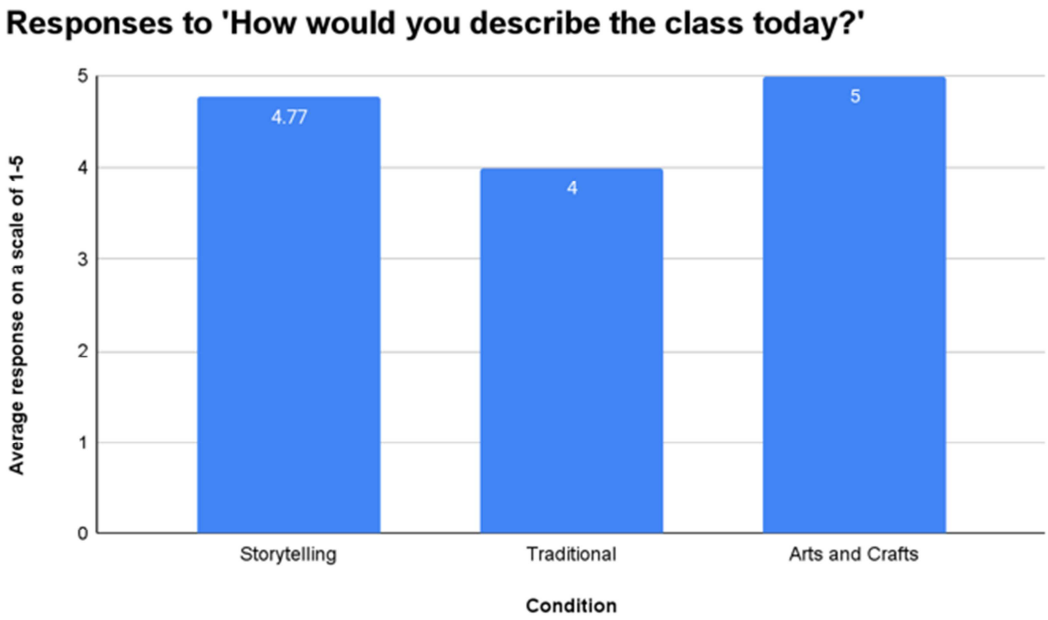

Figure 2. *Bar Graph showing the average response to the question 'How would you describe the class today?'. N=28.*

Figure 2 depicts the qualitative survey responses post the class in order to gauge both enjoyment and engagement. In the survey, a 1 was labeled as 'boring' and a 5 was labeled as 'Super Fun' on the Likert scale. As can be seen in the bar graph, the traditional condition, whose participants gave an average rating of ⅘, has a significantly lower rating as compared to the other 2 conditions (the storytelling condition has an average rating of 4.77/5 and the arts and crafts condition has an average rating of 5/5), indicating that students were less engaged and enjoyed to a lesser extent in the traditional pedagogical approach condition.

This question was asked in the qualitative survey post the class in order to gauge confidence in understanding of the topic. Upon examining the bar graph, it is clear that the traditional and storytelling condition participants had lower confidence in their understanding as compared to participants taught using the Arts and Crafts approach (showing the highest mean score in understanding the topic Sound).

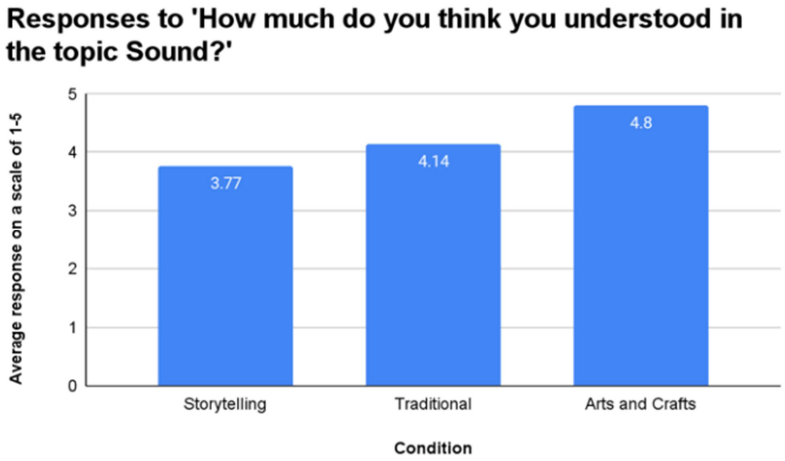

Figure 3. *Bar Graph showing the average response to the question 'How much do you think you understood in the topic Sound?'. N=28.*

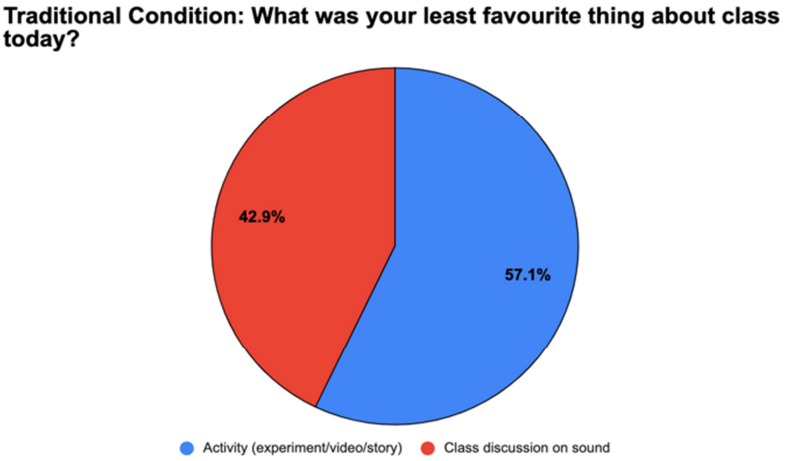

Figure 4. *Pie chart showing responses to the question 'What was your least favorite thing about class today?', in the traditional condition. N= 6.*

This pie chart supports that the pedagogical approach in the traditional condition is not enjoyed by students as 57.1% of respondents felt that their activity (the video and mind map) were their least favorite thing about the class today.

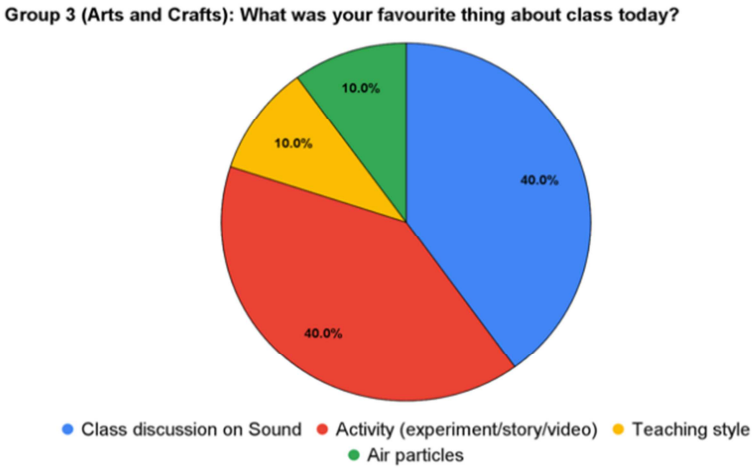

Figure 5. *Pie chart showing responses to the question 'What was your favorite thing about class today?', in the arts and crafts condition. N=10.*

Figure 5 reflects that 40% of respondents in the Arts and Crafts condition preferred the activity (the 2 experiments), which starkly contrasts with how the majority of the traditional condition believed this to be their least favorite thing (Figure 4). Thus, it can be supported that pedagogical approach in the Arts and Crafts condition was more enjoyable than that in the Traditional condition.

3.2. Secondary Findings

Through the questionnaire sent after the classes, it was also noted that the storytelling group had a high percentage of respondents who responded to the free response question 'What activity would you want to be additionally added to this class (if any)?' with asking for more practical activities. Specifically, 4 out of 12 students asked for more practical activities.

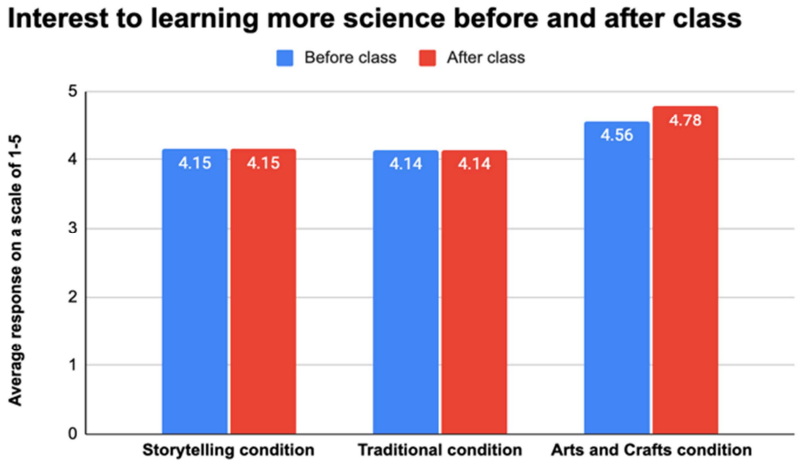

Figure 6. *Bar graph showing responses to the question 'Are you interested in learning more Science?', for all 3 conditions. N=28.*

The Likert scale question on a scale of 1-5, asking 'Are you interested in learning more Science?' was asked before and after the class to all participants in the 3 conditions. As shown in Figure 6, although there was an average change of 0 in response after the class in the traditional and storytelling condition, the arts and crafts condition had a mean increase in motivation to learn more science after the class.

4. Discussion

The result of the present study clearly shows how the traditional pedagogical approach is the least effective approach to teach Science in an online environment for primary school children as the traditional condition had the lowest average score on the class test (Figure 1: reflecting lowest understanding and retention), lowest confidence in their understanding (Figure 3) and lowest average score in terms of enjoyment and engagement (Figures 2 and 4). The arts and crafts condition showed highest confidence in understanding (Figure 3), enjoyment and engagement (Figure 2 and 5). They were also the only group in which the results reflected a change in their overall attitude towards Science due to the class. The storytelling condition had the highest average score on the class test (Figure 1: reflecting highest understanding and retention) and a high enjoyment (Figure 2). However, 33.3% of them expressed desire for more practical activities and they reflected the least confidence in their understanding (Figure 3). This may be due to the novelty of the pedagogical approach which led them to perceive their understanding less than what it really was (they reflected highest understanding through their class test average score).

This supports how both Arts and Crafts and Storytelling are better alternatives to traditional pedagogy in an online environment. Although the traditional condition was shown to be the least effective pedagogical approach, in line with previous research conducted, it must be noted that all three conditions included a brief class discussion about the topic at the beginning of the class. Thus, an aspect of traditional pedagogy, in this case having a classroom discussion, may be significant in building a strong conceptual base from which to build upon.

Previous research by Thornton, R. K., 1999 [16] compares the use of traditional pedagogy and activity based, interactive learning in Science education. The results of that study, concluding that traditional methods are not an effective tool for teaching Physics, strengthen the results generated in this study that traditional pedagogy is the least effective method for teaching science. However, that study comes to the conclusion that traditional pedagogy is not effective in any way; however, this study supports that traditional pedagogy may be significant in setting up a base knowledge framework for students to build upon.

This reasoning is supported by other sources, such as this article from the School of Education, 2020 [17]. This article reasoned that traditional education has been in use for a long time which has led to many educators and students being more comfortable with it. Moreover, the structure that is upheld with traditional education allows students to learn with a sense of organization, thus possibly making it an effective pedagogy to teach the basic overview of content as shown through the results of this study.

Moreover, these results are in line with previous research that revealed various benefits to incorporating hands-on crafts and storytelling to science pedagogy, such as The Protein Man, 2015 [11] and Rowcliffe, S. 2004 [10]. Rowcliffe, S. 2004 [10] supports that storytelling is specifically more enjoyable, as shown in this study, by discussing how children are emotionally involved whilst listening to a story. Moreover, it explains why retention is high with the use of a storytelling pedagogy, describing how storytelling can help children link

cause and effect because events in a story are easily registered as a chain of events. Not only that, but it further explains how exciting events in stories can secrete adrenaline in the bloodstream which boosts memory by raising the level of glucose in the blood. This previous research further strengthens the results obtained from this study and makes them more reliable.

As the storytelling condition had highest understanding and retention, and the arts and crafts group had highest enjoyment, engagement and confidence it can be extended that a mix of these pedagogical approaches may result in the most effective teaching method. In general, the arts and crafts pedagogy demonstrated certain advantages over the storytelling pedagogy. To explain further, the arts and crafts pedagogy had students having a significantly higher average confidence in their understanding. Not only that, but the arts and crafts condition also reflected more enjoyment (Figure 2) and supported a positive change in overall attitude to learning science while the storytelling group did not (Figure 6). This reflects a higher motivation and enjoyment from the class, and thus supports arts and crafts being a more effective pedagogy in certain ways. It must also be noted that the storytelling condition had a high number of students stating that they would want more practical activities in the class, which was a part of the arts and crafts condition. Thus, it is supported that teaching science online through an arts and crafts pedagogy is more effective than storytelling in certain ways such as motivation, confidence in learning and enjoyment.

The results of this study can be strengthened by repeating the study with a larger sample size. Not only that, but its further research scope is provided by investigating different age groups, offline conditions and different subjects. As online learning is utilized to a great extent by children with learning disabilities who may not be able to learn in an offline environment, research can also be done with them as the target population, thereby generating insights to help improve education for children with learning disabilities. Additionally, as the results have supported a possible mix of pedagogies for the most effective teaching method, a combination of pedagogies can be incorporated into a lesson plan and tested for effectiveness as compared to a single pedagogy. This will help better understand if these 3 pedagogical strategies can work with each other to create a more holistic learning experience for students that is enjoyable and strong in explanation.

As the field of education merges with technology and becomes more adaptable and easy to find online, there is a need to transition our pedagogical approaches to teaching science. These results can be utilized by schools, NGOs, educational YouTube channels and Edtech companies to increase the effectiveness of their content. Including instructions on how to teach science incorporating these pedagogies in teacher training workshops and resources will also help accelerate this transition and effectiveness of teaching observed.

5. Conclusion

The aim of the research study was to quantitatively and qualitatively analyse the most effective method of teaching Science online to children in Grade 4. Effectiveness was measured through understanding and retention (from class test score) and enjoyment, engagement, confidence in understanding and motivation (through the survey done post the class). Based on the results, it is evident that Arts and Crafts and Storytelling is more effective than Traditional methods to teach Science in an online environment. Therefore, the null hypothesis set out in this research study is rejected. More specifically, this study shows that the use of Arts and Crafts leads to the most engagement, confidence and motivation in comparison to Storytelling and can thus be considered most effective in a certain way. These findings have direct implications on the adopted pedagogies used by the Edtech industry and hybrid classrooms around the world, to increase the effectiveness of their current science teaching and increase the positive attitude of students towards the subject itself. Overall, a mix of both Arts and Crafts and Storytelling pedagogies is recommended in order to create the most effective teaching method for teaching science in an online environment. As the presence of online education has increased significantly in recent years due to its convenience and room for flexibility, adapting our pedagogical approaches is the first step towards giving students a more well-rounded, effective education.

6. Limitations

The research methodology and design of this study had several limitations, which must be taken note of when evaluating the results generated from this study. Firstly, this study had a small sample size of 28 students due to network issues and technical difficulties, increasing the margin of error in the results generated. This also made it more difficult to conduct statistical tests on the data. This makes the study results less reliable and harder to generalize. Secondly, the traditional condition had a significantly lower number of participants as compared to the other 2 conditions. This made this condition's results more open to distortion and thus more difficult to compare directly to the responses of the participants of the other 2 conditions. Thirdly, it was initially planned that all three conditions would be taught by 3 people not connected to the study who had experience with teaching. However, the night before the study, the teacher for the Arts and Crafts condition had to back out due to personal reasons. Thus, the researcher of this study had to teach the Arts and Crafts condition which may have led to researcher bias, if the researcher put more effort into normal whilst teaching for example. Fourthly, although all teachers had previous teaching experience, the teacher in the storytelling condition had a significantly higher amount of teaching experience then the teachers in the other 2 conditions. The number of years of teaching experience may thus act as a possible confounding variable and affect the effectiveness of the pedagogy measured. Lastly, it must be taken into account that this study was done in an online environment, so cheating may have occurred during the class test which could lead to less reliable results.

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I would also like to thank The Happy School Gurgaon for the opportunity to conduct the preliminary investigation of this study, which provided key insights on how to adapt the methodology of this study.

I would also like to thank the Brij Bhushan Lal Public School Bareilly for their time and resources used to conduct the study at their school.

I would like to thank all the respondents who participated in this study, for giving up their time and contributing to the data collected for analysis; which allowed me to come to a conclusion and generate results.

Last but not least, I would like to thank my friends and family for their love and support. I would like to thank my mother for teaching me to value education since I was of a young age, which has eventually led me to write this paper in the first place.

Appendix

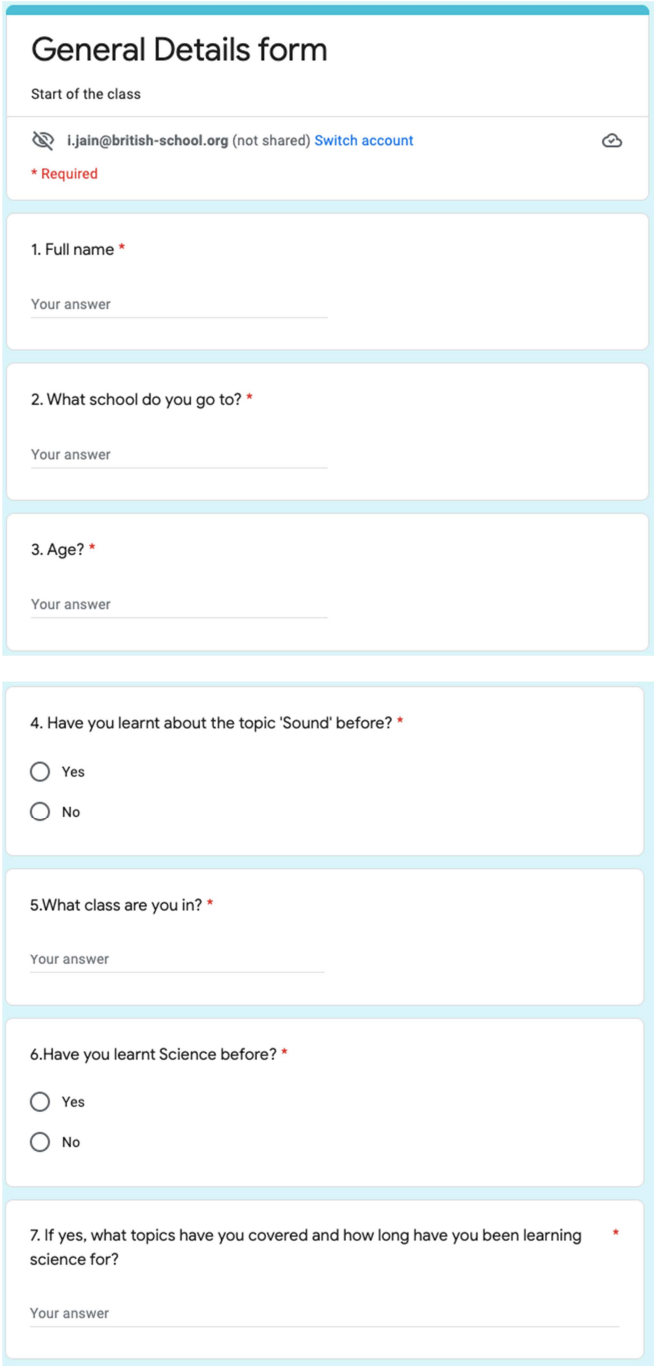
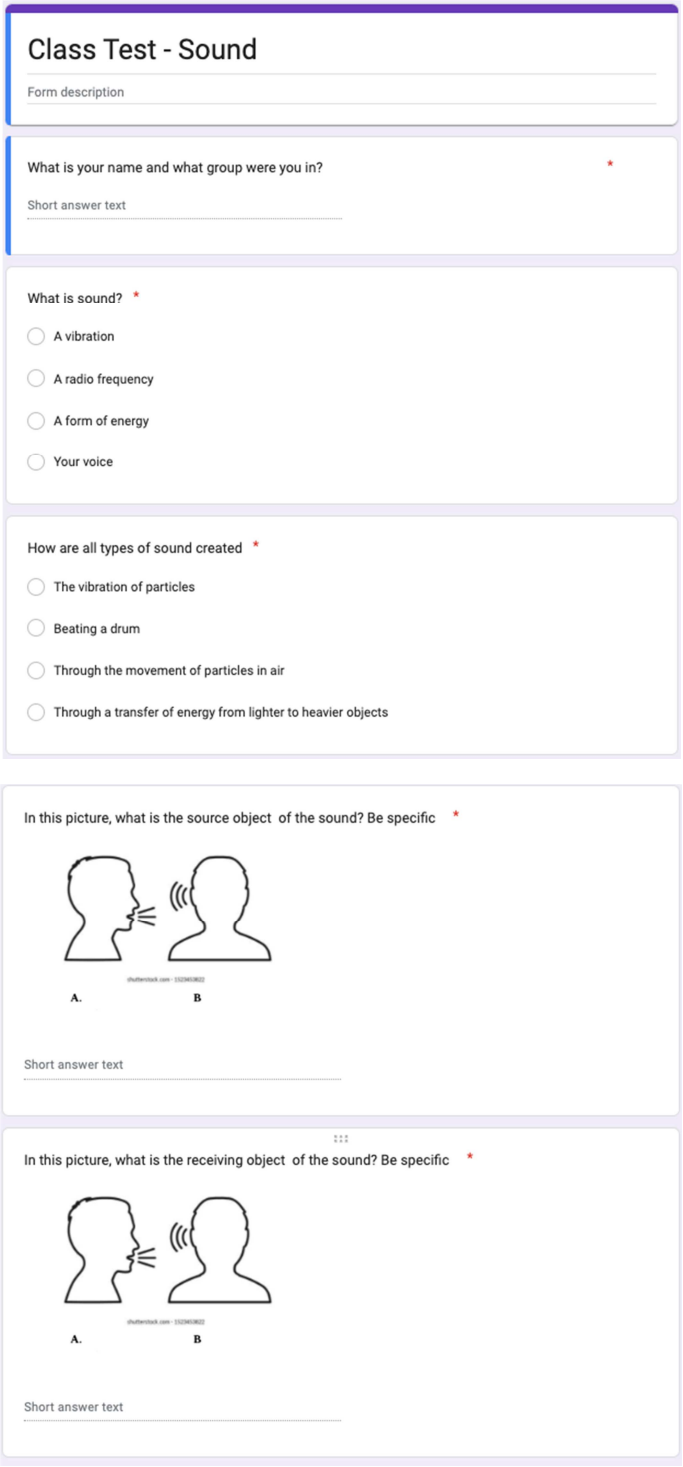


Figure A1. *General Details form.*



How is the sound travelling from the boy to the girl in the picture? *

A. B

Short answer text

When a sound has higher volume, the particles travel a _____ distance *

- Longer
- Shorter

Fill in the blank: When a sound has lower pitch, the particles travel at a _____ speed *

- Higher
- Lower

True or false: Sound vibrations can be transmitted in outer space *

- True
- False

True or false: Sound is important for living things *

- True
- False

True or false: Air particles travel a long distance when sound moves through them *

- Option 1

Person A shouts out to Person B, but Person B does not hear Person A. What is a possible reason for this? Explain your answer. *

Long answer text

Figure A2. *Online class test.*

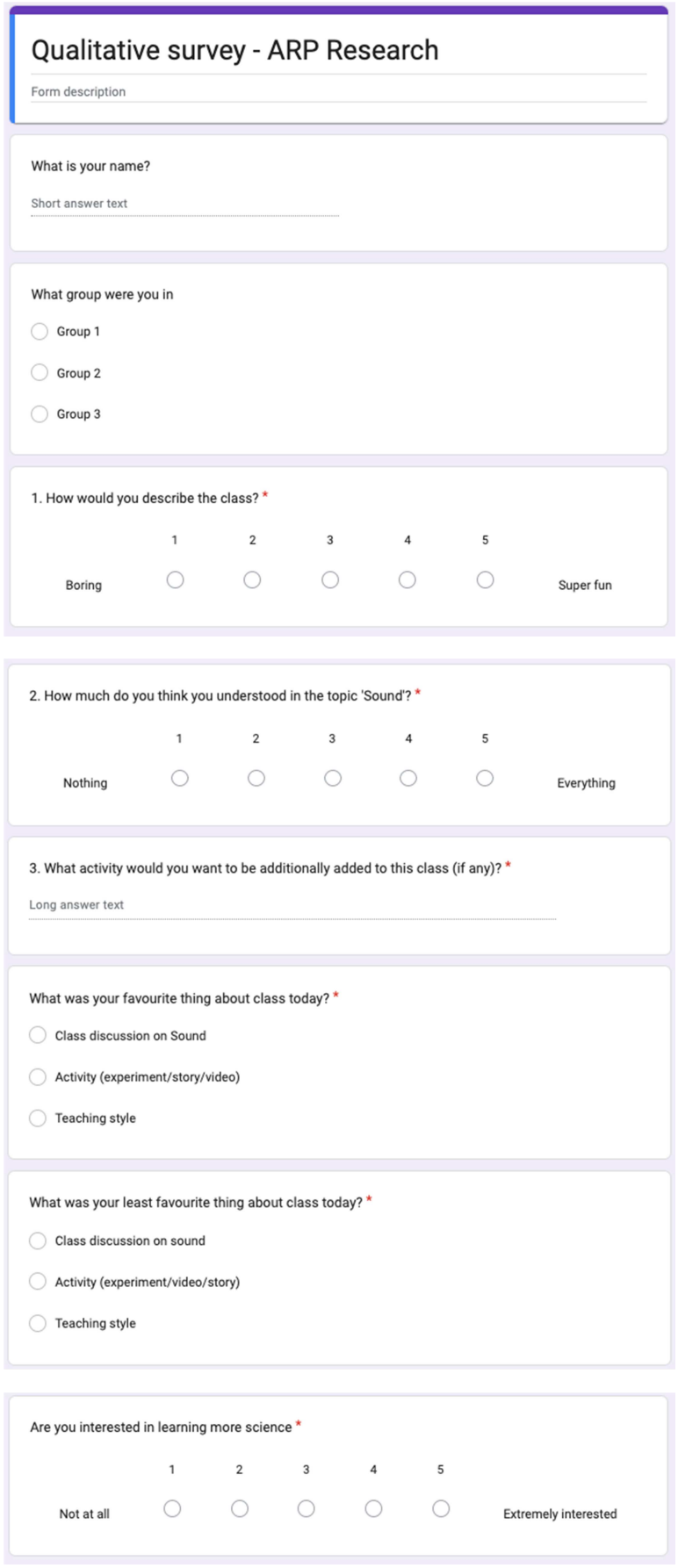
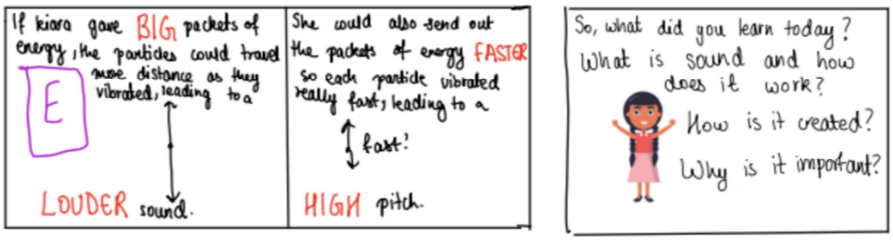


Figure A3. *Qualitative Survey.*


Kira's MAGIC tabla
Hi! My name is Kira
and this is my magic drum!
THE MAGICAL DRUMS!
Her drums could move energy and create music that could flow through the town.
Before drum
After drum
no sound
All she had to do was tap on it!
• Can YOU create sound?
• Why is sound important?
• How do you think sound is created + travels through the air?
HOW did she do it?
Air Particles
Vibrations
The sound vibrations travel in 3 steps
Ear drum
Vocal
Chords
In outer space, you can't hear any sound; why?
The magical sound made → each air particle vibrate up and down, transferring these vibrations from the drum membrane to the ear drum.
Now, the people in the town could hear lots of things like....
BEEP!
Low Pitch
Cars honking
People chatting
Birds chirping
Energy & sound?
Kiara's drum released magical packets of energy.
Like the waves in the sea, this vibration and energy flow created WAVES
However, if she didn't keep tapping, the sound would die out! Why?



Figutre A4. *Story (used in the storytelling condition).*

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