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Students examining their *Hydrilla* setups

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Contents

EDITORIAL

The *School Science* journal strives to bring about the much-needed improvement in the teaching-learning of science, mathematics, and environmental education. This, it does, by disseminating the outstanding studies, researches, ideas, innovative ways of teaching and presenting concepts and contents, especially in the context of India. This unique journal has been serving the various stakeholders—students, teachers, teacher educators, researchers, etc., and it finds its place in the University Grants Commission Consortium for Academic and Research Ethics (UGC-CARE) list of approved journals. Special issues are also brought out occasionally to share key lectures of conferences and seminars and also on burning topics and issues.

As part of our ongoing pursuit to enrich the content of the journal and engage the readers, we have attempted to make some changes. In addition to the research papers and articles, we are including 'Voices' of different stakeholders, which will feature interviews with teachers and other individuals who have made a difference in the area of science, mathematics, and environmental education. This section will also cover comments/views/opinions of stakeholders on different areas related to the above disciplines, which could be on the curriculum, pedagogy, syllabus, teaching-learning resources, textbooks, policies, good practices, issues, challenges, opportunities, etc. Last but not the least, we are also introducing the 'Book Review' section from this current issue.

The present issue has five articles/ research papers. In the first research paper, 'Students' Motivation to Learn Science and Its Relationship to Their Achievement in Science: A Study in the Context of Mizoram," the authors, Nitu Kaur and R.P. Vadhera, indicate that career motivation and grade motivation were found to be the strong motivational constructs by most of the students, whereas students were least motivated by self-determination construct.

Chong Shimray's 'Climate Change and Climate Literacy in India—Some Key Aspects for Consideration in the Curriculum" is a seminal work on climate change and climate literacy in India. The article provides a perspective on incorporating climate change in the curriculum and the possible challenges to be overcome to bring about climate literacy in India.

In their research 'Attitude of Elementary School Students towards Mathematics in Arunachal Pradesh,' Vivek Singh and Jumni Maga find that Class VIII students show average attitudes towards mathematics. The attitude of boys was found to be higher than that of girl students while no significant difference was found based on the types of school (government and private school).

Tamralipta Patra and Sujata B. Hanchinalkar, through their article 'Scientific Argumentation – A Theoretical Framework,' have attempted to bring out how crucial scientific argumentation is for reasoning and thinking, how we can link evidence and claim, and how students and teachers need to be more involved with scientific argumentation.

In "On Using a STEAM Project-based Learning Model for Secondary School Students: Design, Development, and Evaluation," Shivalika Sarkar has carefully designed an interdisciplinary project named 'Our Sun,' through which elements of STEAM were brought into the high school science classroom (secondary level). The Project-based Learning (PBL) approach was found to be effective in providing hands-on experience to the students as well as in developing other skills like creativity, inquiry, sharing, debating of ideas within a learning community.

In addition to the articles and other features mentioned earlier, this issue also contains Science News.

We hope readers will appreciate the changes brought about in the journal. Do let us know your take on those changes. As always, we welcome your valuable suggestions. Happy reading and happy learning!

STUDENTS' MOTIVATION TO LEARN SCIENCE AND ITS RELATIONSHIP TO THEIR ACHIEVEMENT IN SCIENCE: A STUDY IN THE CONTEXT OF MIZORAM

Nitu Kaur*
Assistant Professor
Department of Education
Mizoram University
Aizawl - 796 004, Mizoram, India
Email: nitukaurmzu@mzu.edu.in
*Corresponding author

R.P. Vadhera
Vice Chancellor
ICFAI University
Aizawl, Mizoram
Email: rpvadhera55@gmail.com

There is a strong need for science-motivated high school students to enter the post-secondary science stream. Student enrolment in higher education science needs to be increased and higher levels of science motivation at the secondary and post-secondary levels can help to achieve this. To enrol students in various science courses, we must understand what motivates them. The purpose of the present study was to determine how secondary school students conceptualised their motivation to learn science using the Science Motivation Questionnaire (SMQ II) as a survey instrument. The students' achievement in science courses was measured through their term-end board results of Class X. Stratified random sampling with school types as strata were used to collect the sample comprising 1134 (532 boys and 602 girls) secondary school-going children of Aizawl district of Mizoram, India. All the students studied in schools affiliated to the Mizoram Board of School Education (MBSE). Descriptive, correlation and differential analysis was used to analyse the data. The findings of the study revealed that students were found to have more than moderate level of science motivation, and the mean science achievement score of the highly motivated group was found to be maximum indicating a favourable trait of science motivation within the students. Career motivation and grade motivation were found to be the strong motivational constructs by most of the students, whereas students were least motivated by the self-determination construct. Thus, in the present population, extrinsic motivational constructs are more decisive than intrinsic ones. It was also found that there is a significant positive relationship between students' science motivation and their achievement in science. Through differential analysis, it was revealed that a significant difference exists in the science motivation level of the high and low science achievers on all its five sub-constructs, with high achievers being more science motivated. Also, a significant difference exists in science motivational level in relation to gender, with boys being more science motivated; although, girls had a higher mean motivation level for grade motivation. However, no significant difference exists within the high and low achieving groups with regard to gender. Findings suggest that science motivation within secondary students can positively contribute to their achievement in science both at present and for their choice of a future career in science. The highlight of the findings was incorporating more of students' positive affective traits such as, science motivation inside science classrooms.

Keywords: Science motivation, Achievement in science, Mizoram

Introduction

Motivation is a psychological construct associated while complying to a certain set of needs. In educational psychology it is widely studied as a need of achievement (n-Ach), also referred to as achievement motivation. Brophy (2004) defines student motivation

as the degree to which students invest attention and effort. Motivation to learn refers to students' disposition to find academic activities relevant and worthwhile and derive the intended benefits. Glynn, Aultman and Owens (2005) defined motivation in general as an internal state that arouses, directs, and sustains goal-oriented behaviour. They further highlighted through their literature review that researchers in the past have been trying to employ various motivational constructs in teaching-learning contexts to motivate students to learn. However, it is hard to predict which constructs hold the best explanatory power. They categorised the reviewed construct mainly belonging to three categories: (i) the constructs referring to students' traits and states, such as activity and anxiety level, interest, and curiosity falling together in studies on comparison between intrinsic and extrinsic motivation to learn;
(ii) the constructs related to students' beliefs, such as self-determination, goal orientation, self-regulation, and self-efficacy; and
(iii) constructs that refer to students' responses to others' expectations such as instructors, advisors, and administrators. Domenech Betoret, Rosello and Gomez-Artiga (2017) suggested through their findings that expectancy-value beliefs of students, which included their achievement expectations, the value of the subject matter, process expectations with the teacher, expected cost to pass the subject, are capable of satisfactorily explaining and predicting student achievement and their degree of satisfaction with the teaching process followed with a specific subject matter. Pajares and Schunk (2001) found that students who are encouraged by parents favorably to explore and try different activities are found to be higher on their self-efficacy levels and are motivated to perform better academically. Favourable school environments and positive peer support contribute equally to their self-efficacy level. They reflect positive behaviours such as improved class attendance and class participation, asking questions, seeking advice, and participating in study groups.

Studies exclusively focusing on science motivation started with Glynn and Koballa's (2006) efforts to develop an instrument named students' motivation towards science. According to Glynn and Koballa, motivation to learn science, a social cognitive construct, is defined as an internal state that arouses, directs, and sustains science-learning behaviour. It is believed that high science motivation levels within students seem to be one of the vital indicators of high achievement in science. The six initially identified components of students' motivation were intrinsically motivated science learning, extrinsically motivated science learning, the relevance of learning science to personal goals, responsibility (self-determination) for learning science, confidence (self-efficacy) in learning science, and anxiety about science assessment. After this study, several other studies tried to measure science motivation levels in varied population samples. For example, Glynn, Taasoobshirazi, and Brickman (2009) tried to examine the motivation to learn science of non-science majors enrolled in a core-curriculum science course using the Science Motivation Questionnaire (SMQ). They found that in studying students' science motivation, researchers examine why students strive to learn science, how intensively they strive, and what beliefs, feelings, and emotions characterise them in this process. An exploratory factor analysis suggested that the questionnaire has construct validity. The students conceptualised their motivation to learn science in five dimensions: intrinsic motivation and personal relevance, self-efficacy and assessment anxiety, self-determination, career motivation, and grade motivation.

In yet another study, Glynn, et al. (2011) tried to measure the science motivation of science majors and non-science majors in American undergraduate students in order to assess the differences in the motivation to learn sciences by developing a new version of the Science Motivation Questionnaire, SMQ II using the perspectives of social cognitive theory of Bandura highlighting the importance of environmental factors in human functioning. SMQ II assesses five motivation components: intrinsic motivation, self-determination, self-efficacy, career motivation, and grade motivation. It was reported that the science majors were better on all the components of science motivation. Men had higher self-efficacy in science majors and non-science majors than women and women had higher self-determination than men. This suggested that science motivation differs with the background, i.e., their preference to choose science as a major or non-major subject at the undergraduate level with respect to subject specialisation and gender. Salta and Koulougliotis (2015) tried to adapt Science Motivation Questionnaire II (SMQ II) and made the Greek version of Chemistry Motivation Questionnaire II (Greek CMQ II) to investigate Greek secondary school students' motivation to learn chemistry for the first time. Some studies show that students' science motivational level varies with gender (Bryan, Glynn and Kittleson, 2011; Salta and Koulougliotis, 2015). Science motivational studies are a relatively new arena in science education. They are of far-fetching value in improving the motivational constructs applicable in science teaching-learning processes.

Rationale of the Study

The present study is undertaken in Mizoram, a tiny state in the northeastern part of India with a unique cultural and ethnic diversity. As far as Mizo society is concerned, it is a close-knit society of tribal and ethnic population of north-east. Mizo youth exhibit some unique traits of creativity, musical aptitude, cooperative living, hard-working and resource-sharing. In the last decade, Mizoram has held a record of high literacy rate in the country (Census India, 2011) and the society has a positive outlook for education and possesses a favourable cultural milieu for protecting the environment. However, despite several positive traits in youth, there is prevalent phobia towards science subjects at the school level. According to the Mizoram Board of Secondary Education (MBSE), fewer students choose the science stream at the senior secondary level than humanities. Therefore, the question arises, whether they are afraid of science as it will be more challenging at a higher level or are less motivated to take science as their career.

Why is it so that most science students do not wish to continue their careers in science? Severe implications can be felt at the upper end in terms of the low enrolment of students in higher education in the field of science. The student dropout problem after studying science at the senior secondary level needs to be addressed. There is a strong need for motivated science high school students to enter the post-secondary science stream. Student enrolment in higher education science needs to be increased and higher levels of science motivation at secondary and post-secondary level can help to achieve this. During high school, students' motivation to learn science is one of the highest predictors of science course success (Britner and Pajares, 2006). To enrol students in various science courses, what motivates them must be understood. It is the pre-university stage where the mindset of the students can be captured for motivating them to continue with higher education in science as this is the stage when differentiation and streaming of subject are introduced. Therefore, the present study attempts to understand the science motivation among the secondary school students of Mizoram, which is one of the vital indicators of their entry into the science stream at the higher secondary level.

Research Questions

Based on the rationale of the present study the following research questions were framed

1. What are the factors that motivate secondary school students of Mizoram towards learning science?
2. What is the science motivation level of secondary school students in Mizoram?
3. Are the secondary students of Mizoram with high achievement in science more motivated to learn science?
4. Does gender impact students' science motivation amongst the secondary school students of Mizoram?
5. How does gender impact secondary school students' science motivation within high and low science achieving groups of students in Mizoram?

Objectives of the Study

This study aimed to identify how secondary school students conceptualised their motivation to learn science. Also, it tried to investigate the nature of the relationship between students' science motivation and their achievement in science. Further, attempt was made to compare students' science motivation within the high and low-achieving students in science. Finally, the researchers also sought to find the influence of gender on students' science motivation. Following are the objectives of the present study:

1. To describe and measure the conceptual factors that motivated secondary school students of Mizoram in science.
2. To find out the relationship between students' science motivation and their achievement in science amongst secondary school students of Mizoram.
3. To compare the high and low achievers in science amongst secondary school students of Mizoram in relation to their science motivation.
4. To examine and measure the impact of gender on science motivation amongst the secondary school students of Mizoram.
5. To find out the gender differences among high and low achievers in science amongst secondary school students of Mizoram about their science motivation.

Research Hypotheses

Following are the prime research hypotheses guiding the present study:

1. There is a positive relationship between students' science motivation and their achievement in science.

2. High achievers in science have a higher level of science motivation, whereas low achievers in science have a lower level of science motivation.
3. There is a significant difference in science motivation of secondary school students with respect to their gender.
4. There is a significant difference in science motivation of high achievers of secondary school students with respect to gender.
5. There is a significant difference in science motivation of low achievers of secondary school students with respect to gender.

Population and Sample

The population of the present study comprised all secondary school students of the Aizawl District of Mizoram. The chosen sample comprised 1134 secondary students (532 boys and 602 girls) of Class X from 34 MBSE (Mizoram Board of School Education) affiliated schools in the Aizawl District of Mizoram, India. Therefore, all the MBSE affiliated secondary schools formed the study population. A stratified random sampling technique with school types as strata was used to pool the sample. There are six types of schools mentioned in the Annual Publication by the Directorate of School Education, Mizoram (2014-15): government, deficit, adhoc aided, lumpsum aided, RMSA, and private schools. In the present sample, student are 34.4, 10.23, 8.64, 7.76, 2.73, and 36.24 per cent from each school type, respectively, which approximately corresponds to the total percentage of students in different schools types of Aizawl District according to Annual Publication data (2014-15).

Methods and Procedures

The present study is descriptive in nature intending to measure the secondary students' motivation to learn science and differential analysis on the trait of motivation to learn science, emphasising achievement levels of students in science and their gender. The study used a correlational analysis to understand the relationship between students' science motivation and their achievement in science. Also, a similar point biserial analysis was done between genders and their level of motivation. The instrument used for the present study was Science Motivation Questionnaire II (SMQ II), constructed by Glynn, Brickman, Armstrong and Taasoobshirazi, 2011. The SMQ II is a revised version of SMQ (Glynn and Koballa, 2006). It was used to assess the science motivation level of secondary school students. The SMQ II has five subscales, each with five items measuring the dimensions of intrinsic motivation, self-determination, self-efficacy, career motivation, and grade motivation.

The questionnaire comprises 25 items where students respond to each item on a rating scale of temporal frequency: never (0), rarely (1), sometimes (2), often (3), or always (4). The raw scores should be interpreted carefully since the scale is ordinal. The possible score range of the 5-item scale is 0-20 making a total score range of 0-100. The items were randomly ordered as provided in the online version of SMQ II © 2011 Shawn M. Glynn, University of Georgia, USA. Since SMQ II has been standardised on college students, the score indicates "average" for undergraduate science majors and non-science majors at the University of Georgia; it does not provide any classification criterion based on obtained raw score. Only the magnitude of score can decide students' degree of science motivation from no science motivation to a very high science motivation. The efficiency of the scale is that it uses elementary, unambiguous, declarative, to the point focused questions on the motivation to learn science in courses rather than a multitude of contexts, such as hobbies and the Flesch-Kincaid formula indicates readability at the sixth-grade level (Glynn, et al., 2011). Also, the beauty of SMQ II is that it does not distinguish among different science subjects but focuses on a general motivation to learn science (Chumbley, et al., 2015). The reliabilities (internal consistencies) of the scales, assessed by Cronbach's alphas, are as follows in order from highest to lowest: career motivation (0.92), intrinsic motivation (0.89), self-determination (0.88), self-efficacy (0.83), and grade motivation (0.81). The Cronbach's alpha of all 25 items was reported as 0.92, an excellent and reliable value. The Science Motivation Questionnaire II is confirmed to have good content and criterion-related validity (Glynn, Taasoobshirazi and Brickman, 2009; Glynn, Brickman, Armstrong and Taasoobshirazi, 2011).

Findings

The first objective of this study was to describe and measure the conceptual factors that motivated Mizo secondary school students of Mizoram in science. Tables 1 and 2 describe these findings.

Table 1

Conceptual Factors Motivating Students to Learn Science (n=1134)

Components/ Statements				
Intrinsic Motivation	Mean(0-4)	Median(0-4)	Mode(0-4)	SD
Learning science is interesting	2.99	3	4	1.06
I am curious about discoveries in science	2.56	3	2	1.24
The science I learn is relevant to my life	2.68	2	2	0.96
Learning science makes my life more meaningful	2.84	3	4	1.12
I enjoy learning science	2.63	2	2	1.14
Career Motivation				
Learning science will help me get a good job	3.29	4	4	1.07
Understanding science will benefit me in my career	3.17	4	4	1.09
Knowing science will give me a career advantage	3.16	4	4	1.10
I will use science problem-solving skills in my career	2.56	3	2	1.21
My career will involve science	2.61	3	4	1.29
Self Determination				

I study hard to learn science	2.57	2	2	1.10
I prepare well for science tests and labs	2.31	2	2	1.12
I put enough effort into learning science	2.16	2	2	1.09
I spend a lot of time learning science	2.09	2	2	1.07
I use strategies to learn science well	2.06	2	2	1.09
Self Efficacy				
I believe I can earn a grade of "A" in science	2.54	2	2	1.19
I am confident I will do well on science tests	2.28	2	2	1.09
I believe I can master science knowledge and skills	2.08	2	2	1.32
I am sure I can understand science	3.01	3	4	1.04
I am confident I will do well on science labs and projects	2.26	2	2	1.12
Grade Motivation				
Scoring high on science tests and labs matters to me	2.79	3	4	1.24
It is important that I get an "A" in science	3.07	4	4	1.19
I think about the grade I will get in science	2.75	3	4	1.12
Getting a good science grade is important to me	3.31	4	4	1.09
I like to do better than other students on science tests	3.06	4	4	1.09
Summated score	66.83	-	-	28.24

With reference to Table 1, students have a moderate level of motivation to learn science with a summated average of 66.83 out of possible 100 scores. It was found that the most significant motivators for students were grade motivation; specifically, the importance of getting an 'A' in science (M=3.07) and career motivation, believing that learning science will help them get a good job (M=3.29). The least common motivator was self-determination, about being able to use strategies to learn science well (M=2.06) and self-efficacy, on believing that they can master science knowledge and skills (M=2.08).

Further, with reference to Table 2, the highest motivational constructs were found to grade motivation with an average mean for the five items of 3.00 followed by career motivation (M=2.96), intrinsic motivation (M=2.74), self-efficacy (M=2.43), and self-determination (M=2.24).

Table 2

Statistical Description of Five Motivational Constructs

Construct	Mean (0-4)	Median (0-4)	Mode (0-4)	SD
Grade Motivation	3.00	3.6	4.0	1.15
Career Motivation	2.96	3.6	3.6	1.15
Intrinsic Motivation	2.74	2.6	2.8	1.10
Self Efficacy	2.43	2.2	2.4	1.15
Self Determination	2.24	2.0	2.0	1.09

Table 3

Correlation between Science Motivation (IV) and Achievement in Science (DV)

Independent Variable (IV)	Dependent Variable (DV)	N	Df (N-2)	Pearson Product Moment correlation (r)	r^2	Significance level
Science motivation	Achievement in science	1134	1132	0.314	0.098	S**

Source: Field data. **Significant at 0.01 level.

The second objective of this study was to find out the relationship between Mizo secondary school students' science motivation levels and their achievement in science. Table 3 depicts the Pearson Product moment correlation value of 0.314 (df=1132), which is positive and highly significant at a 0.01 level of significance.

The third objective of this study sought to compare the high and low achievers in science in relation to their science motivation. To identify the high and low achievers in the sample, the obtained Class X MBSE board (the block year 2016-2017) scores for students' science achievement were arranged in descending order such that marks were arranged from highest to lowest. The upper 27 per cent of the sample, i.e., the top 306 samples were identified as the high achievers. Similarly, the lower 27 per cent of the sample, i.e., the bottom 306 samples were identified as the low achievers. The science motivation scores of the two groups were subjected to differential analysis. For the testing of the hypothesis, the student's t-test (independent sample) was performed (Table 4).

Table 4

Significance of Difference between High and Low Achievers in Science in Relation to their Science Motivation

Group	Number	Mean	S.D.	SEM	t value	df	Significance of Difference	Decision on Null Hypothesis
High Achievers	306	72.327	13.484	.7708	10.68	610	S**	Rejected
Low Achievers	306	60.307	14.350	.8204				

Source: Field data, **The test suggests that the difference between the two means is highly significant at 0.01 level

Interpretation of data: A reference to Table 4 reveals that there is a statistically significant difference between the mean science motivation scores of high achievers in science (M=72.327, SD=13.484) and mean science motivation scores of low achievers in science (M=60.307, SD=14.350); the obtained t value (10.68) was found extremely significant at 0.01 level with a degree of freedom 610, 't' critical value (2.576) being < obtained 't' value. It means that the science motivation of secondary school students varies between low and high achievers. Hence the null hypothesis was rejected. Furthermore, the science motivation of high achievers is greater than that of low achievers, which suggests that students who are highly motivated perform better in science.

An analysis was performed where the students' science motivation scores were segregated into five motivation levels. The SMQ (Science Motivation Questionnaire) II by Glynn, et al. (2011) does not specify the general science motivation levels as it is standardised on the American sample, but five motivational factors can be classified into different motivation levels. Students respond to each item on a rating scale of temporal frequency: never (0), rarely (1), sometimes (2), often (3), or always (4). The possible score range on every five 5-item scales is 0–20. For an individual student, on any of the five 5-item scales, they can be put into a degree of science motivation by dividing their scale score (0-20) by 5. For example, a student with an intrinsic motivation scale score of 12 (out of 20) is "sometimes too often" intrinsically motivated 12/5 = 2.4. A similar attempt to classify the total scores (range 0-100) into five levels of motivation was made. Five arbitrary categories of motivation scores were made such that 0 scores mean an absolute absence of science motivation score range from 1-25 meant only low science motivation, 26-50 meant an average or moderate level of science motivation, 51-75 meant an above moderate level and 76-100 meant a high level of science motivation; there were no students with 0 scores, and the least score was 12. there were only five students having science motivation scores between 1 and 25. One hundred forty-eight students scored from 26-50, 653 students scored from 51-75, which were maximum, followed by 328 students scoring from 76-100. The highest science motivation score was that of 100 (Table 5).

Table 5

Comparative Frequency Distribution of Students' Scores on Science Motivation

Classification	Score Range	No. of respondents	Percentage	Cumulative %
High Motivation	76-100	328	28.92%	100%
Above Moderate Motivation	51-75	653	57.58%	71.07%
Moderate Motivation	26-50	148	13.05%	13.49%
Low Motivation	1-25	5	0.44%	0.44%
No Motivation	0	0	0%	0%

Source: Field data

With reference to Table 5, it can be said that only 28.92 per cent of the total students possess high science motivation and 57.58 per cent of students possess above a moderate level of science motivation together, accounting for 86.5 per cent of the total students. This figure indicates that the sample population has an above-average level of science motivation, which is favorable for improving science achievement. There were no students with the absence of science motivation, and only five students possessed a low science motivation score. Nearly 13.05 per cent of students possessed a moderate level of science motivation.

A comparison of mean science scores of all the five categories of students segregated based on their science motivation levels (Fig.1) revealed that students possessing low science motivation (M = 54, SEM = 3.317) did not differ significantly (P>0.05) from any of the other groups. However, the other three groups significantly differed (P<0.001) in their mean science scores. The mean score of the moderate motivation group was the least (M = 48.83, SEM = 1.177), the above moderate level had the second highest (M= 55.92, SEM = 0.5601), and the high science motivation group had a maximum mean science score (M = 62.99, SEM = 0.8083).

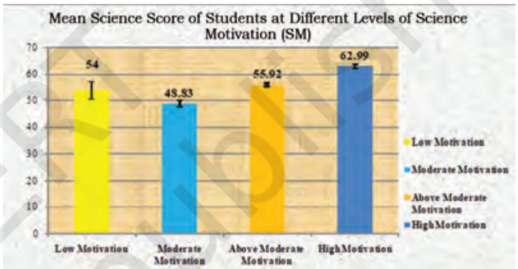

Fig.1. Mean science score of students at different levels of science motivation (SM)

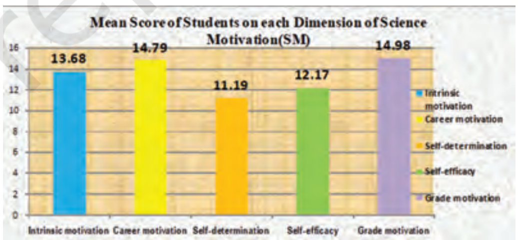

Fig. 2. Mean score of students on each dimension of science motivation (SM)

A further analysis was performed where the students' responses on science motivation were categorised into five dimensions of the SMQ II. As already mentioned, the scale comprises five items under its dimension 'intrinsic motivation', 'career motivation,' 'self-determination,' 'self-efficacy' and 'grade motivation.' Each dimension is measured through 5 items with a score range of 0-20. The minimum score obtained under each dimension can be 0, and the maximum score can be 20. The frequency distribution of the average score of students on each dimension of science motivation was analysed using percentages (Fig. 2). The findings revealed that students scored maximum under the 'grade motivation' dimension with the mean value of 14.98 followed by 'career motivation,' 'intrinsic motivation,' 'self-efficacy,' and minimum under 'self-determination' with the mean value of 11.18. The comparative mean scores obtained on all the five dimensions are summarised in Table 6.

Table 6

Mean Score of Students on each Dimension of Science Motivation

Dimensions of SM	Mean Score on each Dimension of Science Motivation
Grade Motivation (0-20)	14.98
Career Motivation (0-20)	14.79
Intrinsic Motivation (0-20)	13.68
Self-Efficacy (0-20)	12.17
Self-Determination (0-20)	11.19

To have a clear-cut understanding of the differences of high and low achievers in science in terms of their science motivation, a student t-test (independent) was performed to compare the high and low science achievers for their science motivation levels on each of its five dimensions as mentioned before.

Table 7 depicts the results of the hypothesis testing.

Interpretation of data: A reference to Table 7 shows that for all the five dimensions of SMQ II, there is a statistically significant difference between the mean science motivation scores of high and low achievers in science, which are
Intrinsic motivation [$t(610)=6.657$, $p<.0.0001$)], Career motivation [$t(610)=8.114$, $p<.0.0001$)], Self-determination [$t(610)=5.879$, $p<.0.0001$)], Self-efficacy [$t(610)=8.043$, $p<.0.0001$)] and Grade motivation [$t(610)=11.575$, $p<.0.0001$)].

In all the dimensions, the high achievers in science differed significantly with higher mean science motivation scores than those of low achievers.

The fourth objective of the study was to examine the gender variation in science motivation amongst secondary school students. Here the primary variable of concern is the student's science motivation at the secondary level. Gender can be an essential factor impacting students' motivation to learn science. In the present study, the sample comprises more girls than boys, i.e., 602 girls and 532 boys, i.e., 53.086 per cent and 46.91 per cent, respectively, which almost corresponds to the original population of data of secondary school students of Aizawl District (State Yearbook 2014-15), which is 51.44 per cent and 48.55per cent, respectively. Table 8 depicts the t-test analysis.

Table 7
Significance of Difference between High and Low Achievers in Science in Relation to Their Means on Different Dimensions of Science Motivation

Dimensions	Groups	Number	Mean (M)	S.D.	SEM	t value	df	Significance of Difference	Decision on Null Hypothesis
Intrinsic Motivation	High achievers in science	306	14.56	3.497	0.1999	6.657	610	S**(0.01)	Rejected
	Low achievers in science	306	12.67	3.535	0.2021				
Career Motivation	High achievers in science	306	15.91	3.754	0.2146	8.114	610	S**(0.01)	Rejected
	Low achievers in science	306	13.31	4.138	0.2365				
Self-Determination	High achievers in science	306	11.98	3.670	0.2098	5.879	610	S**(0.01)	Rejected
	Low Achievers in science	306	10.29	3.449	0.1972				
Self-Efficacy	High achievers in science	306	13.23	3.719	0.2126	8.043	610	S**(0.01)	Rejected
	Low achievers in science	306	10.69	4.073	0.2329				
Grade Motivation	High achievers in science	306	16.64	3.260	0.1864	11.575	610	S**(0.01)	Rejected
	Low achievers in science	306	13.25	3.950	0.2258				

Source: Field data, ** The test suggests that the difference between the two means is extremely significant at 0.01 level.

Table 8

Significance of Difference between Boys and Girls in Relation to Their Science Motivation

Group	Number (N)	Mean	S.D.	SEM	t value	Df	Significance of difference	Decision on Null Hypothesis
Boys	532	67.938	14.854	.644	2.36	1132	S*	Rejected
Girls	602	65.895	14.282	.582				

Source: Field data. *The test suggests that the difference between the two means is significant at 0.02 level.

Interpretation of data: A reference to Table 8 reveals that the obtained t value (2.36) was found significant at 0.02 level with a degree of freedom 1132, 't' critical value (2.326) being < obtained 't' value. It means that the science motivation of secondary school students varies with respect to their gender, with boys being more science motivated. Hence the null hypothesis is rejected.

Table 9 further depicts the mean and standard deviation scores of students for different dimensions of the Science Motivation Questionnaire (SMQ II) with regard to gender.

Table 9

Mean and Standard Deviation Values of Boys and Girls on Different Dimensions of Science Motivation Questionnaire

Factors of science motivation	Boys (n=532)	Girls (n=602)	Total (n=1134)
Intrinsic motivation	M=14.103	M=13.314	M=13.684
	sd=3.552	sd=3.532	sd=3.562
Career motivation	M=14.881	M=14.723	M=14.797
	sd=3.953	sd=3.976	sd=3.964
Self-determination	M=11.240	M=11.149	M=11.192
	sd=3.678	sd=3.511	sd=3.589
Self-efficacy	M=12.714	M=11.694	M=12.173
	sd=4.048	sd=3.834	sd=3.967
Grade motivation	M=14.951	M=15.015	M=14.985
	sd=3.910	sd=3.795	sd=3.848

A reference to Table 9 suggests that the mean score of boys and girls on all the five dimensions of science motivation differed slightly, with boys' average being slightly higher except for the dimension grade motivation where girls had a higher mean score. Interestingly, the standard deviation for both boys and girls was almost neck to neck except for dimension self-efficacy, where boys had a higher mean score and standard deviation than their counterparts.

Researchers also attempted to perform a point bi-serial correlation between the variable gender and student's score on science motivation, which is a special type of Pearson product-moment Correlation considering the nature of a variable. With reference to Table 10, it can be seen that science motivation and gender are negatively correlated, i.e., a higher level of science motivation is exhibited by a lower number of group variable 'gender,' which is 1 for boys and correspondingly, girls with group variable 2 exhibited a lower level of science motivation. However, the girls did not underperform compared to boys at the same time as the correlation is low negative, although significant at 0.05 level.

The fifth objective of the present study was to find out the gender differences among high and low achievers in science in relation to their science motivation. Table 11 depicts the result of the t-test.

Table 10

Correlation between Science Motivation (IV) and Gender (DV)

Independent Variable (IV)	Dependent Variable	N	Df (N-2)	Point bi-serial Correlation	Significance level
Science motivation	Gender	1134	1132	-0.07	S*

Source: Field data. *Significant at 0.05 level

Table 11

Significance of Difference Between Boys and Girls within High and Low Achieving Groups of Science in Relation to Their Science Motivation (SM)

Group	Number	Mean	SD	SEM	T value	df	Significance of Difference	Decision on Null Hypothesis
SM of High Achieving Boys	156	72.70	14.58	1.168	0.491	304	NS	Accepted
SM of High Achieving Girls	150	71.94	12.27	1.002				

SM of Low Achieving Boys	120	61.26	14.25	1.301	0.931	304	NS	Accepted
SM of Low Achieving Girls	186	59.69	14.42	1.057				

Source: Field data

Interpretation of data: A reference to Table 11 reveals that after the comparison between mean on science motivation of boys and girls within the high achieving group, the obtained t value (0.491) was found not significant at 0.05 level with a degree of freedom 304, 't' critical value (1.960) being < obtained 't' value. It means that there is no variation in students' science motivation within the high achieving group with respect to their gender. Hence the null hypothesis is accepted. A similar comparison within the low achieving group was also performed. Again with reference to Table 11, the obtained t value (0.931) was found not significant at 0.05 level with a degree of freedom 304, 't' critical value (1.960) being < obtained 't' value. It means that there is no variation in science motivation of students within the low achieving group with respect to their gender. Hence the null hypothesis is accepted.

Discussion

The purpose of this study was to determine how the secondary students conceptualised their motivation to learn science, particularly those belonging to a close-knit population of ethnic diversity in the northeastern state of Mizoram, India. When analysing the conceptual factors that motivate the students to learn science, the highest motivational construct existed for grade motivation, followed by career motivation, intrinsic motivation, self-efficacy, and least for self-determination construct. The study also showed a significant positive relationship between students' science motivation level and achievement in science (r =.314**, r^2=.098, p=.000). This finding is sinking with a similar study on Malaysian secondary school students (Chan and Norlizah, 2017). The results indicated that students' motivation towards science learning significantly correlates with students' science achievement (r =.354**, r^2=.125, p=.000). The present study revealed that high and low achievers in science significantly differed on their science motivation level, with high motivators scoring high. This finding is analogous to the finding of Tuan, Chin and Shieh (2005), who found in their study of junior high school students from central Taiwan that high motivators and low motivators showed a significant difference (p <0.01) in students' motivation toward science learning (SMTSL) score measured with six scales of self-efficacy, active learning strategies, science learning value, performance goal, achievement goal, and learning environment.

However, in the present study, a significant difference existed between boys and girls regarding their science motivational level. Comparing their mean scores favours the boys; exceptionally, girls were found to obtain a higher mean score for grade motivation than their counterparts compared to their mean scores for each of the five sub-constructs. It suggests that girls are more motivated to obtain higher grades in science, which is also the highest motivational construct that impacts students' high achievement in science. Although in a similar study by Salta and Koulougliotis (2015) based on the Greek version of Chemistry Motivation Questionnaire II (Greek CMQ II), girls differed from a boy on other dimensions, and gender-based comparisons showed that girls had higher self-determination than boys; also the girls of lower secondary groups had a higher career and intrinsic motivation than the boys of the same age group. In general, the present sample could conclude that extrinsic motivational factors of obtaining good grades and a promising career in science propel students more to perform well than intrinsic motivational factors. The least motivating factor of self-determination and self-efficacy to perform well in science is indicative that science learning is being treated as more of a mechanical endeavour than a practical exercise. As a result, students fail to build upon trust to do well in science. Thus science learning needs a more favourable environment where fears and phobias need to be erased, lacking which intrinsic motivational factors do not work. The findings also indicate no significant difference in students' science motivational levels within high and low science achievement groups with regard to their gender. This suggests that gender is not a deciding factor for students' science achievement differences in extreme groups, although differences exist. In their study, Chan and Norlizah (2017) found that Malaysian secondary school students' motivation towards science learning is impacted by gender. The female students were found to be significantly more motivated than the boys. Also in the Malaysian sample results showed that the level of students' motivation towards science learning was moderate, and the science achievement level was between averages to low.

The present study's findings revealed that the level of science motivation of secondary students in Mizoram is towards a higher range, and it was found that they scored more than average in all the dimensions. They scored a maximum for the dimension of grade motivation followed by career motivation, intrinsic motivation, self-efficacy, and self-determination. The findings agree with earlier studies (Bryan, Glynn and Kittleson 2011; Salta and Koulougliotis, 2015; Chumbley, Haynes and Stofer, 2015). It indicates students are maximally motivated to perform better in sciences to get good grades and find a good career option, and to some extent, they have more than a moderate level of intrinsic motivation. However, self-efficacy and self-determination are of average level, which needs further improvement. It conveys that students are not self-motivated and confident for doing academically better in science, which may be due to a lack of favourable environmental factors.

Recommendations

The present study recommends bringing changes in traditional science classroom experiences for students providing equal opportunities and encouragement for girls and boys. This study tried to show the gender differences in motivational constructs, majorly revealing the dominance of boys in being highly motivated to learn science; however, reasons for less science motivation among girls need to be found out. In the present sample, girls were found to be more than boys, but despite gender parity in the Mizo schools, it needs to be investigated why girls are less motivated to learn science. Further, it needs to be investigated what kind of preferences for learning science are sought by the students at the secondary level of schooling in general. Also, additional research is needed to enrol more students in the science stream and investigate the factors that favour more boys to join the stream than their counterparts. Some specific questions such as, what are the factors preventing girls from choosing science stream in the future and how the science content should be organized to attract an equal audience of both the gender and why is it so that students are moderately motivated to do science in their future endeavours needs to be answered through further research. Secondary school students need to be motivated well for learning science. Students with high science motivation levels should be constantly encouraged to enter higher education in sciences as they befit there very well. The positive affective traits of students such as motivation and interest towards science subjects are needed to be readily incorporated both inside and outside classroom teaching-learning situations. Its beneficial effect on learner gets translated to improved performance of students in science, and vice versa is one of the vital recommendations of the present study.

Conclusion

The present study suggests that science motivation within secondary students can positively contribute to their achievement in science both at present and for their choice of a future career in science. The present findings in the particular context of Mizo secondary school students reveal similarities with many populations of different contexts, emphasising the need to promote students' positive affect in connection with science subjects. Science motivation is an affective construct in science education, which refers to students' psychological state that arouses them to perform better in a science subject. This construct positively influences a student's science performance, so its advantage readily needs to be incorporated in science classrooms. In addition, student environmental factors such as, school, teachers, peers, parents, etc., can also influence it. In the present study, secondary school students possess above moderate level of science motivation, suggesting that students want to learn science and science hold a crucial position in the school curriculum. The affective traits of learners have a significant role in both science and students' overall academic achievement to such an extent that the science teaching and learning process cannot afford to ignore it.

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CLIMATE CHANGE AND CLIMATE LITERACY IN INDIA — SOME KEY ASPECTS FOR CONSIDERATION IN THE CURRICULUM

Chong Shimray

Department of Education in Science and Mathematics
National Council of Educational Research and Training,
New Delhi - 110 016

Climate change is such a threat to human existence that world leaders meet and negotiate to take appropriate measures to address it. Although the Government of India is committed to tackling it, the issue has not caught the attention of its people, and hence it is not a part of daily discourses, not even in educational institutions. A closer look at the existing curriculum reveals that the emphasis given to climate change is inadequate, and climate change is yet to be streamlined in the curriculum. The article provides a perspective on how to incorporate climate change education and the possible challenges to be overcome to bring about climate literacy.

Keywords: Climate change education, Climate literacy, Curriculum, Threat-multiplier

Introduction

So much is said about climate change, so much so that global meetings are organised, forums are created, platforms are provided for world leaders to talk and negotiate climate change. Such is the importance and urgency to take on the 'Armageddon' of the day, or so it seems. However, the pace and reluctance with which we are moving is reason enough to be suspicious if we are even serious about climate change and honestly try to address it. We seem to believe theoretically, but practically, we are no different from those who outrightly deny human-caused climate change. If we were so convinced of its urgency to tackle, countries would not be 'negotiating' so much, unlike what we see today. Every human soul on earth would be 'dousing the fire' (mitigating) or preparing to protect oneself from it (adapting)! One wonders what could be the possible reasons for rejection and also for such passivity or inaction. Is it sheer ignorance? Is there vested interest economically? Are not the evidence enough? Did scientists fail to communicate the message well? Have we failed to nurture climate-literate students and citizens? With this backdrop, the article discusses the strategies that have been adopted to tackle climate change globally with special reference to India. It will primarily focus on how and what aspects of climate change need to be incorporated into the curriculum in schools and colleges and the challenges in this endeavour. Some suggestions on incorporating climate change in the school curriculum have also been provided in brief.

Overview of Global Initiatives on Climate Change

It might surprise many of us to know that one of the earliest warnings about global warming can be traced back to 1912 in *Popular Mechanics Magazine*, March 1912 issue, which shows a photograph of a coal plant with the caption, "The furnaces of the world are now burning about 2,000,000,000 tons of coal a year. When this is burned, united with oxygen, it adds about 7,000,000,000 tons of carbon dioxide to the atmosphere yearly. This makes the air a more effective blanket for the earth and raises its temperature. The effect may be considerable in a few centuries" (Molena, 1912, p.341).

Today, climate change is undoubtedly the most significant threat facing the world, a threat so frightening that borrowing from what Al Gore used in his keynote address at the 2018 Nobel Peace Prize Forum on "How to Solve the Climate Crisis?", we need "all hands on deck" if we are to tackle this daunting challenge facing us. Recognizing this, the United Nations set up the Intergovernmental Panel on Climate Change (IPCC) in 1988, and subsequently, the United Nations Framework Convention on Climate Change (UNFCCC), an international intergovernmental treaty, was adopted in 1992. Since then, there have been rounds of meetings of the Conference of Parties (CoPs) under the Framework. At the same time, there has been significant progress in terms of research on climate change. The famous 'hockey stick' graph that is referred to in the context of climate change was first published in 1999 by Michael Mann and colleagues (Mann, et al., 1999) as an extension of their 1998 paper in 1998 in *Nature* (Mann, et al., 1998). This graph found a place in the 2001 report of the IPCC. Today, climate change is being heavily researched and needfully so. We have more than sufficient data to warn ourselves about the terrifying impacts of climate change. No doubt, significant developments have taken place at the CoPs. For example, the Kyoto Protocol was adopted in 1997 at the CoP-3 meeting held in Kyoto, Japan, in December 1997, wherein it was decided that countries party to the Protocol would implement policies in "achieving its quantified emission limitation and reduction commitments" (UN, 1998). The central aim of the Paris Agreement is: "Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels..." (UN, 2015).

However, as countries such as the United States announced to pull out of the Paris Agreement while other countries were working on their Intended Nationally Determined Contributions (INDCs), a 'tsunami' rocked the world when the IPCC in October 2018 came out with an emergency report titled 'Global Warming of 1.5°C'. The report stressed the disastrous consequences of what a 2°C increase would do compared to a 1.5°C increase in global average temperature from the pre-industrial time. For example, the report mentioned that limiting global warming to 1.5°C is projected to lower global mean sea level rise; reduce impacts on biodiversity and ecosystems; including species loss and extinction; reduce increases in ocean temperature as well as associated increases in ocean acidity and decreases in ocean oxygen levels; reduce climate-related risks to health, livelihoods, food security, water supply, human security, and economic growth, etc. (IPCC, 2018). Soon after this report came out, there was a meeting of the CoP-24 at Katowice, Poland, in December 2018. The outcome was more about agreeing to put the Paris Agreement into practice inviting Parties to make use of the information contained in the special IPCC October report in their discussions under all relevant agenda items of the subsidiary and governing bodies (https://unfccc.int/sites/default/files/resource/cp24_auv_1cp24_final.pdf). Subsequently, the UN Climate Change Conference CoP-25 took place in Madrid, Spain, in 2019. The outcome of the conference was not satisfactory, as is evident from the statement by the Executive Secretary of UN Climate Change, Patricia Espinosa, on the outcome of CoP-25 when she said, "We need to be clear that the conference did not result in agreement on the guidelines for a much-needed carbon market – an essential part of the toolkit to raise ambition that can harness the potential of the private sector and generate finance for adaptation. Developed countries have yet to fully address the calls from developing countries for enhanced support in finance, technology, and capacity building, without which they cannot green their economies and build adequate resilience to climate change. High-emitting countries did not send a clear enough signal that they are ready to improve their climate strategies..." (https://unfccc.int/news/statement-by-the-executive-secretary-of-un-climate-change-patricia-espinosa-on-the-outcome-of-cop25). The IPCC also comes out with reports occasionally on various aspects of climate change, such as the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories that provide methodologies for estimating national inventories of anthropogenic emissions by sources and removals by sinks of greenhouse gases, special reports titled "Climate Change and Land" in 2019, "The Ocean and Cryosphere in a Changing Climate" in 2019, etc. (https://www.ipcc.ch/reports/). Nevertheless, there are reasons not to lose hope as there also appears some silver lining with the change in the administration in the United States. This is significant not only because the United States is one of the highest emitters of greenhouse gases but also because of all other decisions that would be taken in terms of funding for research, innovation, or even the humanitarian sector, etc.

In the World Economic Forum 2019 held at Davos, most prominent leaders of the world, such as the UN Secretary-General, New Zealand, and Netherland Prime Ministers, also spoke of the urgent and vital need to protect the environment with Japan's Prime Minister emphasizing that climate action would be a top priority. Furthermore, in the Global Risks Report 2019 brought out by the World Economic Forum, of the top five Global Risks in Terms of Likelihood for 2019, the top three are related to climate change, i.e., extreme weather events, failure of climate-change mitigation and adaptation and natural disasters (WEF, 2019). In the same line, the WEF 2020 was held in January 2020, and not surprisingly, climate change and its risks emerged as the top issue.

India's Response to Climate Change

Ironically, while India ranks at number 14 (for 2017) in the Global Climate Risk Index 2019 (German Watch, 2018), climate change is yet to receive adequate attention in our daily public conversations, even in educational institutions. This is despite the fact that the Government of India acknowledges the impacts climate change is going to have on India. The Government of India, in its report entitled "Climate Change and India: A 4x4 Assessment – A Sectoral and Regional Analysis for the 2030s," mentioned that no other country in the world is said to be as vulnerable, on so many dimensions, to climate change as India (*MoEF, 2010*). In order to stress and highlight India's concern for climate change, it has also renamed the Ministry of Environment and Forests as Ministry of Environment, Forest and Climate Change. It is also evident from India's Intended Nationally Determined Contribution document that climate change is undoubtedly a priority area (MoEF&CC, 2015).

However, if the public had seriously considered climate change to be a real issue, it should have been an important consideration in everyday discourses, including education. Unfortunately, this is not happening, at least for now. However, this does not mean we disagree with the scientific consensus about climate change. It is just that we do not talk about it. The fact that we do not talk about it or debate about climate change, as it is in some countries like the United States, can be a good sign, as well as bad. Good, because it will be easier to implement policies and actions without much resistance. Bad, because we may passively accept whatever is imposed upon us without critically thinking or questioning possible solutions, or even scrutinizing scientific findings. Passivity towards such a threatening issue seems too huge a risk to take. However, it does seem that we do not 'see' or 'feel' climate change happening, and, therefore, the passivity exhibited towards the issue. Otherwise, by now, we would be already acting "as if the house was on fire," as the sixteen-year-old climate activist Greta Thunberg put it at Davos 2019.

Climate Change Education in India

Education is considered a powerful tool to transform societies and, thereby, nations. Therefore, the importance of climate change education cannot be overemphasized. Recognizing its importance, the National Science Teachers Association even had to issue a statement that climate change is given its due emphasis in the curriculum (NSTA, 2018). The goal of including climate change in the curriculum is to bring about climate literacy amongst the students. Climate literacy is defined as "an understanding of your influence on climate and climate's influence on you and society" (USGCRP, 2009). This implies that climate change is not only a subject matter of science but is interdisciplinary in nature. While science provides the basic understanding of how the climate works, the social sciences can provide the necessary knowledge about economics and its social implications and empower students with an understanding about polity and climate change, historical perspective of climate change, indigenous knowledge and climate change, implications of climate change on language, literature, and culture. Arts, too, have unique ways to portray climate change through different art forms. While the best curriculum for climate change education would be to discuss it holistically, the existing school structures do not support such an interdisciplinary approach (Chang and Pascua, 2017). Hence, a systematic approach through various disciplinary areas such as science, social science, language, arts, and humanities remains the best available option.

I. Present Status

While studies around the world indicate that students' knowledge about climate change is poor or superficial with erroneous information or misconceptions, for example, Singaporean students not able to connect its causes with impacts and hold misconceptions (Chang, 2014; Chang and Pascua, 2016), or poor knowledge exhibited amongst high school students in Austria and Denmark (Harker-schuch, et al., 2013), there is minimal research on Indian students' knowledge about climate change and their preparedness to tackle the issues associated with climate change by way of mitigation or adaptation. Although not for students, one that can be cited here is a study conducted among Indian adults by Leiserowitz, et al. (2013) of Yale University. They found that only 19% were aware and convinced of the reality and danger of climate change and highly supportive of national actions to mitigate the threat, while a huge chunk (16%) of the participants had never heard of climate change and had no opinion about it, even when it was described to them.

Nevertheless, the existing curriculum of the school and college will give a fair idea about how much students can learn about climate change in the best scenario and what aspects of climate change have been focussed on in those syllabi.

(i) The current school curriculum in India at a glance

Climate change can be found incorporated in the school curriculum, especially in disciplinary subjects such as science and geography. We can find topics such as the greenhouse effect, climate change, ocean currents, etc., in the curriculum of these subjects. However, climate change is yet to be streamlined in the curriculum, unlike other 'established' concepts. For example, if we look into the syllabus developed by NCERT (NCERT, 2006a; NCERT, 2006b), the concept of photosynthesis has been systematically introduced spirally in the curriculum of Science for Class VII and Class X and further in Biology Class XI with increasing depth. A similar pattern is followed for other concepts as well, such as reproduction, digestion, sound, motion, electricity, chemical reactions, etc. Unlike these streamlined concepts, a systematic approach to climate literacy is missing in the curriculum. Topics related to climate change are included haphazardly and piece-meal. In addition, most of the critical topics fundamental to learning climate change do not find a place in the curriculum. For example, the basic idea of how scientists measure climate so as to arrive at the global average temperature, how has the temperature changed over the past two centuries which is attributed to anthropogenic activities, or what is the evidence of climate change or why polar regions are getting warmer faster, how different sectors in India will be impacted, etc., are yet to find a place in the curriculum. Given the emergency state we are approaching due to climate change; one would expect that climate change education would form the overarching theme in the curriculum. On the contrary, very few topics have been covered. However, it is essential to point out here that the existing school curriculum was developed based on the National Curriculum Framework-2005. Many of the data about climate science that we have today were not available then. And hence that could be one valid reason the curriculum did not emphasise climate change education. While textbooks are reviewed regularly before reprinting, patchwork to add some topics related to climate change would not be helpful. It would require a complete reorganisation of the curriculum in different subjects if climate change is to be incorporated systematically. Therefore, one can only expect a meaningful and comprehensive change in the curriculum only after the country brings out a new curriculum framework.

(ii) Curriculum in higher education

Of late, it is encouraging to find that environmental science departments are being added to different universities. Such departments provide avenues for an in-depth course and research on climate change. While the compulsory Environmental Studies course for all higher education institutes as per the Hon'ble Supreme Court's order includes climate change and global warming as one of the umpteen topics in the course, it is to be seen how such an isolated approach to climate change will serve the purpose. In addition to incorporating climate change as a separate topic, connecting all other topics in the course with climate change will be helpful.

II. Dimensions for Climate Change Education

This section will discuss the different dimensions that need to be incorporated in climate change education. This will give curriculum developers and educators ideas about the concerns to be considered while dealing with climate change education.

Despite its complexity, today, we know much about climate science, and more keeps unraveling as new findings are added by researchers each day. If humans were the only ones to deal with a 1 degree Celsius rise in temperature, it would not have been so much a problem. We would have come up with certain technologies that would help us cope with that. However, as we know, it is much more complicated and far-reaching, resulting in the worsening of the issues already prevalent today. For example, cyclones are becoming more intense, there is more rainfall in less time, floods are becoming more frequent and severe, etc. Therefore climate change is known to be a threat multiplier. Such ramifications that climate change can have must necessarily form part of the curriculum. Some dimensions for consideration are briefly discussed below.

(a) **Agriculture:** Due to global warming, not only oceans but even lands will get warmer and drier which will impact the soil quality. There will be frequent or erratic droughts and floods. The warming of higher altitudes will impact crop production in such places. Pest dynamics are going to change. All of these are going to impact crop production. Carbon dioxide increase will reduce nutrients in wheat, rice, etc. These will have impacts on different dimensions such as food security which could result in tension within and between countries by manipulating import and export of food items; there will be an issue of Internally Displaced People (IDP) due to the movement of farmers to bigger towns and cities or even migration to and from other neighbouring countries. This will, in turn, change the demographies of such towns and cities and put pressure on the limited available resources; reduction in nutrients in crops can impact the health of those who are already vulnerable. In this situation, scientists are likely to develop different kinds of Genetically Modified (GM) crops to tackle food scarcity and security due to climate change.

(b) **Health:** Health is another sector where climate change is expected to impact severely. There will be an increase in the incidence and geographical range of climate-sensitive infectious diseases such as malaria, dengue, tick-borne diseases, etc. (USGCRP, 2009). Those with respiratory diseases, such as, asthma or those vulnerable to other diseases will be hit hardest. These will be exacerbated by poverty.

(c) **Sea level rise and ocean acidification:** Although coastal India will not be soon inundated underwater due to sea-level rises like what we see in Kirabati or Bangladesh, coastal life will definitely be impacted. Sea will be closer to the mainland, affecting settlements close to the sea. New levies will have to be built. More seawater will get into the mainland affecting agriculture and drinking water. The marine ecosystem will be most affected due to ocean acidification from increased carbon dioxide in seawater.

(d) **Water scarcity:** The rainfall pattern will be more haphazard due to climate change and will cause some places to be drier and some places to be wetter. This will be aggravated by warming atmospheric temperature that will cause the lands to be drier. This will impact water availability for agriculture, domestic use, industries, etc. Forest-fed rivers are likely to be drier with lesser rain. We are already faced with a water war between states due to river water sharing. On the other hand, rivers that are also fed by glaciers to some extent may show some changes in their characteristics. For example, if the Himalayan glacier recedes drastically, it will impact rivers such as the Ganga.

(e) **Biodiversity:** We were already losing biodiversity due to habitat loss. This will now be aggravated by temperature rise. We will soon be losing organisms, especially those sensitive to temperature since they are not likely to adapt to the temperature shock so fast. As such, conservation strategies will change and will be more complicated by the addition of the complex climate change factors. We might have to give up on the conservation of some species and focus on some organisms. In addition, prey-predator dynamics will change, impacting the ecosystem.

(f) **Economy:** The economy of the country will be impacted due to the adverse effects of climate change. At the same time, business strategies will change eventually. For example, in coastal areas, insurance companies could give their customers the option to get insurance for their houses due to sea-level rise, etc.

(g) **Climate justice:** Climate change will have the worst impact on vulnerable populations – physical or mental disability, marginalized populations, indigenous populations, technologically-handicapped citizens, economically vulnerable sections of the society, small islands, those living in places with poor medical facilities, outdoor workers, etc.

(h) **Climate refugees:** There will be an increase in refugees due to reduced availability of water, food, and land, competition and conflict among humans and its impact on the lives and security of the refugees and economy and security of the places where refuge is sought. In addition, we had earlier mentioned the issue of IDPs resulting due to the impact of climate change on agriculture.

The above discussion tells us that every dimension of our lives will be impacted by climate change. Given the enormous consequences it will have, we cannot afford to restrict the teaching of climate change in science or geography alone as it is presently practised. As mentioned earlier, every discipline offers something to make students climate-literate.

III. Content Outline for Climate Change Education

Another important consideration in climate change education is identifying the contents that need to be included. Figure 1 broadly outlines the topics that need to be incorporated in the curriculum in appropriate disciplines so that students are given the opportunity to understand the various aspects of climate change (*Shimray, 2018*). They are grouped under the following heads:

1. Climate System
2. Causes of Climate Change
3. Measuring and Modelling Climate
4. Impacts of Climate Change
5. Human Responses to Climate Change

As shown in Fig. 1, the topics included are numerous. Systematic mapping of the topics/concepts will be required to appropriately reflect them at relevant places in different subjects and classes. While taking up this task, it will also be crucial to identify the core essentials (in terms of concept and competency) to be incorporated as part of compulsory Curriculum for ALL students (for climate literacy) and those that can be incorporated into optional subjects (for climate expertise). This step will be crucial towards streamlining climate change in the curriculum. The figure clearly depicts the interdisciplinary nature of climate change. Climate literacy cannot be achieved through one subject. It will require the collective contribution of different subject disciplines. However, this is easier said than done, as we shall see when discussing the challenges.

IV. Challenges in Climate Change Education in India

There are several challenges when it comes to implementing climate change in the curriculum.

(i) When to start teaching?

We know that climate science is complex, and it requires some level of mental maturity to understand it. Therefore, what will be the appropriate class to start teaching about climate change is a reasonable question to ask.

(ii) What to teach where?

We have discussed earlier the interdisciplinary nature of climate change. However, it will be a herculean task to work out a feasible curriculum to incorporate climate change in different disciplines and ensure that students get the 'whole' even as they are fed in 'pieces.'

(iii) Should we focus only on mitigation and adaptation?

Studies have found that conveying the complexities of climate science can be difficult, while equipping students on how to mitigate and adapt to climate change is much easier (*Gardiner, 2014*). While teaching climate science will be inevitable, it will not be easy to empower students towards mitigation and adaptation.

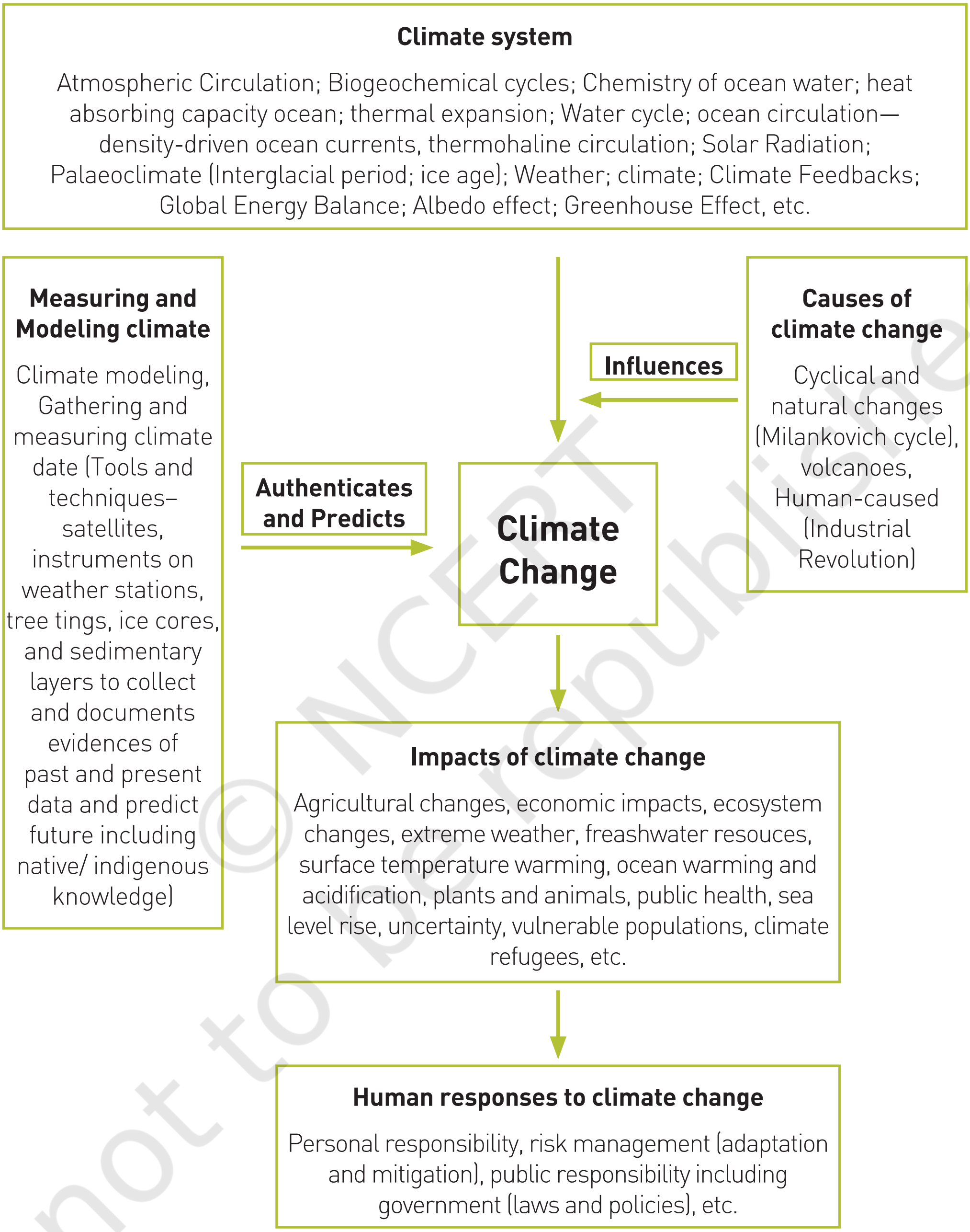

Fig. 1: Content outline for climate change education

(iv) How to make it tangible?

The question of whether climate change is real or not is settled. However, since many do not directly see or feel the impacts, it is a challenge to present it convincingly to students. As a result, students perceive the issue as a distant threat or not relevant to them (Chang, 2014; Newstadt, 2015). What makes the matter worse is that climate change is discussed in terms of decades and not necessarily what is happening at the moment. For example, a particular year may be exceptionally cold compared to other years, yet it does not mean that there is no global warming. The impact is different in different parts of the country or the world. Temperature is also not uniformly increasing, but the average global temperature increases. Therefore, the more significant challenge is to down-scale the climate data or the impact to make it relevant to a smaller geographical area instead of fixating the issue to a global scale so that students can comprehend and contextualize the information. It cannot be denied that climate change itself is a complex phenomenon—the intriguing result of an increase in greenhouse gases, the impact on the average global temperature, atmosphere, and oceans, the effects on precipitation, sea-level rise, and our lives and livelihood, etc. Unless an attempt is made to make these as tangible as possible, the issue will remain too abstract to students and render them lose interest in the issue.

(v) How to communicate about climate change?

Climate change is complex and communicating about it is even more complicated. The hundreds of factors contributing to climate change, the different possible models, data and graphs generated, the various predictions brought forth, etc., are not easily understood by all. Therefore, this information has to be made quantifiable and tailor-made for different audiences in easy-to-understand tables and graphs, animations on various aspects of climate science or its impacts, simplified diagrams, etc. Scientists alone cannot do this daunting task. Teachers, teacher educators, and students have to come along and work in collaboration with scientists to accomplish the task. We are aware of the misconceptions that can arise because of a lack of appropriate or clear information from authentic sources, as we saw in the recent Kerala flood, which was, without authenticity, attributed to climate change by many, including media. However, this claim has been refuted, and the flood has been, to some extent, attributed to ecological mismanagement (Mishra and Shah, 2018). Such misinformation tends to cause more confusion about climate change.

(vi) Have we prepared our teachers?

Climate change is a relatively new topic for many teachers. While some teachers in India are already teaching some aspects of climate change during their teaching of science or geography, teachers, in general, have not been trained to teach climate change specifically in their preparatory courses or in their degree courses. Such lack of training or limited training leads to climate confusion amongst teachers, ultimately reflected in their teaching (Plutzer, et al., 2016). Therefore pointed efforts must be made to prepare teachers accordingly.

(vii) Do we have space for climate change in the school schedule?

The National Education Policy 2020 (NEP-2020)* broadly considers climate change one of the critical issues to focus on. Although there is no specific mention of it under the School Education section, climate change concerns can be incorporated under environmental education. How strongly it will be incorporated is the question. It is also to be noted that our students are already bogged down with the existing curriculum. Therefore, incorporating it into the existing curriculum without burdening students will be a real challenge. This will require meticulous and systematic planning. For example, the 10-day bagless period suggested by NEP-2020 could be explored to engage students in activities that will enhance their capacities on climate change.

V. Some Suggestions to Incorporate Climate Change in the School Curriculum

After understanding the challenges for climate change education, the following briefly discusses how climate change can be more effectively incorporated into the curriculum. In order to achieve this, several aspects have to be taken into consideration. For example, which topics must be included in the curriculum for which class, what resources should be used, which strategy or approach should be used, etc.

Primary stage: At the primary stage, it is not advisable to introduce scientific terminologies used in the context of climate change. Instead, students may be introduced to the ideas they can relate with, such as those of rainfall and changes in the pattern, absorption of light by darker objects or reflection by objects with light, give them an experience of a greenhouse, vegetables, and flowers found in different seasons, scarcity of water, etc. Familiarizing them by allowing them to experience themselves or sharing their experience or what they learn from society will be an excellent way to start.

Upper Primary stage: Students may be introduced to different concepts of the climate system at the upper primary stage, as listed in Fig. 1. They can also be introduced to natural and human-caused climate change, impacts of climate change and human responses, and some aspects of measuring and modelling climate. It is crucial to involve them in climate action at this stage—what they, and others, can do to reduce or adapt to climate change. Students need to be engaged in a lot of critical thinking tasks, for example, what will happen to crops and farmers if it gets warmer and warmer, what happens to people in small islands and the coastal areas if sea level continues to rise, how much more energy we will consume if the temperature keeps on increasing, what kinds of laws and policies should be implemented, etc. A lot of debates and discussions can be taken up at this stage. Simulations, videos, pictures, etc., can be used in addition to hands-on experiences.

Secondary and Higher Secondary stage: The learnings of the previous stage can be strengthened further as students learn

*The Original reference was Draft NEP-2019 but by the time of publication of this issue, NEP-2020 was published and hence modified accordingly..

more profoundly about the concepts and concerns introduced in the upper primary stage. Measuring and modelling may be emphasized in this stage. In addition to learning deeper about climate science and its impacts, the focus at this stage should be about becoming a responsible citizen. They may be introduced to global climate issues, challenges, efforts in different countries, etc. With a focus on problem-solving, they may be allowed to develop a comprehensive plan to tackle climate change which could be in terms of policy, laws, governance, agriculture, transportation, communication, energy production, risk management, zoonotic diseases, etc. This can be given as an individual task or a group task.

Conclusion

There is no denying that climate change is the greatest challenge facing the world today. There is added pressure on developing countries like India, whose route to development is heavily carbon-dependent. Yet we must act and act fast at that. Towards this, first, we need systemic reform in education. Pointed efforts need to be made to not only include but emphasize climate change in all education-related activities—courses, curriculum, or syllabus and policy documents. By doing this, climate change can find adequate space in the curriculum, whether for schools or colleges. All the dimensions of climate change and contents outlined in this article need to be included systematically. Second, scientists/researchers/professors dealing with climate change in universities or other institutes and educators (teacher educators and school teachers) need to work together to come out with audience-specific resources catering to the needs of the users. Platforms such as *Rashtriya Avishkar Abhiyan* under the Ministry of Human Resource Development or the INSPIRE (Innovation in Science Pursuit for Inspired Research) programme managed by the Department of Science and Technology could also be a channel to take up such activities. This is the least that we can do to start with if we say climate change is real and is a threat to our existence. Since there seems to be a clear gap between the challenges facing climate change and the existing curriculum in our schools or colleges, all our attempts should be to fill this gap. Towards this, we need to streamline climate change in the curriculum, map climate change-related concepts for different subjects and classes, develop an appropriate syllabus, textbooks, and other resources, equip teachers and teacher educators, provide necessary infrastructure and space and time in the school curriculum.

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ATTITUDE OF ELEMENTARY SCHOOL STUDENTS TOWARDS MATHEMATICS LEARNING IN ARUNACHAL PRADESH

Vivek Singh*
Department of Education
Rajiv Gandhi University
Arunachal Pradesh - 791 112
Email: vivek.singh02@rgu.ac.in
*Corresponding author

Jumni Maga
Department of Education
Rajiv Gandhi University
Arunachal Pradesh

Mathematics is the science that draws the necessary conclusions, which is very important for our daily life activities. The present research aimed to study Class VIII students' attitudes towards mathematics in private and government schools in the Kamle District of Arunachal Pradesh. Descriptive-cum survey method has been used by applying simple random sampling. Sampling was done at two stages; firstly, six elementary schools were selected out of fifty, and at the second stage, twenty students were selected from each school. In this way, a total of 120 students were selected as respondents for the study. The attitude scale developed by Martha Tapia has been used for the survey. The study's finding reveals that Class VIII students show average attitudes towards mathematics. The attitude of boys was higher than girl students, on the other hand, no difference was found based on types of school (government and private school students).

Keywords: Attitude, Elementary school and Mathematics

Introduction

Mathematics education is necessary to fulfil the needs and expectations of individuals and society. It is vital for the harmonious personality of an individual by developing skills of basic calculations, deductive reasoning, and drawing conclusion. "The main goal of mathematics education in schools is the mathematisation of the child's thinking." (NCF, 2005). Etymologically, mathematics has been derived from the ancient Greek word 'Mathema,' which means 'that which learn.' It has also been considered the science of systematic reasoning and logical thinking. Mathematics is related to other subjects and helps understand other subjects (The National Policy on Education, 1986). For learning this subject, attention, motivation, and a suitable mathematical attitude are required. If students' attitude towards mathematics is positive, then the academic achievement of students will be high and vice versa (Mahanta and Islam 2012). Here mathematical attitude is an action or response expressed by an individual to a particular situation or an object.

The primary purpose of mathematics education is to appreciate mathematics' usefulness, power, and beauty and develop patience and persistence when solving problems. Mathematical curiosity and inductive and deductive reasoning are crucial to analyse and solve problems both in school and in real-life situations. Mathematics is an essential subject in the modern education system and society. Mathematics education at the elementary stage develops the knowledge, skills, and attitudes necessary to pursue further studies in mathematics. Mathematics is used in computer science, physics, engineering, medical science, sociology, history, economics, etc. Hence, mathematics is one of the necessary subjects to be learned. Unfortunately, learning mathematics has been difficult for many students.

Further, in a country like India, learning mathematics is vital to getting a government job or in the private sector, but all the stakeholders like students, parents, and educators need to understand the real meaning and importance of mathematics. The development of mathematical anxiety (Mathemaphobia) in the children's minds is due to the forceful action of the parents and the teachers. Therefore, parents and teachers need to develop a positive attitude towards mathematics rather than forcing them to learn to fetch good marks. In many cases, children opted for mathematics by seeing their friends or by the influence of parents. According to NPE (1986), "Mathematics should be visualised as the vehicle to train a child to think, reason, analyse, and to articulate logically. In the context of NCF (2005), learning mathematics should make students happy rather than scared. It should lead learners to connect the knowledge outside the school. Mathematics is not only concerned with formulas and calculations; it is more than formula and mechanical procedure. Every developed country uses mathematics as a weapon, and every developing country dreams of it because mathematics helps develop technology, leading industries to develop more.

Significance of the Study

Mathematics helps in rational thinking, reasoning skill, self-confidence, time management, and budgeting money in day-to-day life of an individual. Mathematics is also widely referred to as the language of technology and science because the knowledge of mathematics influences the understanding of almost all science subjects. National Achievement Survey (2017) and Annual Status of Education Report- ASER (2018) revealed that the achievement of elementary students of Arunachal Pradesh in mathematics is not satisfactory. Many studies reveal that attitude and achievement are correlated. Hence researchers decided to study the attitude of students towards mathematics. Based on the review of related literature, it was found that many studies have been conducted on the attitude and achievement of students toward mathematics. However, no study has been conducted so far on the attitude of elementary school students toward mathematics in the Kamle district of Arunachal Pradesh. Kamle district is one of the 25 districts of Arunachal Pradesh which is remotely located. The district has a total population of 22,255 and a literacy rate of 69 per cent as of 2017.

Objectives of the Study

(i) To study the attitude of Class VIII students towards mathematics.

(ii) To compare the attitude of male and female Class VIII students towards mathematics.

(iii) To compare the attitude of government and private school Class VIII students towards mathematics.

Hypothesis

(i) $H_0$1-There is no significant difference between the attitude of male and female students of Class VIII towards mathematics.

(ii) $H_0$2- There is no significant difference between the attitude of Class VIII students of private and government schools towards mathematics.

Research Method: In the present study, a descriptive survey method was used to assess the attitude of the Class VIII students towards mathematics in the Kamle district of Arunachal Pradesh.

Population and Sample of the Study

All the 50 middle schools of Kamle district have been considered as the population for the study. A random sampling procedure was applied to select representatives from the population. Sampling was done at two stages; firstly, six elementary schools were selected among all the schools of Kamle district. At the second stage, 20 students were selected from each school. In this way, a total of 120 students were selected as respondents for the study.

Data Collection Procedure

In order to measure the attitude of students toward mathematics, the researcher employed a five-point attitude scale developed by Martha Tapia. It was a bipolar scaling method to measure positive or negative responses to the statements. There were five options against each statement such as; Strongly Disagree (A), Disagree (B), Neutral (C), Agree (D), Strongly Agree (E). Respondents were asked to indicate their degree of agreement with each statement, from strongly agree to strongly disagree. The attitude scale consists of forty statements, of which 11 were negative, and the remaining 29 were positive.

Statistical Techniques

After completing the scoring procedure, the researcher has organised all the raw scores and then logically tabulated them for easy and better understanding and easy analysis and interpretation of the data. For the present study, the researchers applied statistical techniques such as Mean (M), Standard Deviation (SD), Standard Error Deviation (SED), and t-test with the help of Microsoft excel. Furthermore, in the present study, researchers have used quantitative techniques to analyse and interpret the data as per the nature of the data obtained.

Result and Discussion of the Study

The present study attempted to examine students' attitudes toward mathematics concerning their gender and school types. Therefore, the result of the study has been presented in sequential order according to the objectives of the study.

Table 1
Attitude towards Mathematics
Frequency Distribution Table of Total Responses on Attitude

Class Interval	Frequency (f)	C.F
40-60	1	50
61-80	1	70

81-100	6	90
101-120	45	110
121-140	44	130
141-160	15	150
161-180	7	170
181-200	1	190

From Table-1, it can be observed that the maximum number of respondents scored between 100-120, i.e., 45, and the lowest number of respondents scored between 40-60, 60-80, and 180-200, i.e., 1.

Table 2

Comparison of Attitude with Tool Norm

S.No.	Sample	No. of students	Mean	SD
1	Present Study	120	124.67	21.6
2	Tools Norm Value	545	137.36	28.93

Table 2 shows that the mean score of students' attitude of the Kamle District of Arunachal Pradesh is lower than the tool norm value. The possible reason behind this could be the location of the place, tribal society (Ngailiankim, 1987; Rai 1981 and Singh, 2019), and lower educational status. The standard deviation value of the present study is much lower than the normal value. This shows that there are fewer variations in the attitude of students in comparison to tool norm value. The possible reason behind this could be a similar type of exposure and facilities to the Kamle District of Arunachal Pradesh students.

Table 3

Response of Students on Attitude Scale

Total Responses of Student on Each Statement						
S. No.	STATEMENTS	A	B	C	D	E
1	Mathematics is a very worthwhile and necessary subject.	11	23	19	27	39
2	I want to develop my mathematics skills.	5	11	26	35	43
3	I get a great deal of satisfaction out of solving a mathematics problem.	13	26	34	36	11
4	Mathematics develops the mind and teaches a person to think.	6	14	18	47	35
5	Mathematics is important in everyday life.	6	16	18	36	44
6	Mathematics is one of the most important subjects for people to study.	6	16	26	36	36

7	A high school math course would be very helpful no matter what I decide to study.	13	18	42	33	14
8	I can think of many ways that I use math outside school.	1	27	32	39	12
9	Mathematics is one of my most dreaded subjects.	9	36	29	23	21
10	My mind goes blank, and I am unable to think clearly when working with mathematics.	14	24	26	36	18
11	Studying mathematics makes me feel uncomfortable.	9	31	30	33	17
12	Mathematics makes me feel nervous.	15	28	27	27	21
13	I am always under a terrible strain in a math class.	15	23	31	28	23
14	When I hear the word mathematics, I have a feeling of dislike.	13	22	21	35	29
15	It makes me nervous to even think about having to solve a mathematics problem.	15	24	30	32	17
16	Mathematics does not make me scared at all.	27	21	23	32	17
17	I have a lot of self-confidence when it comes to mathematics.	26	29	36	19	10
18	I am able to solve mathematics problems without too much difficulty.	33	32	36	13	6
19	I expect to do fairly well in any math class.	13	33	38	25	10
20	I am always confused in my mathematics class.	11	26	37	30	15
21	I feel a sense of insecurity when attempting mathematics.	12	28	32	33	14
22	I learn mathematics easily.	25	24	35	25	11
23	I am confident that I can learn advanced mathematics.	21	20	28	44	7
24	I have usually enjoyed studying mathematics in school.	24	27	31	24	11
25	Mathematics is dull.	18	17	27	32	24
26	I like to solve new problems in mathematics.	28	16	33	24	16
27	I would prefer to do an assignment in math than to write an easy.	15	37	24	30	13
28	I would like to avoid using mathematics in college.	9	23	27	34	27
29	I really like mathematics.	26	22	31	30	11
30	I am happier in a math class than in any other class.	20	26	32	20	21
31	Mathematics is a very interesting subject.	17	21	26	35	21

32	I am willing to take more than the required amount of mathematics.	19	25	34	27	15
33	I plan to take as much mathematics as I can during my education.	19	24	27	31	19
34	The challenge of math appeals to me.	13	32	31	32	13
35	I think studying advanced mathematics is useful.	11	19	18	39	32
36	I believe studying math helps with problem-solving in other areas.	11	22	31	29	26
37	I am comfortable expressing my ideas on looking for solutions to a difficult problem in math.	24	15	32	28	19
38	I am comfortable answering questions in math class.	18	2	36	31	12
39	A strong math background could help me in my professional life.	10	16	27	34	31
40	I believe I am good at solving math problems.	24	24	33	25	12

The table shows that the highest number of responses strongly agreed (E) against statement No. 5: Mathematics is important in everyday life. Out of 120 responses, 44 respondents strongly agreed with the given statement as they might have felt the importance of mathematics. Again, out of a total of 120 respondents, 33 responded strongly disagree (A) against statement No. 18: I am able to solve mathematics problems without too much difficulty. Most of the responses made by the students towards mathematics were positive. From the table, we can conclude that the attitude of Class VIII students towards mathematics in the Kamle District of Arunachal Pradesh was average.

Table 4

Comparison between the Attitude of Male and Female Class VIII Students towards Mathematics

Group	Number	Mean	SD	SED	Df	t-value
Male	60	127.3	18.32	3.83	118	1.65
Female	60	120.98	23.39			

Significant at 0.05 level of significance

Table 4 shows that the calculated t-value of 1.65 is lesser than the tablet-value of 1.98 with df (118) at a 0.05 level of significance. Hence, the Null Hypothesis ($H_0$1) "There is no significant difference between the attitude of male and female students of Class VIII towards mathematics" is accepted. Hence, it can be concluded that there is no significant difference in attitude of male and female students towards mathematics.

This finding is similar to findings of Mohammed Lawsha, (2011), Farooq and Shah (2008), Singh and Verma (1992), *Khatoon* (1988), who found no difference based on gender. However, Nongsiej and Syiem (2014), *Mahanta* and Islam (2012), Rai (1981) attitude of males is higher than females, but the findings of Baskaran (1991) have the opposite result. The possible reason for this difference may be that male and female students get similar academic experiences in mathematics from their parents and teachers.

Table 5

Comparison of the Attitude of Private and Government Schools of Class VIII Students towards Mathematics

Group	Number	Mean	SD	SED	Df	t-value
Government	60	121.65	24.19	3.85	118	1.30
Private	60	126.67	17.47			

Significant at 0.05 level of significance

Table 5 shows that the calculated t-value 1.30 is lower than table-value 1.98 with df (118) at a 0.05 level of significance. Hence, the Null Hypothesis ($H_0$2) "There is no significant difference between the attitude of Class VIII students of private and government schools towards mathematics" is accepted. Hence it can be concluded that the private and government school students have an equal attitude towards mathematics. Furthermore, the private and government school students of Class VIII were found to have a common attitude towards mathematics; this could be because the government and private schools have shared the same curriculum, assessment, and evaluation.

Conclusion

The present research aimed to study the attitude of Class VIII students in terms of gender (male and female), school type (private and government). The overall attitude score of students was lower than the tool norm. Further, the result of the study shows that no difference was found based on gender and school type. The status of attitude towards mathematics is lower than the tool norm, and achievement in the subject is not up to the mark as per the ASER-2018 report. Hence, there is a need to overhaul the mathematics teaching-learning process in general and the Kamle District in particular.

Educational Implications

The present study has dealt with the attitude of Class VIII students of the Kamle District of Arunachal Pradesh towards mathematics concerning gender and type of schools. The present study is an excellent contribution to the existing body of knowledge. The finding of the research study would be helpful to the policymakers, parents, sociologists, researchers, teachers, and teacher educators. It would help private, and government schools organise desired changes in the mathematics teaching-learning process to develop a suitable attitude towards mathematics. The state government should organise some in-service teacher training to update the teachers with appropriate teaching methods of mathematics at the elementary stage. Department of Education of Rajiv Gandhi University, the only university in the state, should update the curriculum of teacher education programme as per the students' needs to develop a right attitude among the learners.

Delimitation

The present study's findings are delimited to the attitude of Class VIII students towards mathematics in the elementary schools of Kamle District of Arunachal Pradesh.

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SCIENTIFIC ARGUMENTATION — A THEORETICAL FRAMEWORK

Tamralipta Patra*
RIE, Mysuru
NCERT
Email: tamralipta78@gmail.com
*Corresponding author

Sujata B. Hanchinalkar
RIE, Mysuru, NCERT
Email: sbhncert@gmail.com

Science is a subject that involves the construction of theories that explain phenomena that are open to challenge and refutation, which is done by regular observation, framing and questioning hypothesis, experimentation, collecting data, etc. All these processes make the subject practical and instill curiosity among learners. scientific concepts are meant to be questioned to arrive at an answer or explain the why, how, what, and what if. Thus, it is said that science can be better understood if it proceeds through dispute, conflict, and argumentation. To bring out the essence of scientific discussion in a classroom or to make students more involved in the classroom discussion, argumentation in science is essential. Cavagnetto, R. (2010) pointed out that students' participation in argument develops communication skills, critical thinking, an understanding of the culture, practice of science, and scientific literacy. This paper has tried to bring out how crucial scientific argumentation is for reasoning and thinking, how we can link between evidence and claim, and why students and teachers need to be more involved with scientific argumentation. One need to understand that there is a vast difference between typical argumentation and scientific argumentation. Also, our discussion has further emphasised understanding Toulmin's definition of argument from a theoretical perspective and as a methodological tool for analyzing an argument, also known as Toulmin's Argument Pattern (TAP). In this theory, he has discussed various components of an argument and how it helps students evaluate the validity and strength of arguments in science. The paper has even focused on the teaching strategies for carrying out argumentation, as discussed by Simon, Erduran, and Osborne (2006). With this, it can be concluded that still many teachers are unaware of this method of argumentation and can be brought to them by collective workshops. Even in the in-service teaching programmes, an attitude towards scientific argumentation can be introduced.

Keywords: Scientific Argumentation, Toulmin's Argument Pattern (TAP), scientific literacy.

Introduction

Science is a discipline that fosters curiosity and creativity in a child. This subject needs a systematic approach, starting from observing phenomena and collecting data, formulating hypotheses, experimenting, and constructing theories. To learn science better, one needs to proceed through dispute, conflict, and argumentation (Latour and Woolgar, 1986). Argumentation has been of increasing interest in science education as a means of actively involving students in science and, thereby, as a means of promoting their learning (Duschl and Osborne, 2002; Kim, M., and Roth, W.M. 2014). Argumentation is not a new area. Some great philosophers, such as Plato and Aristotle, have been engaged in argumentation (Erduran, S., Ardac, D. and Yakmaci, B., 2006).

Argumentation in science solely means giving justifications and pieces of evidence for a claim. It is an activity that draws a quality conclusion based on proof and justification and explains the relation between a claim and proof (Driver, et al., 2000; Dusch, et al., 2007; Chin and Osborne, 2010). However, it turns out that many students are unaware of how to proceed in scientific argumentation, or rather, we can say they fail to give evidence and justification to some of their claims about the natural world (Erduran, S., Ardac, D. and Yakmaci, B., 2006). For instance, if we take the question, "Does the sun really set and rise?" Few students could answer this question, but some have undertaken the statement as a given fact without knowing the actual cause behind the phenomena. This fact has to be questioned; they have to be argued systematically for a proper understanding. Thus, it was observed that argumentation improved students 'conceptual understanding, thinking critically, helping them to make an informed decision, and enabling them to work in a scientist's way (Faize, Husain and Nisar, 2017). Gradually, the demand for argumentation increased in science, and we started working with different dimensions of argumentation. In this paper, to further understand the depth of argumentation, we will discuss Toulmin's Argumentation Pattern (TAP) and its importance.

It has been analysed that students' participation in argument develops communication skills, metacognitive awareness, critical thinking, and scientific literacy (Cavegnetto, A., 2010). So, here we have tried to discuss further why an argument is necessary, how it develops different skills in students, and how it fosters scientific temper? This paper has even focused on how scientific Inquiry differs from scientific argumentation.

Toulmin's Argumentation Pattern helped in modelling a structured argumentation, and it had some drawbacks too. First, Toulmin's component is bleak, and sometimes it is not easy to distinguish the components from one another, such as data, warrant, and backing (Erdurn, et al. 2004; Faize, F., Husain, W., and Nisar, F., 2017). And second, there were no proper tools to analyse the quality of the argument.

In conclusion, the paper discusses how Toulmin's work has been used to develop a theoretical framework on the argument, how this argument can encourage students towards scientific literacy, and what strategies can enhance the argumentation process in scientific discourse.

Objectives

1. To critically analyse Toulmin's Argumentation Pattern.
2. To find out the role of scientific argumentation in developing scientific temper.

Research Questions

1. What is the framework of Toulmin's Argumentation Pattern?
2. What is the role of scientific argumentation in developing scientific temper?

Methods and Procedure

In this paper, we have used the approach of document analysis to understand the importance of scientific argumentation in a classroom. According to Bowen (2009), "In Document Analysis, the documents—both printed and electronic material are evaluated and reviewed in a systematic procedure." Here, the document containing both text and images is examined and interpreted to elicit meaning and understanding. Documents can take different forms like advertisements, minutes of the meeting; background papers;

books and papers; news and television; newspapers; books and journals in libraries, etc. The preferred documents undergo an analytic procedure that includes finding, synthesizing, comprehending the data present in the document.

As pointed by Bowen (2009),

"Document analysis involves skimming (superficial examination), reading (thorough examination), and interpretation."

In document analysis, the sequential analysis process combines elements of content analysis and thematic analysis. Content analysis is the process where information is put into categories related to the central questions of the research, whereas in thematic analysis, a form of pattern is recognised within the data, with emerging themes, and thus further categorised for analysis (Fereday and Muir-Cochrane, 2006; Bowen, 2009).

This paper has focussed on the work of Toulmin's Argumentation Pattern from the document: by The Uses of Argument. "Toulmin, S. (1958)." The analysis helped us understand the model and the proper structure in argumentation. The paper has discussed the role of different components like data, quantifiers, warrant, backing, claim, and rebuttals and their role in scientific argumentation. In addition to this, other documents like 'The Argument to Foster Scientific Literacy: A Review of Argument Interventions in K-12 Science Contexts' (Cavagnetto, A.R., 2010); 'Learning to Teach Argumentation: Research and Development in the Science Classroom' (Simon, S., Erdnran, S., and Osborne, J., 2006) and 'Using Toulmin's Argument Pattern in the Evaluation of Argumentation in School Science' (Simon, S., 2008) were analyzed that further us to interpret the original document by Toulmin (1958), as most of these papers researched and reviewed Toulmin's work and upon further scrutiny, they had developed a scheme where argumentation was assessed in terms of level. Also, the six elements of TAP for constructing an argument were simplified to five elements. Important excerpts and concepts were taken from the documents, and these original and reviewed papers were analyzed to produce empirical knowledge; through this, an understanding of the concept was developed.

Analysis and Discussion

To critically analyse Toulmin's argumentation pattern

Meaning of Argumentation

Argumentation in science education is quite different from how it is used daily. It is not a 'heated exchange' of opinions and emotions between two rivals to defeat them (Duschi, Scweingruber, and Shouse, 2007; Scientific argumentation, 2013; Faize, F., Husain, W. and Nisar, F., 2017). Instead, it is a systematic approach to find the relation between ideas and shreds of evidence. These include evaluation and validation before reaching any conclusion. Furthermore, the argument in education follows a particular structure involving certain components (Toulmin, 1958; Faize, F., Husain, W. and Nisar, F., 2017). This makes argumentation different from casual dialogues, which are less certain, but argumentation welcomes different opinions from different groups giving justifications for their claims Osborne and Patterson, 2011). In a way, we can say that the process of argumentation undergoes a series of criticism, explanation, evidence, and refutation. First, however, one needs to understand that there is a slight difference between argument and argumentation. Argument refers to the subject of claims, data, warrants, and backings that contribute to the content of the argument, whereas argumentation refers to the process of assembling these components (Simon, Erduran and Osborne, 2006).

Toulmin's Theoretical Perspective on Argumentation

To involve in a proper argumentation, one should follow a proper structure. There had been many researchers on the same. However, here, among all, we tried to discuss the idea given by Toulmin (1958). From Toulmin's perspective, arguments have specific components, which include a claim, data that supports the claim, warrants that provide a link between the data and the claim, backings that strengthen the warrants, and rebuttals indicate the situations under which claim would not be valid (Simon, S.,2008). This interconnection between argument components helps to understand the meaning of the argument. The figure below shows Toulmin's Argument Pattern (Toulmin, 1958) and further modified by from Simon, S. (2008).

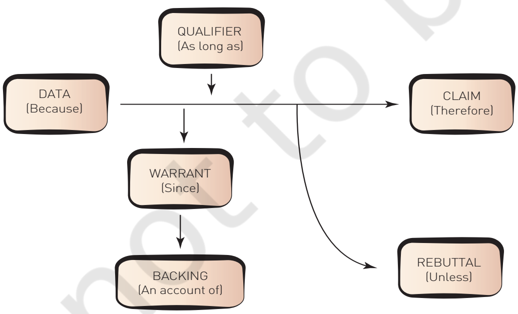

Fig. 1 Toulmin's Argument Pattern

Table 1

Definitions of Different Terms related to Argumentation

Terms	Definitions
Claims	The assertion about what exists or values that people hold.
Data	Statements that are used as evidence to support the claim.
Warrants	Statements that explain the relationship of the data to the claim.
Qualifiers	Special conditions under which the claim holds.
Backings	Underlying assumptions that are often not made explicit.
Rebuttals	Statements contradict either the data, warrant, backing, or qualifier of an argument.

The terms given in Table 1 are according to Toulmin (1958) and later redefined by Simon, S. (2008). Further research was done on Toulmin's definition by Osborne, Erduran, and Simon as a framework for analysing the components of arguments occurring in the classroom discourse and hence the quality of education (Erduran, Simon, and Osborne, 2004; Osborne, Erduran and Simon, 2004a; Simon, Erduran and Osborne, 2006). Upon deep analysis, it was found that the more elements of TAP were present in the dialogue, the better the quality of argumentation and vice-versa. Let us try to understand Toulmin's Argument pattern model with an example given below.

Erduran, Osborne, and Simon generated a scheme where argumentation was assessed in terms of levels, which depicted the quality of opposition or rebuttals in the students' small group discussions (Erduran, Simon, and Osborne, 2004; Osborne, Erduran and Simon, 2004).

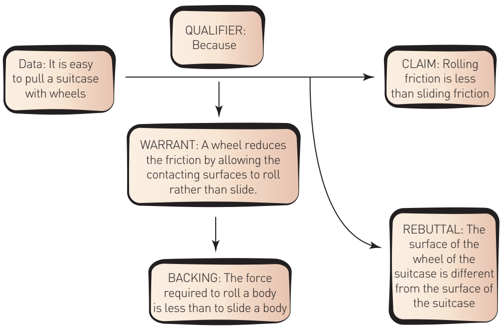

Fig. 2 Toulmin's Argument Pattern with an example

It is seen that the arguments with a rebuttal increase the strength of the argument. We can define arguments in two ways: (i) Low-level arguments included counter-arguments that were unrelated, and (ii) Higher-level arguments included rebuttals (Simon, S., 2008).

The analytical framework used for assessing the quality of argumentation is shown in Table 2 (from Erduran, et al. 2004 p. 928; Simon, S., 2008).

Table 2

Analytical Framework Used for Assessing the Quality of Argumentation

Level 1	Argumentation consists of arguments that are straightforward claims versus a counter-claim or a claim versus a claim.
Level 2	Arguments consist of a claim versus a claim with either data, warrant, or backings but do not contain any rebuttals.
Level 3	Argumentation has arguments with a series of claims or counter-claims with either data, warrants, or backings with the occasional weak rebuttal.
Level 4	Argumentation shows arguments with a claim with an identifiable rebuttal. Such an argument may have several claims and counter-claims as well.
Level 5	Argumentation displays an extended argument with more than one rebuttal.

These levels ensure the complexity of an argument. If a student's argument consists of more rebuttals, it implies that the student has critical thinking skills and comprehends things better.

In Table 1, we observed that TAP has six elements, but in the recent research, it has been simplified to five elements (Erduran, et al., 2004; Hanri, C, Arshad, M. and Surif, J., 2017), they are claim, data, warrant, backing, and rebuttal. In the present research, TAP was further modified. First, the warrant, qualifier, and backing are grouped based on their common value (Erduran, et al., 2004; Hanri, C, Arshad, M. Y. and Surif, J., 2017), which in justification one new element is added, i.e., refutation. A refutation is required if a claim is questionable or controversial. The next important thing is how these TAP can be used in a classroom discourse by students and teachers.

The Role of Scientific Argumentation in Developing Scientific Temper

Science as a subject demands a constructive approach and critical thinking. It requires the ability to accurately and effectively interpret and construct science-based ideas (Cavagnetto, A., 2010). Therefore, scientific temper develops overall skills of a human-like ability to understand the cultural aspect of science, metacognitive processes, communication skills, and reasoning skills (Cavagnetto, A., 2010). These skills help learners to understand scientific concepts better. However, in this scientific field, we need to know the importance of argumentation. There are different forms of argumentation. However, all form does not foster a scientific temper; for a lawyer, the argument is to win the case. However, scientists use arguments to vet ideas to work towards a common goal – advancing scientific knowledge (Toulmin, Rieke, and Janik, 1984; Cavagnetto, A. 2010).

There are many research on whether argument interventions in school science foster scientific temper. This paper has tried to summarise all previous research on how scientific argumentation fosters scientific temper or literacy.

We need to emphasise why argumentation is necessary for students after all. First, argumentation makes the learning meaningful, which means it helps learners connect with the scientific nature, and now, they know the reason behind a particular phenomenon, which further helps them get more involved. Second, it develops communication skills; as we talk about communication, we emphasise the role of language. Third, it is fundamental because it drives the in-depth and epistemic nature of science and captures the culture of science (Cavagnetto, A., 2010). Fourth, argumentation somehow prompts students' critical thinking and reasoning. It is seen that very few people understand the structure of argumentation. Primarily, students lack the very idea of argumentation. As a result, it becomes difficult to identify a warrant and backing. According to Sadler (2004), it was found that students struggled with argument construction and consideration of evidence that contradicted their initial views. They go for more direct evidence for any claim given. Lack of an argument has led to the conception of sciences as a collection of static facts about nature and perception of Science as a secular religion (Driver, et al., 2000; Cavagnetto, 2010). To foster argumentation, students must understand the importance of social interaction and how cultural factors influence science (Kuhn, T., 1962; Cavagnetto, 2010).

According to Cavagnetto (2010), it has been often noticed that, in school science, the facts or the right answers have been emphasised to the exclusion of scientific practice and thinking. Students are reinforced in the classroom to give correct answers without knowing why it has to be the correct answer. As a result, students lack the motivation or have minimal opportunity to share findings, interpretations, or ideas. To encourage scientific temper, the perspectives of the nature of science must change.

Ford (2008) believes that to understand science, it is necessary to understand the nature of science, its social and cultural elements. Further, he defined certain things that showed the interaction between material and social aspects of science. It explained, (a) getting nature to "speak," which means helping students to identify questions for exploration, designing appropriate ways to answer those questions, conduct investigations, and communicate these processes to others, and (b) "portraying nature's voice," which includes interpretation of data and subsequently construction of evidence-based explanations. To ensure scientific temper among children, it is necessary to understand what argumentation in science means and how it can be framed and practised within the classroom.

Argumentation can be promoted within the classroom through appropriate activities and pedagogical strategies. Adopting any new approach that promotes the use of argument would require a shift in the nature of the discourse in science lessons (Simon, Erduran, and Osborne, 2006). To make argumentation more effective in the classroom, the teacher subsequently plays a significant part. It has to be ensured that certain strategies are followed in the classroom to help learners identify the components of arguments, construct meaningful evidence, and enhance critical thinking among them.

Teaching Strategies and Role of Teachers

In order to help learners to be a part of scientific argumentation, teachers must follow up specific teaching strategies, which will help both the learners and teachers to move forward in a meaningful argumentation. The teaching strategy, as discussed by Erduran, et al. (2006), must focus on how the teachers (a) structure the task, (b) use group discussions, (c) question for evidence and justifications, (d) model argument, (e) use presentations and peer review, (f) establish the norms of argumentation, and (g) provide feedback during group discussion. If practised, these strategies might help teachers and learners take part in the argumentation process and construct meaningful arguments. Over that, the teachers and the learners have an essential part to play. According to Simon, Erduran, and Osborne (2006), along with the strategies mentioned above, a few more points are necessary for this process, i.e. (i) the learner needs to work in groups and listen to each other articulating their ideas in the discourse. In addition, the teacher must make sure that learners are paying attention to what others are speaking; (ii) the teacher must attempt to help learners understand what arguments mean. This can be done by defining an argument or exemplifying it; (iii) encouraging learners to take up a position individually or as a group. This helps them to be more determined for what they are arguing for and thus, will help them to justify themselves; (iv) to encourage learners to provide evidence for any justification; (v) learners must be engaged to construct arguments, either by summing up in sheets or through presentations; (vi) teacher must ensure evaluating the evidence, as it makes a string argument; (vii) to encourage counter arguing and debating, as it will help learners talk out about their feelings on the arguments; and (viii) help learners reflect upon the argument process.

However, there are certain specific roles that a teacher must take up to encourage the idea of argumentation, as it is seen that teachers' passive explanation can decline the very idea of argumentation. Argumentation is avoided due to teachers' limited knowledge and sometimes, focussing on correct answers. In many parts of our country, teachers are still unaware of scientific argumentation and its elements. Teachers contribute a lot to this society; thus, they have to put in some effort. To achieve this process, teachers can help learners polish and improve argumentation skills (Hanri, Arshad and Suri, 2017); teachers can help students improve their higher-order thinking skills (Hanri, Arshad and Suri, 2017).

It has also been noticed that language plays a central role in scientific practice – the reason is, it requires and enhances abilities, such as metacognition and critical reasoning. Language drives the epistemic nature of science and captures the culture of science. It can be noticed that science is othing without texts, various modes of representation, and talk. Among all, argument plays an essential aspect in the language practices of science (Cavagnetto, 2010).

Conclusion

In this paper, we have tried to analyse the meaning of argumentation and how the argument is different from argumentation. While emphasising argumentation, we have tried to bring the theoretical perspective on the argument given by Toulmin by using its different components, also called Toulmin's Argument Pattern (TAP). This framework provides a means of modelling arguments for students by focussing on components and links that can emphasize the use of evidence (Simon, S., 2008). With its use of different components, one can assess the complexity of the argument, i.e., more the components, the argument is considered to be stronger. However, it has its limitations, like, identifying the components can be misleading, and there is no proper way to evaluate the quality of the argument.

Further, it has discussed how argumentation can foster scientific temper. As per the discussion above, argumentation helps learners think critically, enhances higher-order thinking skills and communication, and a proper approach to solving problems. These skills make learners more involved to understand the nature of science, or we can say, these are the skills, what the subject demands. Moreover, along with the learners, the teachers' role is crucial. Teachers must ensure that class is not passive and put more effort into making it student-centred, where learners construct their arguments.

Furthermore, teachers should follow strategies to help students be involved in scientific explanations and create a scientific environment. Lastly, it was seen, among all, that language also plays an important role. Because, without it, we cannot represent science.

To conclude, for the upcoming research on argumentation, we need to promote the very idea of argumentation within the classroom and its effect on the learners. Because learning science is not about memorizing facts but understanding the underlying depth, thus teacher's awareness must be created on the same.
Teachers must undergo professional development courses to understand it better and train the learners. Models must be created to simplify the components further, and a proper tool must be developed to assess the quality of arguments. Further, the argumentation course in the pre-service course would help budding teachers for the coming generation and help create a scientific environment.

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ON USING A STEAM PROJECT-BASED LEARNING MODEL FOR SECONDARY SCHOOL STUDENTS: DESIGN, DEVELOPMENT AND EVALUATION

Shivalika Sarkar
Regional Institute of Education
Shyamla Hills
Bhopal – 402 002
Email: shivalikasarkar@gmail.com

There has been much talk about using the STEAM pedagogy to promote active learning and achieve the desired competencies. However, bringing STEAM pedagogy into the classroom can be a challenging task. A STEAM pedagogical model on project-based learning for the secondary level is discussed in this paper. Through a carefully designed interdisciplinary project named "Our Sun," the elements of STEAM were brought into the high school science classroom. The model was also tested on 80 students of a school in Icchawar Block, Sehore District of Madhya Pradesh. The PBL approach is effective in providing hands-on experience to the students as well as in developing other skills like creativity, inquiry, sharing, debating of ideas within a learning community. It was found that this approach goes in line with the principles of STEAM.

Keywords: STEAM, Project-based learning, Secondary school

Introduction

STEAM stands for Science, Technology, Engineering, Arts and Mathematics, and STEAM pedagogy encompasses various activities which involve the integration of STEAM in the classroom. As we move from STEM to STEAM, the integration of arts in STEM has been done to improve student learning, creativity, and competencies. STEM was coined by the NSF (National Science Foundation) in the USA two decades ago, and since then, STEM has gained much popularity and has proved to be an effective pedagogy in enhancing student learning and achievement (Armknech, 2015). To improve and inculcate the 21st century skills among the learners, arts were added to STEM, which gave birth to STEAM. Hence STEAM education promises to inculcate among the learners the skills of problem-solving through innovation, creativity, critical thinking, communication, collaboration, and competencies required in the real world. As National Education Policy 2020 states that "no hard separations between arts and sciences, between curricular and extra-curricular activities, between vocational and academic streams, etc. in order to eliminate harmful hierarchies among, and silos between different areas of learning."

The need for STEAM education and pedagogy has now been recognised worldwide. With poor performances of students in science and maths, the last decade has seen an upsurge of interest in activities related to STEAM. In the 2009 Program for International Student Assessment (PISA), India was ranked 72nd among 73 countries. After a gap of almost a decade, India is all set to participate in PISA 2022, earlier planned for 2021. PISA 2022 will focus on mathematics, with an additional test of creative thinking. In order to improve the ranking in PISA, different state governments are planning to include STEAM pedagogy in schools. Therefore, a multidisciplinary approach needs to be followed for holistic development and lifelong learning. The effectiveness of this approach has been investigated by many researchers (Sadler, 2004; Walker and Zeidler, 2007; Land 2013; Madden, et al., 2013; Bevan, et al., 2019; Bevan, et al., 2020). Yakman (2008) describes STEAM education in two ways. First, it is an education in which the fields of science, technology, engineering, and mathematics are approached in a multidisciplinary manner in addition to their individual standards. Second, STEAM education is holistic, aiming at current fields and teaching subjecand ts (Park and Ko, 2012). Yakman (2008) describes the STEAM framework with the help of a pyramid to present STEAM education more concretely. The pyramid consists of five steps. The lowest order constitutes the subject content of the STEAM training areas in particular, and the contents described in this step form the basis of the disciplines given in the higher step. While the areas covered by STEM education are presented in the multidisciplinary step, the disciplines covered by this approach, i.e., state of the art integrated into STEM, are given in the integrative step. The top step refers to life-long learning. The subject areas covered in the first step of the pyramid are related to high school and professional education areas, the multidisciplinary step is appropriate for the secondary school level, and the integrative step for primary and secondary school education (Park and Ko, 2012).

STEAM is gaining increased popularity, but how this concept should be deployed and what model or framework to follow is still unclear to many (Colucci-Gray, et al., 2019; Conner, et al., 2017; Wilson, 2018). This paper presents a STEAM model whose effectiveness is also tested in the high school science classroom.

STEAM is an interdisciplinary approach and is in line with the constructivist principles of learning. The most popular approaches for integrating STEAM in the classroom are problem-based learning, project-based learning, and inquiry-based learning. This paper proposes an interdisciplinary project-based learning model to promote STEAM pedagogy in the high school classroom. Project-based learning (PBL) allows students to conduct investigations, collect, analyse, interpret data, draw conclusions, present their findings, and socially interact. PBL provides the joy of learning and gives opportunities to students to create, reflect, collaborate, solve a problem and share responsibility in their learning. The model was tested on 80 students, and the success of the model was assessed through text analysis and questionnaire survey.

Methodology

An interdisciplinary project was planned to promote STEAM pedagogy in the high school classroom. The project was named "our sun as a source of energy". Under this project, students had to participate in interactive activities, and they were challenged to create their artifacts—the project integrated science, technology, engineering, arts, and mathematics concepts. Many principles related to life processes, electrical circuits included in the Class X curriculum are often difficult for students to understand. When all these principles were integrated under a single project, "Our Sun" students could easily connect different phenomena. Through this project, we tried to imbibe the qualities of discovery, curiosity, and exploration among the students. Different activities of the project involved creating a hypothesis followed by experimenting, observing, classifying, and predicting. Each artifact built by different groups involved collaboration, creativity, optimism, and communication. The objectives of the research were:

- To use and apply project-based learning techniques in science classroom situations at the secondary level.
- To analyse the effect of project-based learning techniques on the students' conceptual understanding.
- To study the effectiveness of PBL in implementing STEAM principles in the high school science classroom.

In the project on 'Sun as a source of energy,' students learning was promoted through the following tasks/activities:

1. Learning by doing with the help of real objects.
2. Learning by experimentation.
3. Learning through peer group discussion.
4. Learning with the help of a mentor/ teacher.

The four experiments included in the project were 'Make Your Own Solar Oven,' 'Experiments with Solar Cells (Conversion of Solar Energy into Electrical Energy),' 'Sunlight (Solar Energy) Is Essential for Plants (Autotrophs),' and 'Showing Transpiration in Plants in the Presence of Sunlight.'

Research Design

The methodology for the project was interpretivist qualitative research based on an exploratory case study to examine school students' engagement and reflections on the PBL approach and completing specific project tasks given to them. The research employed a paper-based survey of students' engagement and scientific knowledge, self-reflection of learning followed by open-ended questions and observations to verify students' understanding of the scientific concepts and reflections in the project. The survey items were designed through a workshop of experts in the field. After each task of PBL, students completed the open-ended questions associated with each task given in the manual. After completing all the project tasks, students completed the survey.

Sample for the Study

The research was conducted at Government. Model Higher Secondary School, Icchawar Block, Sehore District. The respondents of the study were the two sections of Class X comprising 80 students, wherein the researcher conducted the project-based learning technique. Most students belonged to an economically backward class. The school did not have well-equipped labs and a computer facility. Students did not have access to technology. Due to the above points implementing PBL was a challenging task.

Tools

This research made use of the following data gathering instruments:

Student Reaction Scale

Students in the traditional classroom were presented with the content and were given few opportunities to bring their learning to life. We needed to measure whether PBL could provide enjoyment in learning, develop science concepts and processes, critical and creative thinking, learning through peers, and social skills like collaboration. For this, a survey on students' engagement and scientific knowledge was conducted to verify students' reflections about the project. Thirteen items were selected for the survey, and the school students were asked to indicate on a 5 = point scale (5 = almost always, 4 = frequently, 3= occasionally, 4 = Seldom, 5 = Never).

Self-reflection of Learning

This tool was designed to find out whether students enjoyed the whole process and to find out whether the students were engaged in the process. Finally, we wanted to know whether the student's level of interest is sufficiently high and they believe they will accomplish something of worth by doing it.

Open-ended Questions for Discussion

Each group had to answer a set of questions given in the instruction manual related to the scientific principles associated with the task, observations taken, and application of those principles to their daily lives. These questions were open-ended and helped us understand whether this approach could develop the conceptual understanding of the students in science.

Project Report Collected from Each Group

Each group was asked to submit a project report at the end with the title and duration of the project, names of the students in the group, class, description of the project, learning methodology followed, answers to the questions given along with each task in the instruction manual and learning achievement. This helped us evaluate each group's overall performance based on rubrics.

Data Collection

The class was divided into ten groups, with eight students. An interdisciplinary project from Class X Science Curriculum on the topic 'Our Sun' was assigned to imbibe the concepts of photosynthesis, electricity, our environment, and sources of energy. Four project tasks were given to each group. Data for self-reflection of the students' learning was collected through a questionnaire. A survey on students' engagement and scientific knowledge was conducted to verify students' reflections about the project. Open-ended questions were given in the instruction manual related to the scientific principles associated with the task, observations taken, and application of those principles to their daily lives. Each group had to submit their artifacts, project report and were required to make a presentation on 'Sun as a Source of Energy.' The final project was evaluated with the help of rubrics.

Intervention

The facilitator explained to the students that they had to work in teams on STEAM challenges.

The first day of PBL comprised students being divided into groups. Ten groups of eight students were formed. Students were asked to name their groups by a scientist of their choice. All students enthusiastically participated in this process and chose different scientists' names from their groups.

A group leader was selected from each group democratically. Students were also asked to prepare badges of their choice for each group. A poster competition was also announced on the theme 'Our Sun.' A brief documentary on our Sun was shown to the groups. After the documentary was finished, each group was asked to discuss themselves and reflect on the documentary. After this, an ice breaker activity was conducted to become familiar with the students. This activity comprised mulling over why a candle extinguishes when covered with glass. Students enthusiastically participated in the activity.

After this, necessary material to conduct the different activities was supplied to each group. Students were asked to perform each task within their groups and discuss the results obtained. After all the groups finished the experiment and their discussion within the group, the instructor asked one student to present their observations and reflect on the possible cause behind the observations.

The second day of PBL started with the presentation of the badges and posters by each group. Every group member was asked to wear the badge prepared within each group. The theme for poster making was again 'Our Sun.' All the posters were displayed on the wall of the classroom. Figure 1 shows a sample poster made by one of the groups.

Now it was time to start with the project-related activities. The project's first task was to make their own solar oven and test it. A kit comprising required material (pizza box, scissors, aluminum foil, clear tape, plastic wrap, black construction paper, newspapers, ruler or wooden spoon, thermometer) to make the solar oven was distributed to each group along with a lab manual comprising steps to be followed to make the solar oven and discussion questions related to each task was given. The manual comprised all the

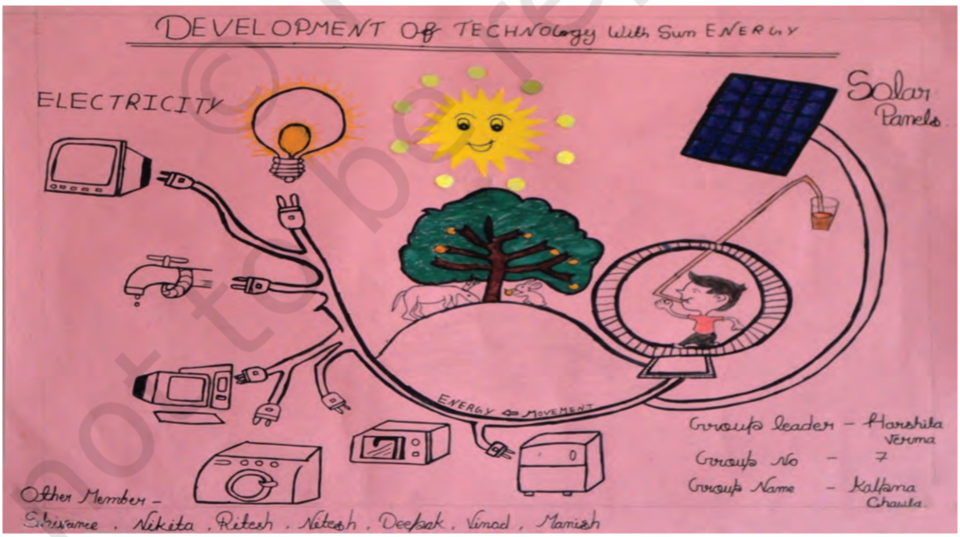

Fig. 1: A poster made by the group on the theme

tasks to be completed under the project 'Our Sun' and discussion questions that were conceptual in nature to discuss within the groups and their answers to be written neatly on a separate sheet of paper. The manual also comprised plenary questions to be discussed among groups at the completion of the task. Each group actively participated in the task, made their artifacts, and tested them (Figure 2).

Fig. 2: Students testing their own solar ovens

The next activity was making a solar-powered fan. All necessary material (solar cell, plastic-coated wire, electric motor, soldering gun, solder (rosin core), sandpaper, knife or wire stripper (optional), 6-inch (15-centimetre) diameter cardboard circle, utility knife, glue (hot or white), plastic wheel with axle hole in centre, black marking pen, stopwatch, one sheet of black construction paper, several sheets of coloured transparency film in a variety of colors, paper, and pencil or pen) was distributed to each group.

Students were asked to draw the circuit diagram connecting the solar-powered fan. Then, they checked the current and voltage rating of the solar panel provided in the kit. Students also checked the open-circuit voltage (Voc) and short circuit current (Isc) using a multimeter provided in the kit. Next, they connected the solar panel to the DC

Fig. 3: Models of solar-powered fan made by students

motor and the fan and checked how the speed of the motor changes when the solar panel is illuminated in sunlight. They also checked how the motor speed changes with the orientation of the solar panel. They also calculated the theoretical power, actual power, efficiency of the solar panel, and the effect of different colour transparencies on the output power and speed of the fan. Figure 3 shows the artifacts made by the students under this task. A discussion was then conducted among different groups on how to make a closed circuit, how solar panels can be used as a source of electrical energy, and how solar energy as a renewable source of energy can be used in any area. All the activities required integration of science, technology, engineering, and mathematics.

The next day, students had to work on a different task: examining that plants release oxygen in the presence of sunlight during photosynthesis. Again, all necessary materials (beaker, test tube, funnel (all materials should be transparent), some sprigs of hydrilla *(Vallisneria)* aquatic plants, baking soda) were distributed to each group as mentioned in the manual. Accordingly, different groups had to perform the task under different conditions, as shown in Figure 4.

Fig. 4: Different tasks assigned to different groups under project task 2

Fig. 5: Students examining their hydrilla setups

After completing their experiment, all the setups were displayed at a place, and a discussion on the observations in different setups was done. Many questions were raised, like, are there air bubbles in your setup? If yes, why if not, then why? Which setup has more air bubbles? Can we count the number of bubbles? After two hours, all the experimental units were inspected to find out the test tube, which was more than half-filled with gas bubbles. The facilitator raised the question, "let us try to identify the gas in these bubbles in the test tube." The facilitator showed the students that a lighted incense stick, when inserted in the test tube with its mouth tightly closed, lights up instantly, showing the presence of carbon dioxide gas in the test tube. This activity showed the students how gas evolution occurs in sunlight.

On day 5, two activities were completed. One was to observe transpiration in plants in the presence of sunlight, and the other was to examine the process of photosynthesis. The first activity conducted was to observe transpiration in plants in the presence of sunlight. All necessary materials were distributed to each group as mentioned in the manual. For the first activity, students went outdoor and tied transparent polythene bags to cover the leaves of some plants. Some of them tied polythene bags to cover the leaves of plants coated with Vaseline. The difference had to be observed. After finishing, students returned to their classes and discussed among themselves, and then discussion within the groups was conducted.

After completing each activity, students discussed among themselves and completed the open-ended questions given in the

Fig. 6: Leaves tied with polythene bag

Fig. 7: Water droplets visible on the polythene bags

instruction manual. Also, on completing all the activities, students had to prepare a project report, and a presentation by each group was made on the topic 'Our Sun.'

While constructing each artifact, students were using their creativity, working collaboratively to achieve a common goal, using different science concepts, analysing and plotting data, and becoming aware of the technology used.

Results

This research project was created using in mind that students understand the concept of the sun as a source of energy and its different applications. In the NCERT Science Textbook for Class X, different chapters on photosynthesis, electric circuits, our environment, and energy sources are given. Through this project, we have tried to integrate the various concepts given in these chapters in a single project entitled 'Our Sun.' The PBL students were assigned to research the essential question, "How can we utilise energy from the sun?"

We needed to know whether students enjoyed this process of learning. Table 1 gives the self-reflection of the learning of the students.

Table 1
Results of Self Reflection of Learning

 I enjoyed making my own artifacts. I liked this way of learning very much. I would like to learn this way	76%
 I did not understand the activities completely I needed help in completing the tasks. With teacher support, I am willing to learnthis way again.	22%
 I did not like performing the activities I did not find the activities interesting I want to learn by the method I used to	2%

A survey on students' engagement and scientific knowledge was conducted to verify students' reflections about the project. Thirteen items were selected for the survey, and the school students were asked to indicate on a 5 = point scale (5 = almost always, 4 = frequently, 3 = occasionally, 4 = sleldom, 5 = never).

Table 2
Survey on Student's Engagement and Knowledge

Statement	Almost always 5	Frequently 4	Occasionally 3	Seldom 2	Never 1
Provides enjoyment in learning	79%	18%	3%	-	-
Working in a small group with a mentor helped to learn	48%	42%	8%	2%	
Easily develops science concepts and processes	80%	18%	2%	-	-
Develop critical and creative thinking	47%	39%	6%	8%	-
Promotes learning through peers and collaboration	65%	19%	16%	-	-

Provides an opportunity to correlate the subject matter in a real-life situation	22%	36%	18%	24%	-
Provides an opportunity to work in groups	40%	32%	7%	21%	-
Give freedom to plan and perform own learning in own ways	58%	28%	8%	6%	-
Helps in developing practical skills	52%	30%	8%	10%	-
Involves in life-like and purposeful activities to promote learning	55%	32%	11%	2%	-
Promotes learning by doing	63%	34%	3%	-	-
Provides a real and direct experience.	34%	43%	15%	8%	-
Helps to develop social skills and values among the students	50%	32%	7%	11%	

In this project, school students engaged in the activity in groups of ten. Each group was given all necessary components to complete the project tasks and was encouraged to use their logical reasoning and trial and error to complete a given project task. Different items of the survey are displayed in Table 2. According to the data given above, 97 per cent of the students enjoyed the PBL approach. This agreed with the item mentioning that working in a group with a mentor helped them successfully complete their tasks (90%). It is worth mentioning that 87 per cent of the students also found these activities purposeful and linked to their daily lives. The students experienced a different way of science learning through working in groups and collaborating with peers, giving them a new learning experience. This different learning experience provided the students with new perspectives on science learning. In addition, students developed their collaboration and communication skills. They learned that collaboration helped them complete the tasks in an enjoyable environment.

For the final source of data, each group had to answer a set of questions given in the instruction manual related to the scientific principles associated with the task, observations taken, and application of those principles to their daily lives. In addition, they had to submit a project report, and also each group had to make their presentation on the topic 'Our Sun.' Finally, the overall project was evaluated with the help of a survey, answers to discussion questions, self-reflection of learning, project report, and presentation made by each group with the help of rubrics. Figure 8 shows the overall performance of the different groups.

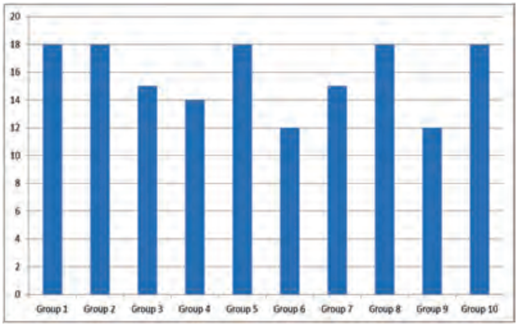

Fig. 8: Overall performance of the groups

Discussion

The learning experiences provided by PBL are relevant to the principles of National Education Policy 2020 (NEP-2020)* that envisages critical thinking, analysis based learning by meaningful experiences to the learners. Conceptual understanding became easier as students could link the concepts to their daily lives. Students experienced the benefits of working together, which stimulated their collaboration and communication skills. Students were also interested in completing the project and finding different ways to complete their tasks. This project-based learning model of integrating STEAM concepts effectively targets many content areas. The STEAM approach has overtaken the STEM approach, and research has proved its success, especially in countries like Japan and South Korea (Jin, et al., 2012; Yakman and Hyonyong, 2012). However, a challenge is how to implement the STEAM principles in the traditional classroom. In our simple PBL framework presented in the paper, we touched several content areas belonging to different science disciplines like physics, chemistry, and biology. However, teachers can start small in their first implementations and pick only a couple of content areas to target. However, as teachers and students become more PBL-savvy, STEAM can be an excellent opportunity to create a project that hits science, math, technology, and even art content.

From designing to creating the artifacts, the entire project involved many concepts of science, mathematical concepts like measurements, calculations, graphs, technology, and the use of various tools in building the artifacts. This experience will help the students build their creativity and critical thinking, which will help them find solutions to real-life problems (Chung, et al., 2017; Jho., H., Hong, D. and Song, J., 2016).

In the traditional classroom, students usually listen to a lecture or get a chance to view a demonstration done by the teacher, but in the PBL classroom, students were actively involved in all the activities discussing and collaborating with their peers. The role of the teacher was that of a mentor providing guidance whenever required.

Creating, building, testing, improving, reflecting, predicting, building higher-order skills, and positive approaches to learning were the attributes of the project activities. Students understood various processes that can be explained by the conversion of energy received from the sun. In this process, students' collaborating skills improved as they gained more experience working in groups to complete the different project tasks. Initially, students had a tough time working with groups and participating in group discussions,

*The Original reference was Draft NEP-2019 but by the time of publication of this issue, NEP-2020 was published and hence modified accordingly.

which gradually improved. After completing the project, most of the students expressed their satisfaction with STEAM integration of different concepts in a single project, evident from the results presented in Tables 1 and 2. Creating the artifacts successfully also demonstrated that they had acquired diverse skills like problem-solving, creativity, and critical thinking (Herro and Quigley, 2017; Zalaznick, 2015).

Conclusions

This study proves that project-based learning in the high school science classroom is an effective instructional approach. Specifically, PBL is valuable for promoting understanding of critical concepts in science and for learning and using scientific practices. Students expressed very positive attitudes towards doing project tasks as part of their science instruction. Many principles related to life processes, electrical circuits, are often complex for students to understand. When all these principles were integrated under a single project, 'Our Sun' students could easily connect different phenomena. By completing the project tasks and gaining the skills to record and analyse data on different tasks, students could construct their understanding of the several concepts of the high school science curriculum. From the students' viewpoint, this is a very different experience than reading about different concepts in a book, doing different activities in the classroom, watching a video about the sun, interacting with peers, discussing and presenting their viewpoints and ideas. By gathering their data and then using it to contribute to a real-life problem, students draw on various skills from other disciplines and use higher-order reasoning to accomplish the task. By engaging in this project, the students experienced a sense of gratification as they realised that their ideas were valued and actively involved in making the world a better place. The many advantages to this instructional approach include: contextualising and establishing a purpose for learning, creating a shift in the teacher's role from being an expert to being the facilitator, and developing a stronger sense of classroom community. This context made the abstract more concrete and will provide a strong foundation for the student's future study of physics, chemistry, and biology. Additionally, the 'real world' application embedded within the project was equally important for creating a purpose for the learning and keeping students engaged and motivated.

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INTERVIEW WITH PRAGYA NOPANY

Pragya Nopany has taught higher secondary physics for 25 years at Birla Vidya Niketan, New Delhi. Her passion to teach and the innovative ways of her teaching have earned her numerous recognition and awards, the most recent one being the prestigious National Award for Teachers - 2017 by the Government of India.

She continues to share her experiences and expertise through different platforms such as Anveshika, which is an Experimental Physics Centre established by the Indian Association of Physics Teachers to provide a base for generating interest in experimental physics in young students upto +2 level through learning by doing.

Pragya Nopany
PGT, Physics, HoD (Retd.)
Birla Vidya Niketan
New Delhi
Email: pragya.bvn@gmail.com

What made you choose physics as your subject?

I fell in love with physics in my school days because my cousin Vasundhara showed me very intriguing and fun activities whenever she visited us in the summer holidays. The interest made me pursue my higher studies in physics at BITS, Pilani.

What and who motivated you to become a teacher?

Mrs. S Muttoo, my Hindi teacher, was also my class teacher in Class VIII. The way she saw in me something that I could not see in myself, how she invested her time, energy, and effort in my growth – I think that motivated me indirectly. A story on this was published in the September 2009 issue of *Reader's Digest*.

And then, I come from a family of excellent teachers, social reformers, and freedom fighters who were deeply interested in and committed to the overall growth of children, youth, and society.

According to you, what does it mean to be a teacher?

A teacher is someone who ignites the minds and puts the learners on a path of self-learning. A quote from Sadhguru best describes my idea of a teacher: A guru or true teacher is a doorway through which a learner can walk into any room of their choice and explore.

How have you been able to bring about improvement in the teaching-learning of physics? Kindly share some innovations that you have made in terms of teaching methods or teaching-learning materials.

I have always been driven by the challenge – what can a student do after my class, other than just passing an exam? This has made me look for strategies to develop a culture of thinking and learning by doing. Designing multidimensional learning strategies, innovative demonstration activities, and collaborative learning platforms have been my interests.

In 2012, I established the Delhi chapter of Anveshika – a unique platform of the Indian Association of Physics Teachers (IAPT) operating under the national coordinatorship of the renowned Professor H C Verma – at my school Birla Vidya Niketan. This enabled us to build a network of teachers and schools willing to change the way science, especially physics, is taught in the classroom. We designed activities and experimental challenges and organised multiple stage shows, competitions, training for teaching-learning of physics through low-cost activities in Delhi-NCR. The tremendous response to this programme made it a movement in the region as more and more teachers and students became eager to participate. Over the years, enhanced internet connectivity enabled us to expand our programme to other states of the country.

In physics, I am especially proud of designing the following:

(i) Drawing of 2-dimensional equipotential curves on *atta roti*. I was awarded by IAPT for this innovative activity.

(ii) Choose your hurdle—an optics-based competition where a laser beam is to be taken from point A to point B but not directly. Multiple hurdles involving multiple optical phenomena are to be introduced on the way, and therein lies the challenge!

(iii) A shadow-play competition where students must interpret the following lines, write a screenplay based on their interpretation, enact it as a shadow play on stage, and use at least one indigenously designed light source during the presentation.

There was a lady called Bright.
Who could travel faster than light
One day she went for a walk in a relative way
And came back the previous day!

From your years of experience, what do you think is the best way to motivate students and nurture their talents to become their best version?

The best way is to engage with students at a personal level, discover their interests and strengths, and then build on them through innovative challenges. Giving them space and time to explore themselves individually and collectively, nurturing their strive towards excellence by constant constructive feedback, and cultivating an attitude of using failures as stepping stones to growth—these go a long way in building a relationship of trust. Once this trust is built, the students and the teacher become co-travellers in solving challenges and driving learning.

"A teacher is a student for life." What have you learned from your students?

Oh, ask me what I have not learned! I think what I have learned is best described in this self-written poem:

I sat down to write
And asked myself
"why do they call me an excellent teacher?"

My mind said
- because of your knowledge of the subject.
But my heart said
- because of your love of children.
And then I heard my soul speak
It said- it's your faith.
Your faith in innate goodness of the children
Your faith in uniqueness of each in the human ocean
Your faith in the adventurous spirit of the young!
Your faith in the power of human endeavour!

I laughed at my soul and said
"Oh my good soul, where would I be
without your unending faith in me!
But isn't excellence a pursuit, a journey?"

It has been so exhilarating
to open young minds to possibilities...
It has been so humbling
to say 'I don't know the answer to that one'!
It has been so thrilling
To find the answer to 'that one'!
It has been so glorious
to see the 'weak' rising like phoenix from the ashes of disastrous scores!
It has been so satisfying to investigate,
to venture into unknown.
It has been invigorating to cross frontiers
and to make new ones.

It has been so good to laugh with the class and to be laughed at!

It has been so rewarding
to see quality emerging from unacceptable work!

I am a teacher because
I have a debt to repay.
The debt of a teacher
who saw in me
what I could not see in myself.
I would consider my debt repaid in full
if I can find a hidden spark
in each child
and help him to do the best
what he enjoys doing the most!
Would I then
'become'
An excellent teacher?

My most valued learning: Human potential is unlimited and continues to throw surprises.

What has been your most touching experience so far as a teacher?

In the year 2017-18, I was teaching physics to a biology section of Class XII in which most students did not pursue Maths as a subject. Their scores in the examination were abysmal, and I was dejected and at my wit's end as to how to improve their performance. During this time, I chanced across an article about 'Foldscope' – a paper-folding microscope designed by Manu Prakash at Stanford University. I wrote to Mr Prakash requesting him to send one piece; he sent 20 of them free of cost. I gave 10 of them to some of the bio students to use for exploration. The students came back with great observations, e.g., videos of pollen and micro-organisms in water magnified 240 times, the likes of which I had never seen. I thought the students deserved recognition for their work, but I also wanted them to use this for further growth. So, we organised an interschool students' workshop in which my bio students were the volunteers – they guided the participants from other schools as to how to collect samples, how to fold the paper-folding microscopes, how to mount on mobiles, how to prepare slides, and video record the observations. It was a workshop for the students, by the students! It received all-around appreciation. Soon, the event was forgotten.

Come the year-end. To my utter surprise, where I had expected at least 12 students to fail, not only everyone passed, but the average class score in physics was 80per cent ! Moreover, when I called to find from some of the weakest students how they had managed such scores, their reply brought tears to my eyes – it was the 'Foldscope' workshop that transformed their perspective, they felt empowered individuals who could reach new frontiers. I had no idea that this small effort could make such a difference.

It touches my heart to think of the amazing transformation the students chose to bring about in themselves, little imagined when I got the 'Foldscopes' from Manu Prakash!

It taught me never to underestimate the potential of an individual and to respect the choices individuals make and commit themselves to. It only makes me think about what can I do to help a striving individual.

Kindly suggest some areas where you think your district/state/country needs attention concerning science education in general and physics education in particular.

Urgent attention is required in making each educator have a vision – a vision that their role is NOT to merely explain but to ignite! I'm indebted to Professor H C Verma to give me this vision.

And then how to translate this vision into an action plan – a plan with clear identification of learning outcomes of a science lesson, practices that will enable those outcomes, and transfer of knowledge.

For physics education, how to take physics education from fear to fascination. Teachers' misconceptions in physics need to be taken up urgently. I offer my efforts through programme like 'Misconceptions in Newton's Laws of Motion,' which has been conducted online in 13 states so far and continuing.

Do you also make an effort to popularise science/physics or science/physics learning in your community? If so, kindly elaborate.

Yes, I am constantly engaged with popularising science and physics through various stage shows, competitions, lectures, and webinars.

'The Story of Pendulum Clock' is one such programme – not many people know how a humble thread and a bob changed the fortunes of empires, changed the norms of societies, forever changed the way science is done!

'From Fear to Fascination' is a demonstration-based programme that endears students to physics.

'Motion Magic' is another much-liked programme that makes senior students look at motion in new ways, beyond just the equations of motion.

'Teaching Science through Stories' is yet another programme.

What are your top two regular practices that have helped you stay motivated?

Staying connected with a large number of teachers and students, identifying their difficulties, and designing programmes to help them. Seeing their joy is motivating.

Challenging myself to new learning by accepting unusual assignments and discussions and training with stalwarts of physics and education – Satsang in short!

INTERVIEW WITH NINGMAREO SHIMRAY

Ningmareo Shimray
Ukhrul Higher Secondary School
Wino Tang, Ukhrul, Manipur
Email: sningmareo@gmail.com

Ningmareo Shimray began his teaching profession in mathematics in 2002 at Alice Christian Higher Secondary School, Ukhrul, Manipur. In 2007, he was appointed as Science Graduate Teacher by the Government of Manipur. He was promoted as Lecturer in 2019 and is currently teaching mathematics and English pronunciations. He has received several recognitions and awards for his contributions to improve teaching-learning in mathematics which includes the National Award for Teachers - 2021 by the Government of India.

What made you choose mathematics as your subject?

Mathematics was my favourite subject right from my childhood days.

What and who motivated you to become a teacher?

I started giving home tuition while I was stuyding Class X. From then on, I was teaching mathematics throughout my academic career. I was earning and learning at the same time. And I found immense satisfaction in teaching the subject. When I looked back, after getting a government job as Science Graduate Teacher in 2007, I discovered that I was already in the teaching profession for the past more than ten years. Those long years of teaching experiences helped me to be an effective mathematics teacher.

According to you, what does it mean to be a teacher?

Today's students are the future pillars of our nation; today's teachers are builders of our nation.

How have you been able to bring about improvement in the teaching-learning of mathematics? Kindly share some innovations that you have made in terms

of teaching methods or teaching-learning materials.

In 2018, I developed a new strategy: Teaching and Learning of Mathematics for Standard I to XII. The strategy was a paradigm shift: from teaching the students how the mathematical problems are solved to teaching the students how the mathematical problems can be solved by themselves. In this strategy, firstly, the students are taught to write well (both Arabic numerals and alphabet), write fast, calculate fast and basics of mathematics (according to the standard of the students, before lesson's transaction) and then only after that the teachers start lesson's transaction in such a way that the students can solve mathematical problems by themselves.

I have recently discovered a new number system: BI-Quartet number system, which enhances the speed of calculation and also highly simplifies the calculating process of all the existing operations: addition, subtraction, multiplication, and division. The discovery of the new number system is nothing short of a major breakthrough in learning mathematics. The new number system will enlighten and assist slow learners in overcoming many hurdles and greatly enhance fast learners' performance. At present, the new number system is applied in the following areas of mathematics: 1. Addition, 2. Times tables up to 9 digits. 3. Multiplication.4, Subtraction. 5. Division. 6. Identification of prime numbers between 1 and 100. 7. Test of divisibility by prime numbers between 1 and 100.

In early 2019, I conducted a series of experiments and found that the main hurdle of learning mathematics of any standard is the lack of reading skills. Later on, I found that the lack of reading skills is the main hurdle in teaching and learning of any subject/language of any standard and that the only way to overcome this hurdle is to learn pronouncing skills.

Towards the end of 2020, I developed the Concept of Sub-syllables for English Pronunciation which is a non-phonetic language. The concept of sub-syllables is a new system for learning English pronunciation efficiently. It has enabled us to pronounce every word in English dictionary correctly and efficiently. It indicates the silence of sounds while pronouncing some words. It identifies different words having the same pronunciation and different words with similar pronunciations. Significantly, it has enabled to write the spellings of all the English IPA. Currently, I am teaching mathematics and English pronunciation side by side, and the students are making remarkable progress in learning mathematics.

From your years of experience, what do you think is the best way to motivate students and nurture their talents to become their best version?

Everything around us contains mathematics. We have to teach mathematics to the students in such a way that they find the imparted knowledge useful throughout their lives. The most important motivational factor for the students in mathematics learning is to score 100 per cent (by the fast learners) or at least pass-mark (by the slow learners) in the mathematics test/examination. So, we have to set the test/terminal examination questions so that every student gets at least a pass mark, and some get 100 per cent. The standard of question pattern should be gradually upgraded in accordance with the performance of the students in the classes.

"A teacher is a student for life." What have you learned from your students?

The way I write (handwriting), teach (methodology), and speak (pronunciation) are reflected in the students' performance in the classes and tests/examinations.
To bring about progressive change in our students, the teachers need to change first. For the last more than 20 years of teaching mathematics, I have been continuously trying to improve the technique of teaching the subject, which culminated in the development of a New Strategy Teaching and Learning of Mathematics in 2018, the discovery of a new number system: Bi-quartet Number System in 2019 and development of the Concept of Sub-syllables in 2020. A teacher should never stop developing new teaching techniques that are relevant to changing times and circumstances. As for me, every mathematics class is a competition for the students and an experiment for the teacher.

What has been your most touching experience so far as a teacher?

Every year on Teachers' Day, it reminds me of my past students who are now doctors, engineers, bureaucrats, and those leading successfully in various professions, which gives me immense joy and satisfaction for being their teacher. No one else can give/take away this experience of joy and satisfaction from me.

Kindly suggest some areas where you think your district/state/country needs attention concerning mathematics education.

Mathematics is a number game involving symbols and figures, and the students can only learn mathematics efficiently by performing activities. The current mathematics textbooks for Classes I to V lack the main essence of learning mathematics efficiently. I would like to point out some flaws and inadequate methods in the Class VI mathematics textbook. Regarding the test of divisibility by 4, the book says 'a number with 3 or more digits is divisible by 4 if the number formed by its last two digits (i.e., ones and tens) is divisible by 4'.The statement is inadequate because it does not cover the test of divisibility by 4 of one and two digits numbers. Similarly, the statement of the test of divisibility by 8 is inadequate. Explanation of the identification of prime numbers between 1 and 100 in Class VI (which is absent in higher standards) is inadequate. The only test of divisibility by the prime numbers 2, 3, 5 and 11 are explained (which is absent in higher standards). In learning mathematics for Class VI and above, the identification of prime numbers between 1 and 100 and test of divisibility by prime numbers between 1 and 100 play vital roles. By applying the prime factorization method, the students can quickly identify prime numbers between 1 and 100, and by applying the new number system, the students can easily test the divisibility by prime numbers between 1 and 100.

I would like to suggest that the basic concept of the set be introduced right from Class I so that the students can learn the number system very easily.

Do you also make an effort to popularise mathematics or mathematics learning in your community? If so, kindly elaborate.

I was the Secretary of Longyo Education Trust, Ukhrul, which conducted District Level Open Mathematics Competition in collaboration with the district administration consecutively for five years till 2019. Each year, around 800 students of Classes V to X participated in the competition. As a result, there was a visible improvement in students' performance in mathematics subjects.

What are your top two regular practices that have helped you stay motivated?

1. I always try to improve my technique of teaching mathematics and English pronunciation.
2. I apply both my head and heart in teaching mathematics to the students so that the students can learn mathematics with both head and heart

Opinions of stakeholders

Teaching and Assessing Mathematics through Problem Posing: The Key Concern for School Curriculum

Mathematics is acclaimed as an essential school subject. It gives increased emphasis on the use of puzzles and games to mathematize students' thinking. This facilitates in promoting greater critical thinking, evidence-based thinking, problem-solving, and other Higher Order Thinking (HOT) skills among young students. All students must learn these skills and competencies to lead their life successfully. Problem-solving is inbuilt in mathematics. In school, mathematics problem-solving is done in various forms like completing practice problems, unit exercises in textbooks, etc. However, mathematics problem-solving deals with situations asking for data and information rather than posing tasks. Therefore, there is less learning opportunity in problem posing of real-world based, leading towards problem-solving in mathematics. As a result, students are not oriented to learn how to understand problems and apply their knowledge and skills to solve problems to increase their process of mathematization. Problem posing has been recognized as a vital step of problem-solving (Singer, F. & Voica, C.,2013). However, in contrast to the importance of problem-solving in school mathematics, problem-posing has been far less noticeable in mathematics textbooks. Problem posing, the process of formulating problems based on a given situation, is a critical cognitive skill that can promote HOT skills needed for 21st-century students. Therefore, problem-posing should be embedded in school mathematics curricula and practice to bring conceptual understandings of mathematics. Moreover, 21st-century skills in mathematics have always required posing real-life and significant problems.

Singer, F. and Voica, C. 2013. A problem-solving conceptual framework and its implications in designing problem-posing tasks. *Educational Studies in Mathematics*. Vol. 83, No. 1. pp. 9–26.https://doi.org/10.1007/s10649-012-9422-x

Biswajit Behera
Assistant Professor
Department of Education
Central University of Punjab
VPO-Ghudda, Bathinda
Punjab.
Email: biswajit70behera@gmail.com

Empowering Students through Environmental Science Education

Hands-on, engaging science education can empower students at all levels. They gain new knowledge about the world around them, new confidence in their ability to answer questions through data collection, and new professional skills that can translate to a meaningful career. When educators infuse environmental topics into their science education instruction, additional possibilities for empowering students arise. The knowledge students acquire might help them evaluate the effectiveness of different solutions to environmental problems in their communities. Students can also gain the confidence, motivation, and skills necessary to implement those solutions. Just understanding the problem is not enough. At a time when young people are faced with a myriad of ecological, social, and economic challenges, discovering that through science, they can make a difference is very powerful.

Yet how will educators and administrators know whether infusing environmental topics into science education does indeed have an added value for students? First, assessments are needed that do more than measure scientific knowledge and laboratory skills. By gathering data on environmental attitudes, views on science, motivations to act, and civic engagement, educators can document the impact of their environmental science instruction. Assessing change over an extended period or long after instruction has occurred can be particularly valuable. Students may need time to integrate information, alter attitudes, and turn motivation to act into new behaviours. The time spent on these assessments does not need to be for the benefit of the teachers alone, although they do need to document outcomes and find ways to improve. K-12 students can be empowered through assessment, too, as they discover what they have learned and how they have developed through environmental science instruction. A win for all involved.

Numerous studies have documented the benefits of environmental education. To learn more, see the following two recent open-access review articles.

1. Ardoin, N. M., Bowers, A. W. Roth, N. W., and Holthuis, N. 2018. Environmental education and K-12 student outcomes: A review and analysis of research. *The Journal of Environmental Education*. Vol. 49, No. 1. pp. 1–17. https://doi.org/10.1080/00958964.2017.1366155
2. Kuo, M., Barnes, M., and Jordan, C. 2019. Do experiences with nature promote learning? Converging evidence of a cause-and-effect relationship. *Frontiers in Psychology*. Vol. 10, pp. 305–305. https://doi.org/10.3389/fpsyg.2019.00305

Kendra Liddicoat
Associate Professor
University of Wisconsin-Stevens Point
Wisconsin, USA

Conceptualising the School Science Curriculum: Some Reflections

What knowledge should constitute the school science curriculum, and what should not? What kind of content and representation should be given in the science textbook?

Would the content be in the form of a presently accepted view of the scientific concept or an exploration of the concept, considering that scientific knowledge is dynamic? Should both success and failure stories, with arguments related to the past political and sociological contexts, be shared with learners as part of historical inquiry of scientific concepts? What should be the pedagogic considerations? Questions such as these often form the basis of the thought processes of teachers and teacher educators. It is well understood that the science curriculum needs to develop scientifically, technologically, and environmentally literate persons who possess a repertoire of competencies that are important in the light of 21st-century skills. Also, many writings, such as those of Driver, et al. (1994), suggest that school students should learn science as the scientific community practices it. The NCF (2005) focuses on the need for a science curriculum that is more valid and more motivating. Looking through another lens, it is seen that the works of several philosophers of science, including that of Allchin (1999), point out that scientific knowledge is not entirely objective as modern science represents it, but it is socially and culturally embedded. In this light, indigenous knowledge would need to be integrated into the science curriculum. Further, the science curriculum cannot distance itself from social questions and issues of social justice and ethics; therefore, these need to lie at the heart of inquiry in science in schools (Levinson, 2017). Finally, the curriculum should enable learners to connect science to their experiences as lived. It may be asserted that the call is for an 'evolutionary' model of science teaching-learning that draws together thinking about the history of science and the developments in the nature and philosophy of science over the past several decades. This would perhaps be a step towards an alternative, leading to a somewhat more 'authentic' science curriculum.

Allchin, D. 1999. Values in Science: An Educational Perspective. *Science and Education*. Vol. 8, pp. 1–12.

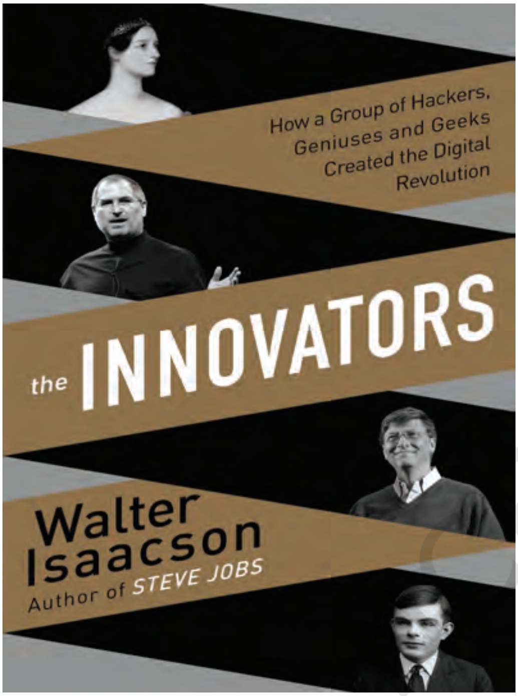
Driver, R. et al. 1994. Constructing Scientific Knowledge in the Classroom. *Educational Researcher*. Vol. 23, No. 7. pp. 5–12.

Levinson, R. 2017. Realising the School Science Curriculum. *The Curriculum Journal.* British Educational Research Association 10.1080/09585176.2018.1504314.

NCF 2005. National Curriculum Framework, NCERT.

Alka Behari
Professor
Department of Education
Delhi University
Email: alka_behari@yahoo.co.in

BOOK REVIEW



- Title of the Book: *The Innovators: How a Group of Hackers, Geniuses, and Geeks Created the Digital Revolution*
- Author: Walter Isaacson
- Publisher: Simon & Schuster
- Year of Publication: 2014
- Price: 699 (Paperback)
- Language: English
- Hardcover: 560 pages
- ISBN,10-147670869X
- ISBN,13-978-1476708690

The Innovators: How a Group of Hackers, Geniuses, and Geeks Created the Digital Revolution is a panoramic history of the technological revolution from the author who previously enthralled us with the biographies of Benjamin Franklin, Albert Einstein, Henry Kissinger, Steve Jobs. While Walter Isaacson's previous books focused on a single person and his lifetime, 'The Innovators' does an excellent job in exploring several fascinating personalities that created our digital revolution and condensing over 250 years of evolution of the digital technology industry in about 500 pages. Here, the author's challenge was in translating technical jargon to prose for the general audience, and he delivered a flawless and triumphant performance. Well, everybody knows the stories in bits and pieces about the digital world; however, few authors are as adept as Walter Isaacson in stitching together well-researched and deftly crafted anecdotes into a vigorous and gripping narrative, a task so laborious and daunting that it could be compared to arranging a Rubik's cube that's fighting back.

In the world of innovation, there are endless and unsettled debates about who did what, when and where, who copied and who stole ideas and who deserves what credit. Once again, Isacson provides a balanced view in answering most of these questions. The book begins with Ada Lovelace, Lord Byron's prodigious daughter, who pioneered computer programming in the 1840s. With this curtain-raising, the book has also tried to bring out the forgotten role women played from the beginning in the tech revolution, be it the contribution of Grace Hopper or the classic example of the creation of ENIAC, where the system's programming fell to a remarkable group of women: Fran Bilas, Betty Jennings, Ruth Lichterman, Kay McNulty, Betty Snyder, and Marlyn Wescoff. The story then skips forward to World War II, where engineers worked to build machines that could calculate the trajectories of missiles and shells. The subsequent chapters then navigate on to the origin and role played by programming, transistor, microchips, video games, internet, personal computer, software, transitioning online, and the web and finally culminating in the emergence of giant companies like Big 5 (Google, Amazon, Meta, Apple, Microsoft). Much of the action happens at universities like MIT (Vannevar Bush's differential analyzer), Bletchley Park (the all-electronic computer called the Colossus which deciphered German codes), the Bell Labs in drab New Jersey (where the transistor was invented). In this masterly saga, we meet exciting personalities like Vannevar Bush, Alan Turing, John von Neumann, J.C.R. Licklider, Doug Engelbart, Robert Noyce, Bill Gates, Steve Wozniak, Steve Jobs, Tim Berners-Lee, and Larry Page. This book is a powerful story of how their minds worked and made them so inventive and innovative. It is also a narrative of how their ability to collaborate and master the art of teamwork made them even more successful. What led few people to turn visionary ideas into reality? Why few succeed and others fail? Is being a genius guarantee breakthroughs? Questions such as these are answered in this book. The author reiterates that innovation is collaborative labour and the interplay between hackers, companies, universities, academic researchers. We come across plenty of anecdotes like the bitter patent fight over the world's first true computer between John Mauchly and John Atanasoff and the 1979 visit to Xerox PARC by a group of Apple executives led by Steve Jobs.

The current generation is overly focused more on Applications, web, and mobile, to begin their journey of a modern-day innovator. However, this book takes us to the early 1950s that would make us tinker with the hardware of a computer and that would willingly awaken interest in computer programming. Therefore, this book is destined to be the standard history of the digital revolution and a definitive and an indispensable guide for anybody who wants to understand how innovation happens, the bottom line being that it occurs at the intersection of humanities and science, and it's a team game.

Shrishail E Shirol
Junior Project Fellow
Department of Education in Science and Mathematics
National Council of Educational Research and Training (NCERT)
New Delhi, 110116

Anti-solar Cells: A Photovoltaic Cell that Works at Night

Date: January 29, 2020
Source: University of California - Davis

What if solar cells worked at night? That's no joke, according to Jeremy Munday, professor in the Department of Electrical and Computer Engineering at UC Davis. In fact, a specially designed photovoltaic cell could generate up to 50 watts of power per square metre under ideal conditions at night, about a quarter of what a conventional solar panel can generate in daytime, according to a concept paper by Munday and graduate student Tristan Deppe. The article was published in, and featured on the cover of, the January 2020 issue of *ACS Photonics*.

Munday, who recently joined UC Davis from the University of Maryland, is developing prototypes of these night time solar cells that can generate small amounts of power. The researchers hope to improve the power output and efficiency of the devices.

Munday said that the process is similar to the way a normal solar cell works, but in reverse. An object that is hot compared to its surroundings will radiate heat as infrared light. A conventional solar cell is cool compared to the sun, so it absorbs light.

Space is really, really cold, so if you have a warm object and point it at the sky, it will radiate heat toward it. People have been using this phenomenon for night time cooling for hundreds of years. In the last five years, Munday said, there has been a lot of interest in devices that can do this during the daytime (by filtering out sunlight or pointing away from the sun).

Generating power by radiating heat

There's another kind of device called a thermoradiative cell that generates power by radiating heat to its surroundings. Researchers have explored using them to capture waste heat from engines.

"We were thinking, what if we took one of these devices and put it in a warm area and pointed it at the sky," Munday said.

This thermoradiative cell pointed at the night sky would emit infrared light because it is warmer than outer space.

"A regular solar cell generates power by absorbing sunlight, which causes a voltage to appear across the device and for current to flow. In these new devices, light is instead emitted and the current and voltage go in the opposite direction, but you still generate power," Munday said. "You have to use different materials, but the physics is the same."

The device would work during the day as well, if you took steps to either block direct sunlight or pointed it away from the sun. Because this new type of solar cell could potentially operate around the clock, it is an intriguing option to balance the power grid over the day-night cycle.

Climate Change Increases the Risk of Wildfires Confirms New Review

Date: January 14, 2020
Source: University of East Anglia

Human-induced climate change promotes the conditions on which wildfires depend, increasing their likelihood – according to a review of research on global climate change and wildfire risk published today.

In light of the Australian fires, scientists from the University of East Anglia (UEA), Met Office Hadley Centre, University of Exeter and Imperial College London have conducted a Rapid Response Review of 57 peer-reviewed papers published since the IPCC's Fifth Assessment Report in 2013.

All the studies show links between climate change and increased frequency or severity of fire weather – periods with a high fire risk due to a combination of high temperatures, low humidity, low rainfall and often high winds – though some note anomalies in a few regions.

Rising global temperatures, more frequent heatwaves and associated droughts in some regions increase the likelihood of wildfires by stimulating hot and dry conditions, promoting fire weather, which can be used as an overall measure of the impact of climate change on the risk of fires occurring.

Observational data shows that fire weather seasons have lengthened across approximately 25 per cent of the earth's vegetated surface, resulting in about a 20 per cent increase in global mean length of the fire weather season.

The literature review was carried out using the new ScienceBrief.org online platform, set up by UEA and the Tyndall Centre for Climate Change Research. ScienceBrief is written by scientists and aims to share scientific insights with the world and keep up with science, by making sense of peer-reviewed publications in a rapid and transparent way.

Dr Matthew Jones, Senior Research Associate at UEA's Tyndall Centre and lead author of the review, said: "Overall, the 57 papers reviewed clearly show human-induced warming has already led to a global increase in the frequency and severity of fire weather, increasing the risks of wildfire.

"This has been seen in many regions, including the western US and Canada, southern Europe, Scandinavia and Amazonia. Human-induced warming is also increasing fire risks in other regions, including Siberia and Australia.

"However, there is also evidence that humans have significant potential to control how this fire risk translates into fire activity, in particular through land management decisions and ignition sources."

At the global scale, burned area has decreased in recent decades, largely due to clearing of savannahs for agriculture and increased fire suppression. In contrast, burned area has increased in closed-canopy forests, likely in response to the dual pressures of climate change and forest degradation.

Co-author Professor Richard Betts, Head of Climate Impacts Research at the Met Office Hadley Centre and University of Exeter, said: "Fire weather does occur naturally but is becoming more severe and widespread due to climate change. Limiting global warming to well below 2°C would help avoid further increases in the risk of extreme fire weather."

Professor Iain Colin Prentice, Chair of Biosphere and Climate Impacts and Director of the Leverhulme Centre for Wildfires, Environment and Society, Imperial College London, added: "Wildfires can't be prevented, and the risks are increasing because of climate change. This makes it urgent to consider ways of reducing the risks to people. Land planning should take the increasing risk in fire weather into account."

NASA Planet Hunter Finds Earth-size Habitable-zone World

Date: January 6, 2020
Source: NASA/Jet Propulsion Laboratory

NASA's Transiting Exoplanet Survey Satellite (TESS) has discovered its first earth-size planet in its star's habitable zone, the range of distances where conditions may be just right to allow the presence of liquid water on the surface. Scientists confirmed the find, called TOI 700 d, using NASA's Spitzer Space Telescope and have modelled the planet's potential environments to help inform future observations.

TOI 700 d is one of only a few earth-size planets discovered in a star's habitable zone so far. Others include several planets in the TRAPPIST-1 system and other worlds discovered by NASA's Kepler Space Telescope.

"TESS was designed and launched specifically to find earth-sized planets orbiting nearby stars," said Paul Hertz, astrophysics division director at NASA Headquarters in Washington. "Planets around nearby stars are easiest to follow-up with larger telescopes in space and on earth. Discovering TOI 700 d is a key science finding for TESS. Confirming the planet's size and habitable zone status with Spitzer is another win for Spitzer as it approaches the end of science operations this January."

TESS monitors large swaths of the sky, called sectors, for 27 days at a time. This long stare allows the satellite to track changes in stellar brightness caused by an orbiting planet crossing in front of its star from our perspective, an event called a transit.

TOI 700 is a small, cool M dwarf star located just over 100 light-years away in the southern constellation Dorado. It's roughly 40% of the sun's mass and size and about half its surface temperature. The star appears in 11 of the 13 sectors TESS observed during the mission's first year, and scientists caught multiple transits by its three planets.

The star was originally misclassified in the TESS database as being more similar to our sun, which meant the planets appeared larger and hotter than they really are. Several researchers, including Alton Spencer, a high school student working with members of the TESS team, identified the error.

"When we corrected the star's parameters, the sizes of its planets dropped, and we realized the outermost one was about the size of earth and in the habitable zone," said Emily Gilbert, a graduate student at the University of Chicago. "Additionally, in 11 months of data we saw no flares from the star, which improves the chances TOI 700 d is habitable and makes it easier to model its atmospheric and surface conditions."

Gilbert and other researchers presented the findings at the 235th meeting of the American Astronomical Society in Honolulu, and three papers – one of which Gilbert led – have been submitted to scientific journals.

The innermost planet, called TOI 700 b, is almost exactly earth-size, is probably rocky and completes an orbit every 10 days. The middle planet, TOI 700 c, is 2.6 times larger than earth – between the sizes of earth and Neptune – orbits every 16 days and is likely a gas-dominated world. TOI 700 d, the outermost known planet in the system and the only one in the habitable zone, measures 20 per cent larger than earth, orbits every 37 days and receives from its star 86 per cent of the energy that the sun provides to earth. All of the planets are thought to be tidally locked to their star, which means they rotate once per orbit so that one side is constantly bathed in daylight.

A team of scientists led by Joseph Rodriguez, an astronomer at the Center for Astrophysics | Harvard and Smithsonian in Cambridge, Massachusetts, requested follow-up observations with Spitzer to confirm TOI 700 d.

"Given the impact of this discovery – that it is TESS's first habitable-zone earth-size planet – we really wanted our understanding of this system to be as concrete as possible," Rodriguez said. "Spitzer saw TOI 700 d transit exactly when we expected it to. It's a great addition to the legacy of a mission that helped confirm two of the TRAPPIST-1 planets and identify five more."

The Spitzer data increased scientists' confidence that TOI 700 d is a real planet and sharpened their measurements of its orbital period by 56 per cent and its size by 38 per cent. It also ruled out other possible astrophysical causes of the transit signal, such as the presence of a smaller, dimmer companion star in the system.

Rodriguez and his colleagues also used follow-up observations from a 1-metre ground-based telescope in the global Las Cumbres Observatory network to improve scientists' confidence in the orbital period and size of TOI 700 c by 30 per cent and 36 per cent, respectively.

Because TOI 700 is bright, nearby, and shows no sign of stellar flares, the system is a prime candidate for precise mass measurements by current ground-based observatories. These measurements could confirm scientists' estimates that the inner and outer planets are rocky and the middle planet is made of gas.

Future missions may be able to identify whether the planets have atmospheres and, if so, even determine their compositions.

While the exact conditions on TOI 700 d are unknown, scientists can use current information, like the planet's size and the type of star it orbits, to generate computer models and make predictions. Researchers at NASA's Goddard Space Flight Center in Greenbelt, Maryland, modelled 20 potential environments of TOI 700 d to gauge if any version would result in surface temperatures and pressures suitable for habitability.

Their 3D climate models examined a variety of surface types and atmospheric compositions typically associated with what scientists regard to be potentially habitable worlds. Because TOI 700 d is tidally locked to its star, the planet's cloud formations and wind patterns may be strikingly different from earth's.

One simulation included an ocean-covered TOI 700 d with a dense, carbon-dioxide-dominated atmosphere similar to what scientists suspect surrounded Mars when it was young. The model atmosphere contains a deep layer of clouds on the star-facing side. Another model depicts TOI 700 d as a cloudless, all-land version of modern earth, where winds flow away from the night side of the planet and converge on the point directly facing the star.

When starlight passes through a planet's atmosphere, it interacts with molecules like carbon dioxide and nitrogen to produce distinct signals, called spectral lines. The modeling team, led by Gabrielle Englemann-Suissa, a Universities Space Research Association visiting research assistant at Goddard, produced simulated spectra for the 20 modelled versions of TOI 700 d.

"Someday, when we have real spectra from TOI 700 d, we can backtrack, match them to the closest simulated spectrum, and then match that to a model," Englemann-Suissa said. "It's exciting because no matter what we find out about the planet, it's going to look completely different from what we have here on earth."

TESS is a NASA Astrophysics Explorer mission led and operated by MIT in Cambridge, Massachusetts, and managed by NASA's Goddard Space Flight Center. Additional partners include Northrop Grumman, based in Falls Church, Virginia; NASA's Ames Research Center in California's Silicon Valley; the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts; MIT's Lincoln Laboratory; and the Space Telescope Science Institute in Baltimore. More than a dozen universities, research institutes and observatories worldwide are participants in the mission.

The Jet Propulsion Laboratory in Pasadena, California, manages the Spitzer Space Telescope mission for NASA's Science Mission Directorate in Washington. Science operations are conducted at the Spitzer Science Center at Caltech in Pasadena. Space operations are based at Lockheed Martin Space in Littleton, Colorado. Data are archived at the Infrared Science Archive housed at IPAC at Caltech. Caltech manages JPL for NASA.

The modelling work was funded through the Sellers Exoplanet Environments Collaboration at Goddard, a multidisciplinary collaboration that brings together experts to build comprehensive and sophisticated computer models to better analyze current and future exoplanet observations.

New Technology Could Help Solve AI's 'Memory Bottleneck'

Date: February 10, 2020
Source: Northwestern University

Electrical engineers at Northwestern University and the University of Messina in

Italy have developed a new magnetic memory device that could potentially support the surge of data-centric computing, which requires ever-increasing power, storage and speed.

Based on antiferromagnetic (AFM) materials, the device is the smallest of its kind ever demonstrated and operates with record-low electrical current to write data.

"The rise of big data has enabled the emergence of artificial intelligence (AI) in the cloud and on edge devices and is fundamentally transforming the computing, networking and data storage industries," said Northwestern's Pedram Khalili, who led the research. "However, existing hardware cannot sustain the rapid growth of data-centric computing. Our technology potentially could solve this challenge."

The research will be published on 10 February in the journal *Nature Electronics*.

Khalili is an associate professor of electrical and computer engineering in Northwestern's McCormick School of Engineering. He co-led the study with Giovanni Finocchio, an associate professor of electrical engineering at the University of Messina. The team also included Matthew Grayson, a professor of electrical and computer engineering at McCormick. Jiacheng Shi and Victor Lopez-Dominguez, who are both members of Khalili's laboratory, served as co-first authors of the paper.

From promise to probable

Although AI offers promise to improve many areas of society, including health care systems, transportation and security, it can only meet its potential if computing can support it.

Ideally, AI needs all the best parts of today's memory technologies: Something as fast as static random access memory (SRAM) and with a storage capacity similar to dynamic random access memory (DRAM) or Flash. On top of that, it also needs low power dissipation.

"There is no existing memory technology that meets all of these demands," Khalili said. "This has resulted in a so-called 'memory bottleneck' that severely limits the performance and energy consumption of AI applications today."

To meet this challenge, Khalili and his collaborators looked to AFM materials. In AFM materials, electrons behave like tiny magnets due to a quantum mechanical property called 'spin,' but the material itself does not demonstrate a macroscopic magnetization because the spins are aligned in antiparallel fashion.

Typically, memory devices require an electric current to retain stored data. But in AFM materials, it is the magnetically ordered spins that perform this task, so a continuously applied electric current is not needed. As an added bonus, the data cannot be erased by external magnetic fields. Because densely packed devices will not interact with magnetic fields, AFM-based devices are very secure and easy to scale down to small dimensions.

Easily adoptable technology

Because they are inherently fast and secure and use lower power, AFM materials have been explored in past studies. But previous researchers experienced difficulties controlling the magnetic order within the materials.

Khalili and his team used pillars of antiferromagnetic platinum manganese – a geometry not previously explored. With a diameter of just 800 nanometers, these pillars are 10 times smaller than earlier AFM-based memory devices.

Importantly, the resulting device is compatible with existing semiconductor manufacturing practices, which means that current manufacturing companies could easily adopt the new technology without having to invest in new equipment.

"This brings AFM memory – and thus highly scaled and high-performance magnetic random-access memory (MRAM) – much closer to practical applications," Khalili said. "This is a big deal for industry as there is a strong demand today for technologies and materials to extend the scaling and performance of MRAM and increase the return on the huge investment that industry has already made in this technology to bring it to manufacturing."

Khalili's team is already working on the next steps toward this translation to applications.

"We are working now to further downscale these devices and to improve methods to read out their magnetic state," Khalili said. "We also are looking at even more energy-efficient ways to write data into AFM materials, such as replacing the electric current with an electric voltage, a challenging task that could further increase the energy efficiency by another order of magnitude or more."

Astronomers Detect Biggest Explosion in the History of the Universe

Date: February 27, 2020
Source: International Centre for Radio Astronomy Research

Scientists studying a distant galaxy cluster have discovered the biggest explosion seen in the Universe since the Big Bang.

The blast came from a supermassive black hole at the centre of a galaxy hundreds of millions of light-years away.

It released five times more energy than the previous record holder.

Professor Melanie Johnston-Hollitt, from the Curtin University node of the International Centre for Radio Astronomy Research, said the event was extraordinarily energetic.

"We've seen outbursts in the centres of galaxies before but this one is really, really massive," she said.

"And we don't know why it's so big.

"But it happened very slowly – like an explosion in slow motion that took place over hundreds of millions of years."

The explosion occurred in the Ophiuchus galaxy cluster, about 390 million light-years from earth.

It was so powerful it punched a cavity in the cluster plasma – the super-hot gas surrounding the black hole.

Lead author of the study Dr Simona Giacintucci, from the Naval Research Laboratory in the United States, said the blast was similar to the 1980 eruption of Mount St. Helens, which ripped the top off the mountain.

"The difference is that you could fit 15 Milky Way galaxies in a row into the crater this eruption punched into the cluster's hot gas," she said.

Professor Johnston-Hollitt said the cavity in the cluster plasma had been seen previously with X-ray telescopes.

But scientists initially dismissed the idea that it could have been caused by an energetic outburst, because it would have been too big.

"People were sceptical because the size of outburst," she said. "But it really is that. The Universe is a weird place."

The researchers only realised what they had discovered when they looked at the Ophiuchus galaxy cluster with radio telescopes.

"The radio data fit inside the X-rays like a hand in a glove," said co-author Dr Maxim Markevitch, from NASA's Goddard Space Flight Center.

"This is the clincher that tells us an eruption of unprecedented size occurred here."

The discovery was made using four telescopes; NASA's Chandra X-ray Observatory, ESA's XMM-Newton, the Murchison Widefield Array (MWA) in Western Australia and the Giant Metrewave Radio Telescope (GMRT) in India.

Professor Johnston-Hollitt, who is the director of the MWA and an expert in galaxy clusters, likened the finding to discovering the first dinosaur bones.

"It's a bit like archaeology," she said.

"We've been given the tools to dig deeper with low frequency radio telescopes so we should be able to find more outbursts like this now."

The finding underscores the importance of studying the Universe at different wavelengths, Professor Johnston-Hollitt said.

"Going back and doing a multi-wavelength study has really made the difference here," she said.

Professor Johnston-Hollitt said the finding is likely to be the first of many.

"We made this discovery with Phase 1 of the MWA, when the telescope had 2048 antennas pointed towards the sky," she said.

"We're soon going to be gathering observations with 4096 antennas, which should be ten times more sensitive."

"I think that's pretty exciting."

How Meditation Can Help You Make Fewer Mistakes

Date: November 11, 2019
Source: Michigan State University

New research tested how open monitoring meditation altered brain activity in a way that suggests increased error recognition. Meditating just once proves to make a difference

If you are forgetful or make mistakes when in a hurry, a new study from Michigan State University–the largest of its kind to-date–found that meditation could help you to become less error prone.

The research, published in *Brain Sciences*, tested how open monitoring meditation–or, meditation that focuses awareness on feelings, thoughts or sensations as they unfold in one's mind and body – altered brain activity in a way that suggests increased error recognition.

"People's interest in meditation and mindfulness is outpacing what science can prove in terms of effects and benefits," said Jeff Lin, MSU psychology doctoral candidate and study co-author. "But it's amazing to me that we were able to see how one session of a guided meditation can produce changes to brain activity in non-meditators."

The findings suggest that different forms of meditation can have different neurocognitive effects and Lin explained that there is little research about how open monitoring meditation impacts error recognition.

"Some forms of meditation have you focus on a single object, commonly your breath, but open monitoring meditation is a bit different," Lin said. "It has you tune inward and pay attention to everything going on in your mind and body. The goal is to sit quietly and pay close attention to where the mind travels without getting too caught up in the scenery."

Lin and his MSU co-authors – William Eckerle, Ling Peng and Jason Moser – recruited more than 200 participants to test how open monitoring meditation affected how people detect and respond to errors.

The participants, who had never meditated before, were taken through a 20-minute open monitoring meditation exercise while the researchers measured brain activity through electroencephalography, or EEG. Then, they completed a computerized distraction test.

"The EEG can measure brain activity at the millisecond level, so we got precise measures of neural activity right after mistakes compared to correct responses," Lin said. "A certain neural signal occurs about half a second after an error called the error positivity, which is linked to conscious error recognition. We found that the strength of this signal is increased in the meditators relative to controls."

While the meditators didn't have immediate improvements to actual task performance, the researchers' findings offer a promising window into the potential of sustained meditation.

"These findings are a strong demonstration of what just 20 minutes of meditation can do to enhance the brain's ability to detect and pay attention to mistakes," Moser said. "It makes us feel more confident in what mindfulness meditation might really be capable of for performance and daily functioning right there in the moment."

While meditation and mindfulness have gained mainstream interest in recent years, Lin is among a relatively small group of researchers that take a neuroscientific approach to assessing their psychological and performance effects.

Looking ahead, Lin said that the next phase of research will be to include a broader group of participants, test different forms of meditation and determine whether changes in brain activity can translate to behavioural changes with more long-term practice.

"It's great to see the public's enthusiasm for mindfulness, but there's still plenty of work from a scientific perspective to be done to understand the benefits it can have, and equally importantly, how it actually works," Lin said. "It's time we start looking at it through a more rigorous lens."

Even Mild Physical Activity Immediately Improves Memory Function

Now you just need to remember to exercise!

Date: September 24, 2018
Source: University of California - Irvine

Researchers found that even very light workouts can increase the connectivity between parts of the brain responsible for memory formation and storage.

People who include a little yoga or tai chi in their day may be more likely to remember where they put their keys. Researchers at the University of California, Irvine and Japan's University of Tsukuba found that even very light workouts can increase the connectivity between parts of the brain responsible for memory formation and storage.

In a study of 36 healthy young adults, the researchers discovered that a single 10-minute period of mild exertion can yield considerable cognitive benefits. Using high-resolution functional magnetic resonance imaging, the team examined subjects' brains shortly after exercise sessions and saw better connectivity between the hippocampal dentate gyrus and cortical areas linked to detailed memory processing.

Their results were published in *Proceedings of the National Academy of Sciences*.

"The hippocampus is critical for the creation of new memories; it's one of the first regions of the brain to deteriorate as we get older– and much more severely in Alzheimer's disease," said project co-leader Michael Yassa, UCI professor and Chancellor's Fellow of neurobiology and behaviour. "Improving the function of the hippocampus holds much promise for improving memory in everyday settings."

The neuroscientists found that the level of heightened connectivity predicted the degree of recall enhancement.

Yassa, director of UCI's Center for the Neurobiology of Learning and Memory and the recently launched UCI Brain Initiative, said that while prior research has centred on the way exercise promotes the generation of new brain cells in memory regions, this new study demonstrates a more immediate impact: strengthened communication between memory-focused parts of the brain.

"We don't discount the possibility that new cells are being born, but that's a process that takes a bit longer to unfold," he said. "What we observed is that these 10-minute periods of exercise showed results immediately afterward."

A little bit of physical activity can go a long way, Yassa stressed. "It's encouraging to see more people keeping track of their exercise habits – by monitoring the number of steps they're taking, for example," he said. "Even short walking breaks throughout the day may have considerable effects on improving memory and cognition."

Yassa and his colleagues at UCI and at the University of Tsukuba are extending this avenue of research by testing older adults who are at greater risk of age-related mental impairment and by conducting long-term interventions to see if regular, brief, light exercise done daily for several weeks or months can have a positive impact on the brain's structure and function in these subjects.

"Clearly, there is tremendous value to understanding the exercise prescription that best works in the elderly so that we can make recommendations for staving off cognitive decline," he said.

One of Darwin's Evolution Theories Finally Proved

Date: March 17, 2020
Source: St John's College, University of Cambridge

Scientists have proved one of Charles Darwin's theories of evolution for the first time – nearly 140 years after his death.

Laura van Holstein, a PhD student in Biological Anthropology at St John's College, University of Cambridge, and lead author of the research published today (March 18) in *Proceedings of the Royal Society*, discovered mammal subspecies play a more important role in evolution than previously thought.

Her research could now be used to predict which species conservationists should focus on protecting to stop them becoming endangered or extinct.

A species is a group of animals that can interbreed freely amongst themselves. Some species contain subspecies – populations within a species that differ from each other by having different physical traits and their own breeding ranges. Northern giraffes have three subspecies that usually live in different locations to each other and red foxes have the most subspecies – 45 known varieties– spread all over the world. Humans have no subspecies.

van Holstein said: "We are standing on the shoulders of giants. In Chapter 3 of *On the Origin of Species* Darwin said animal lineages with more species should also contain more 'varieties'. Subspecies is the modern definition. My research investigating the relationship between species and the variety of subspecies proves that sub-species play a critical role in long-term evolutionary dynamics and in future evolution of species. And they always have, which is what Darwin suspected when he was defining what a species actually was."

The anthropologist confirmed Darwin's hypothesis by looking at data gathered by naturalists over hundreds of years — long before Darwin famously visited the Galapagos Islands on-board HMS Beagle. *On the Origin of Species by Means of Natural Selection*, was first published in 1859 after Darwin returned home from a five-year voyage of discovery. In the seminal book, Darwin argued that organisms gradually evolved through a process called 'natural selection'–often known as survival of the fittest. His pioneering work was considered highly controversial because it contradicted the Bible's account of creation.

van Holstein's research also proved that evolution happens differently in land mammals (terrestrial) and sea mammals and bats (non-terrestrial) because of differences in their habitats and differences in their ability to roam freely.

van Holstein said: "We found the evolutionary relationship between mammalian species and subspecies differs depending on their habitat. Subspecies form, diversify and increase in number in a different way in non-terrestrial and terrestrial habitats, and this in turn affects how subspecies may eventually become species. For example, if a natural barrier like a mountain range gets in the way, it can separate animal groups and send them off on their own evolutionary journeys. Flying and marine mammals – such as bats and dolphins – have fewer physical barriers in their environment."

The research explored whether subspecies could be considered an early stage of speciation – the formation of a new species. van Holstein said: "The answer was yes. But evolution isn't determined by the same factors in all groups and for the first time we know why because we've looked at the strength of the relationship between species richness and subspecies richness."

The research acts as another scientific warning that the human impact on the habitat of animals will not only affect them now, but will affect their evolution in the future. This information could be used by conservationists to help them determine where to focus their efforts.

van Holstein explained: "Evolutionary models could now use these findings to anticipate how human activity like logging and deforestation will affect evolution in the future by disrupting the habitat of species. The impact on animals will vary depending on how their ability to roam, or range, is affected. Animal subspecies tend to be ignored, but they play a pivotal role in longer term future evolution dynamics."

van Holstein is now going to look at how her findings can be used to predict the rate of speciation from endangered species and non-endangered species.

Notes to editors: What Darwin said on page 55 in '*On the Origin of Species*': "From looking at species as only strongly-marked and well-defined varieties, I was led to anticipate that the species of the larger genera in each country would oftener present varieties, than the species of the smaller genera; for wherever many closely related species (i.e species of the same genus) have been formed, many varieties or incipient species ought, as a general role, to be now forming. Where many large trees grow, we expect to find saplings."

Datasets: Most of the data is from Wilson and Reeder's 'Mammal Species of the World,' a global collated database of mammalian taxonomy. The database contains hundreds of years' worth of work by taxonomists from all over the world. The current way of 'doing' taxonomy goes all the way back to botanist Carl Linnaeus (1735), so the accumulation of knowledge is the combined work of all taxonomists since then.

Regular Exercise Benefits Immunity – even in Isolation

Date: March 31, 2020
Source: University of Bath

A new analysis highlights the power of regular, daily exercise on our immune system and the importance of people continuing to work-out even in lockdown.

Being in isolation without access to gyms and sports clubs should not mean people stop exercising, according to a new study from researchers at the University of Bath. Keeping up regular, daily exercise at a time when much of the world is going into isolation will play an important role in helping to maintain a healthy immune system.

The analysis, published in the international journal *Exercise Immunology Review*, involving leading physiologists Dr James Turner and Dr John Campbell from the University of Bath's Department for Health, considers the effect of exercise on our immune function.

Over the last four decades, many studies have investigated how exercise affects the immune system. It is widely agreed that regular moderate intensity exercise is beneficial for immunity, but a view held by some is that more arduous exercise can suppress immune function, leading to an 'open-window' of heightened infection risk in the hours and days following exercise.

In a benchmark study in 2018, this 'open window' hypothesis was challenged by

Dr Campbell and Dr Turner. They reported in a review article that the theory was not well supported by scientific evidence, summarising that there is limited reliable evidence that exercise suppresses immunity, concluding instead that exercise is beneficial for immune function.

They say that, in the short term, exercise can help the immune system find and deal with pathogens, and in the long term, regular exercise slows down changes that happen to the immune system with ageing, therefore reducing the risk of infections.

In a new article, published this month, leading experts, including Dr Turner and Dr Campbell, debated whether the immune system can change in a negative or positive way after exercise, and whether or not athletes get more infections than the general population. The article concludes that infections are more likely to be linked to inadequate diet, psychological stress, insufficient sleep, travel and importantly, pathogen exposure at social gathering events like marathons – rather than the act of exercising itself.

Author Dr James Turner from the Department for Health at the University of Bath explains: "Our work has concluded that there is very limited evidence for exercise directly increasing the risk of becoming infected with viruses. In the context of coronavirus and the conditions we find ourselves in today, the most important consideration is reducing your exposure from other people who may be carrying the virus. But people should not overlook the importance of staying fit, active and healthy during this period. Provided it is carried out in isolation – away from others – then regular, daily exercise will help better maintain the way the immune system works – not suppress it."

Co-author, Dr John Campbell added: "People should not fear that their immune system will be suppressed by exercise placing them at increased risk of Coronavirus. Provided exercise is carried out according to latest government guidance on social distancing, regular exercise will have a tremendously positive effect on our health and wellbeing, both today and for the future."

Regular moderate intensity aerobic exercise, such as walking, running or cycling is recommended, with the aim of achieving 150 minutes per week. Longer, more vigorous exercise would not be harmful, but if capacity to exercise is restricted due to a health condition or disability, the message is to 'move more' and that 'something is better than nothing'. Resistance exercise has clear benefits for maintaining muscles, which also helps movement.

At this current time in particular, the researchers underline the importance of maintaining good personal hygiene when exercising, including thoroughly washing hands following exercise. To give the body its best chance at fighting off infections, they suggest in addition to doing regular exercise, people need to pay attention to the amount of sleep they get and maintain a healthy diet, that is energy balanced to account for energy that is used during exercise. They hope that this debate article will lead to a wave of new research exploring the beneficial effects of exercise on immune function.

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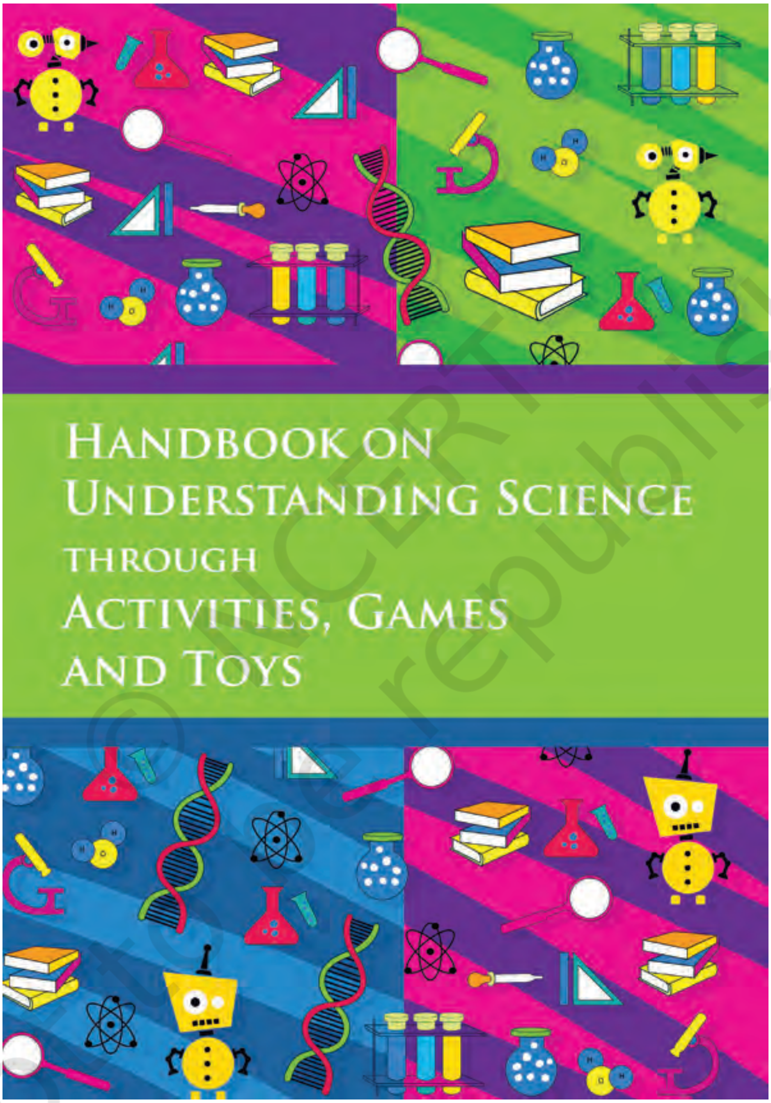

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