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Enhancing Positive Attitude towards Learning STEM Subjects through Differentiated Instruction

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The study explored the effectiveness of differentiated instruction in enhancing positive attitude towards learning STEM subjects. It employed quantitative approach with purposive sampling method. A total of 102 students of grade IX participated in the study. The study found out the mean of the differences (pre-test and post-test) was 2.00 (*SD* = 1.9836) and the paired-samples *t*-test indicated that this mean of the differences is not significantly greater than zero. This indicated that the differentiated instruction was not effective in developing positive attitudes towards STEM learning.

It is recommended to have an intensive study on the differentiated instruction in enhancing positive attitude towards learning STEM subjects by taking small sample

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size with one specific STEM subject. Further, the present study focused on only some students of grade IX, a study may be carried out across schools to get a deep understanding of the subject.

Keywords: Differentiated; attitude; STEM; effectiveness; learning.

1. INTRODUCTION

Bhutan and its people share mutual co-existence with peace, harmony, and nature. Hereditary monarchs of the country worked tirelessly to strengthen and sustain this irreplaceable aspect of livelihood by primarily focusing on education. Ever since the beginning, many reforms and developments were seen in the country to cater the needs of the crucial system governing the future of our country. The latest effort to education mainly revolved around STEM (Science, Technology, Engineering, and Mathematics) subjects. STEM education prepares students to become literate in science and technology and to contribute to a workforce that is employable [1]. On top of this initiative by the Royal Government of Bhutan, language and arts were seen important to everyone due to its advantage in terms of content delivery methods and communication skills. Therefore, the acronym "STEM" is now changed to "STEAM" (Science, Technology, Engineering, Arts, and Mathematics).

However, the primary focus of this action research is on STEM and to encourage positive mindset towards science and technology subjects as the researcher and co-researchers are teachers of STEM subjects in Gaselo Higher Secondary School. The school has seen lots of changes in the curriculum as well as pedagogy in all the subjects taught to students particularly in STEM subjects. With more than 500 students studying in the school every year, catering to His Majesty's vision of every student to become a life-long learner is a real challenge. Still then, implementation of authentic teaching style and the support of the government to teachers pedagogically has helped this important process of teaching and learning. The newest of revolution to mindset of education is differentiated instructions because of its vast application and advantage. The differentiated instruction is one of the approaches that provides an opportunity to consider differences in students and provide them with individualized instruction for good comprehension [2]. Therefore, teachers should be capable of carrying out this work of celebrating differences in students and impart the same mindset to students themselves. Teachers who view their class as a whole entity doesn't consider varying levels of student's attitude towards learning and thereby over-challenges or under-challenges students' competency [3]. Hence, this project will provide necessary information about the effectiveness of differentiated instruction and flexibility in typical Bhutanese schools. On top of this, it also serves as a pedagogy teacher can use on long term basis because Action research is a back-and-forth process. This also serves as a follow-up to other literature since it is stated that the differentiated instruction approach has important effect on student success; however, there is a gap between the applicability and effectiveness of this approach and thus there is a need for further action research to examine this issue [2].

1.1 Aims and Objectives

- To enable positive attitude towards learning STEM subjects
- To improve students' academic performance in STEM subjects
- To acknowledge diversity of learners in school

1.2 Reconnaissance

Jamtsho and Rinchen [4] describes reconnaissance as a diagnostic phase in action research that requires most critical analysis of point of attack towards fulfilling the aims and objectives of the action research. It is a systematic integration of situational analysis, competence of researcher and critical friend, and literature review [5]. Therefore, diagnostic situational analysis followed by competence of the researchers are noted in the following.

1.3 Situational Analysis

Gaselo Higher Secondary School (GHSS) is situated in Gasetshogom Gewog at an altitude of 1300 metres on 52.4 acres of land under Wangdue Phodrang Dzongkhag. GHSS was established in 2004 as a Middle Secondary School (MSS). Later it was upgraded to HSS in

2009. It is approximately 21 km away from Dzongkhag Headquarters and the school has grade levels from VII to XII. Currently, there are 41 teaching staff and 21 non-teaching staff.

An ideal location, superb infrastructures and boarding facilities offered by the school attracts thousands of students every year from the 20 Dzongkhags. This is mainly due to Hydro-electric projects of Punatsangchuu I and II, Military Training Centre (MTC) and other large institutions being located in the vicinity of the school. The school also caters education to the children of illiterate and poor farmers of Taksha, Selli, Athang, Rukha, Gaybakha, and other far flung areas under Wangdue Dzongkhag.

According to Mr. Singye Dorji, "Due to the diverse backgrounds of the students, the performance of the students in general and STEM subjects in particular had not been that satisfactory". It is also being observed that the students opting for the STEM subjects have been declining over the years as compared to other streams. For instance, statistical data of class XII students of Gaselo HSS in 2021 indicated that there were only 16 students in science, while there were approximately 70 and 60 in Arts and Commerce streams respectively. A learning preference test was also done for the students of class IX by the science department of the school and it was found that 41.5% of the students prefer kinesthetic learning style, while 28.7% preferred visual and 29.7% preferred auditory learning techniques. Owing to this fact, a need for bringing up a positive attitude of students towards STEM subjects was seen necessary by the school.

2. LITERATURE REVIEW

Literature suggest a more profound viewpoint when it comes to implementation of differentiated instructions in classroom. The differentiated instruction is an approach which is forward-looking, quantitative rather qualitative, based on evaluation, multi-dimensional for the content, process, product, student-centered, and mixture of large, small group and individual teaching (Tomlinson, 2001, p.2-5). It is therefore advisable to link assessment to mostly tests and exams rather than generalize whole quality of students' learning than just by their description. Other literature suggests a less rational idea to go about this pedagogy, according to Koeze (2019), differentiation is about understanding students rather than letting them choose what they want to learn.

Every educational system consists of an examination system through which the qualities and abilities of the students are assessed by giving grades and positions [6]. It is well known through researches that student performances are affected due to social, psychological, economic, environmental and personal factors, which vary from person to person and country to country [6]. Therefore, it is the duty of a teacher to address these issues so that the performances of the students are better that. As per the Bhutan Professional Standard for Teachers [BPST], these issues can be addressed by;

i. Applying differentiated teaching strategies that suit learners' gender, needs and interests across a full range of abilities [7].
ii. Implementing teaching strategies that are appropriate for learners' language, cultural, religious, and socio-economic backgrounds [7].
iii. Using teaching strategies based on understanding of physical, social, emotional and intellectual development of learners [7].
iv. Use teaching strategies that are responsive to learners with disabilities, giftedness and talents [7].

Furthermore, differentiated Instruction is a teaching theory based on the premise that instructional approaches should vary and be adapted in relation to individual and diverse students in classrooms [8]. When teachers differentiate, they make proactive adjustments to content, process, and product, according to patterns in student readiness, interest, or learning profile, using instructional strategies, informed by standards-aligned learning goals; pre- and formative assessment; and interest or preference surveys and inventories, implemented through varied instructional groupings, flexible classroom routines, and efficient management tools and techniques in the context of supportive, growth-oriented, community-centered classrooms [9].

The academic success of the students in STEM subjects can be predicted by their attitudes towards learning. The learning attitudes of the students is the feelings and thoughts displayed by the students in terms of learning environment and learning processes with appropriate or inappropriate behaviors in accordance with the expectations of the environment [10]. In other words, the learning attitudes refer to interests (situational and individual) towards learning.

Moreover, the situational interest can be enhanced through the modification of certain aspects of the learning environment and contextual factors such as teaching strategies, task presentation, and structuring of learning experiences [11]. According to Ofem and Domike (2015), creating a learning environment that evokes or triggers situational interest of the child, plays an important role in the development of individual interest to learning any subject [12].

2.1 Competence

Collaborative researchers are Sonam Tenzin (MSc Physics), Ugyen Dorji (M.Ed. Physics), Tendrup Gyeltshen (B.Ed. Math/Physics), Phub Lhamo (M.Ed. Biology), Yangchen Lhamo (PGDE Chemistry), Kezang Wangmo (B.Ed Math/Physics), Sonam Tobgay (PGDE Chemistry), Dorji Nidup (PGDE Mathematics), Yonten Zangmo (B.Sc Computer Science), and Tashi Wangmo (B.Tech Computer Applications).

The critical friend is Mr. Singye Dorji. He has a Master's in Educational Leadership & Management (M.Ed.). He attended many professional developmental programs specifically associated with research like the training on qualitative and quantitative research methodology and action research. The critical friend has also conducted research on career education.

Participants of this research are 114 class IX students of Gaselo Higher Secondary School. The participants are from diverse backgrounds and hence suitable for application of this action research.

2.2 AR Question

How can I improve class IX students' attitude towards learning STEM subjects using differentiated instruction?

2.3 Research Methodology

Data collection followed the conventionalized method of quantitative data collection as differentiated instruction mainly focuses on the quantitative assessments of the students rather than qualitative assessments. Quantitative data collection in this action research includes likert-scale survey questionnaire associated with attitudes of the students as shown in Appendix 1.

Sample: 102 students of Gaselo Higher Secondary School, Wangdue, Bhutan.

2.4 Intervention Plan

One significant change from the intervention plan provided in the AR proposal is the lesson plan intended to use during the intervention. Rather than using a common lesson plan for all the five different subjects, the team agreed on making separate lesson plans respectively for each subject. A systematic application of content, process, and product inculcating the need to celebrate diversity of learners was done for two weeks to class IX students. Team leader conducted training on the implementation of differentiated instruction to STEM teachers in the school and developed lesson plans for five different subjects for the intervention period. Although being of different backgrounds, the supporting teachers shared a common idea of implementation to teach their respective subjects in grade IX. The lesson plan covered a wide range of topics under different subjects with the same intent of providing differentiated instruction based on learners' interest, need, and readiness. The teacher researchers also instructed the supporting teachers to differentiate content input, procedural learning, and product presentation by the student since these are the main aspects of differentiated instruction.

3. FINDINGS AND DISCUSSION

Fig 1 shows the attitude scores in percent for each subject under STEM and Table 2 shows detailed representation of mean attitude scores of all the participants under different subjects with the percentage change. The pre-test and post-test data were entered into Microsoft Excel 2016 and represented as shown above.

2.5% increase in the attitude score of Biology indicates a strong evidence that the intervention improves the attitude of the students towards the subject. This is a good indication since the nature of the subject relies mostly on predisposed knowledge about life processes and the presentation of these knowledge in varied methods is the only thing that can be done to make learning authentic and interesting. Therefore, the Biology teacher grouped the students based on their readiness and differentiated the "Product of students' learning" followed by Question and Answer session to assess the progress of the students.

The attitude score rise in Chemistry of 1.8% indicates that the intervention helped students develop positive attitude and also infer a positive mindset towards Chemistry in their school education.

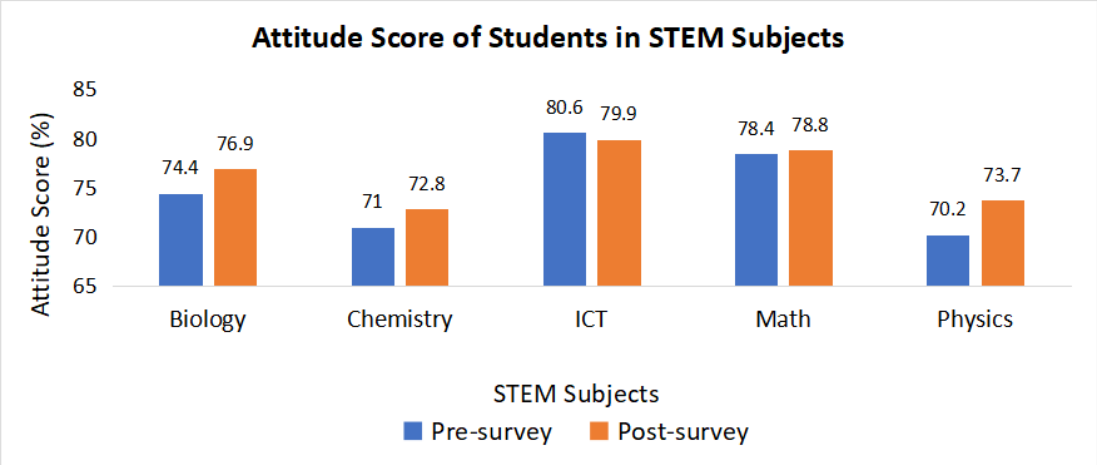

Fig. 1. Attitude scores (%) of students before and after the intervention

Table 1. Attitude scores (%) for STEM subjects

Subjects	Pre-survey			Post-survey			Percentage change
	Male	Female	Overall	Male	Female	Overall	
Biology	75	74.1	74.4	77	76.9	76.9	2.5%
Chemistry	70.3	71.4	71	72.9	72.8	72.8	1.8%
ICT	80.1	80.9	80.6	81.6	79	79.9	-0.7%
Mathematics	81.2	76.8	78.4	83	76.8	78.8	0.4%
Physics	72.3	68.9	70.2	73.7	73.7	73.7	3.5%

Table 2. Paired sample test to compare the means

Paired samples test									
		Paired differences					t	df	Sig. (2-tailed)
		Mean	Std. deviation	Std. error mean	95% confidence interval of the difference				
					Lower	Upper			
Pair 1	Pre_survey - Post_survey	-2.00000	1.98368	.88713	-4.46307	.46307	-2.254	4	.087

As for ICT (Information and Communication Technology), -0.7% change in attitude score indicates that the differentiated instruction does not necessarily improve their attitude towards learning computers. The sole reason for this is due to the fact that students love to explore themselves in front of a computer rather than be facilitated by many different classroom strategies that only discourages their curious minds.

A slight increase in the mean attitude score of the participants towards Mathematics of 0.4% shows that the intervention is slightly effective in improving the mindset towards learning mathematics. The mathematics teacher grouped the students according to their readiness level and used the strategy of “Six thinking hats” and “Six thinking dots” to differentiate students’ learning based on content, process, and product. Use of varied activity styles proved to be an good

idea to be implemented while differentiating Mathematics lessons.

The 3.5% rise in the mean attitude score of Physics indicates that the differentiated instruction is effective in the subject owing to the vast nature of the subject and many ways in which a student can learn it. The Physics teacher grouped the students and differentiated the lessons based on students interest. Students were given open choice of materials through which they can learn the concept and present through their own choice of methods. The final presentation of their works itself proved that the intervention is going on a good path.

Boys show greater improvement in their attitude score than girls as per the data shown in Table 1. This could be mainly because male students are more active and shows interest in learning by doing than most of the girls.

For further validation of the result, a paired sample t test was used. The result was not as expected, there were not much of improvement in post survey compared to pre survey.

From Table 2, the degree of freedom (df) is 4 which have a critical value (CV) of 2.132 and t value of the study was 2.252 which is bit larger than CV. However, the p value of the study was 0.087 which is more than .05. Therefore, the mean difference between pre and post survey was 2.00 and the paired-sample t-test indicated that this mean of the difference is greater than zero. However, its not significantly greater than zero. So, the differentiated instruction was not 100% effective in enhancing positive attitude towards learning STEM.

4. CONCLUSION AND RECOMMENDATION

In general, there are enough evidences to suggest that differentiated instruction works well for STEM subjects since these they are vast in nature. It can be concluded from the results that students show positive attitude towards learning STEM subjects when they are given variable methods of learning the same concept. However, as per the paired-sample t-test the difference was not significant.

On the downside of this research, many teacher researchers found that applying differentiated instruction is time consuming and disturbs other classes before the intended lesson. Even if the intended differentiated instruction brings out positive changes to the learners, other classes of the researcher are mostly disturbed. For this, the team suggests that learning style analysis, learning interest, and readiness of the students should be done in the beginning of the academic year so that when applying any teaching pedagogy, teachers can directly use the data and apply accordingly.

Another point to note is that differentiated instruction is not always applicable to all the concepts in the subject; there are some concepts which require more of input of the concept than the effort from the students. Since our team consists of 10 researchers, we found it difficult to connect with each other before and during the intervention period. Hence, we suggest future researchers to limit the number of researchers to only one or two.

For future researchers, there is a need to do more number of intensive studies on the effectiveness of differentiated instructions on individual STEM subjects in Bhutan. We suggest small number of participants and use quantitative form of research methods. This is because, Bhutan only has few number of Action Researches done in this area and since the objective of this project is to test the effectiveness of differentiated instruction in Bhutanese class IX students, follow-up Action Research is greatly encouraged.

Action Plan

Activity	Timeline	Remarks
AR proposal Preparation	2nd week of April	Done
AR proposal Presentation to Gaselo HSS Research Committee	3rd week of April	Done
AR proposal presentation to Cluster AR Committee	4th week of April	Done
Pre-Data collection	3rd week of May	Done
Conduct Intervention	3rd week of August	Done
Post-Data collection and analysis	2nd week September	Done
Research Finding presentation to School and Cluster Research committee	3rd week of October	Done
Research report submission to the Ministry of Education	2nd week of November	Done

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Appendix I: Sample Survey questionnaire (Biology)

Demographic Information: Please provide your information in the following parts by tick marking [√] in the box provided:

Gender: □Male □ Female

Grade: □ IX

Section: □ A □ B □ C

Name of the school: ……...

Sl. No	Statements on rubric usage	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1	Biology is very interesting to me.	5	4	3	2	1
2	I have always enjoyed studying biology in school.	5	4	3	2	1
3	Biology makes me feel secure, and at the same time it is stimulating.	5	4	3	2	1
4	I find what we learn in my biology class interesting.	5	4	3	2	1
5	Getting a good grade in biology is important to me.	5	4	3	2	1
6	The biology I learn is relevant to my life.	5	4	3	2	1
7	I am curious about discoveries in biology.	5	4	3	2	1
8	I use the biology that I learn in school in my life.	5	4	3	2	1
9	Learning biology will help me get a good job.	5	4	3	2	1
10	If I study hard, I can do well in biology	5	4	3	2	1
11	I believe I can master biology knowledge and skills.	5	4	3	2	1
12	I put enough effort into learning biology.	5	4	3	2	1
13	I spend a lot of time learning biology	5	4	3	2	1
14	I like to do better than other students on biology tests.	5	4	3	2	1
15	I am confident about taking biology tests.	5	4	3	2	1
16	I want to study biology because I want to make a contribution to society.	5	4	3	2	1
17	I prepare well for biology tests and labs.	5	4	3	2	1
18	I like taking the biology tests.	5	4	3	2	1
19	To understand biology, I sometimes think about my personal experiences and relate them to the topic being analyzed	5	4	3	2	1
20	Mathematical skills are important for understanding biology.	5	4	3	2	1

Appendix 2: Survey Questionnaire (Physics)

	Questions	SD	D	N	A	SA
1	I like physics as a subject					
2	The basic knowledge of physics is useful for everyone					
3	I am punctual with my physics homework					
4	I wait eagerly for physics period					
5	I discuss Physics with my friends					
6	I feel very pleased and satisfied on answering physics questions					
7	I try to correlate physics problems with my daily life situation					
8	There are many situations in physics that are difficult to visualize					
9	I study physics only when exams are near					
10	Physics has lots of scopes in the future					
11	I like solving physics problems					
12	Physics helps to develop my thinking skills					
13	Physics is all about understanding rather than memorizing laws					
14	I like participating in physics class					
15	I am able to understand physics concepts clearly					
16	I am always eager to ask questions beyond the classroom					
17	I like physics more than other subjects					
18	Physics is a very easy subject					
19	Physics helps me to build my confidence					
20	Getting good marks in physics is important to me					

Appendix 3: Lesson Plan

Lesson Plan No.: 25					
Subject: **BIOLOGY**	**Grade:** **9**	**Sec:** A and B	**Period:** 5th	**DATE**: 19/09/2022	**Duration:** 50 Mins
TOPIC: 1.5. Transport and Exchange in our body					
Competencies **1.** Use scientific evidence to support the explanation that an organism contains several interacting systems and subsystems. **2.** Use scientific concepts from human biological organisation to explain that processes, behaviours, and emotions of an organism are coordinated by several interacting systems and subsystems					
Teaching strategy: **Differentiated learning**		**CL Structures Used** **Numbered Heads Together** **Muddiest Point**		**TLM, Text book/Websites/Chalk and chalkboard /handouts**	
Learning objectives: 1. State what double circulation is 2. Draw and label the types of circulation in human body 3. State the function of circulatory system in human being					
Previous knowledge of students: Students knows that the hearts have four chambers and each chambers has its own function.					

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