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EVALUATING FORMATIVE ASSESSMENT PRACTICES IN STEM EDUCATION IN PUNJAB, PAKISTAN: PRINCIPLES, POLICIES, AND PRACTICES

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ABSTRACT

This paper delves into the significance of Formative Assessment as a powerful tool for promoting STEM learning and discusses the need for seamlessly blending seemingly disparate subjects, such as mathematics and general science, within a cohesive STEM framework. The research endeavor embarks on an extensive investigation into the development and application of formative assessment tasks in select classrooms, aiming to shed light on the potential of such interventions in promoting STEM. The research will involve the use of a mixed-methods approach to capture comprehensive data, combining qualitative observations, student interviews, and quantitative assessments. The findings will highlight the multifaceted impact of formative assessment on the students' cognitive and metacognitive development, fostering higher-order critical thinking skills and enhancing problem-solving capabilities. While the paper would celebrate the numerous benefits of formative assessment in STEM Education, it also acknowledges the challenges encountered during its implementation. These challenges range from initial resistance among educators to time constraints within the curriculum. Addressing these obstacles requires a transformative shift in pedagogical practices, fostering a culture of continuous improvement and embracing a growth-oriented mindset. In conclusion, this paper serves as a comprehensive exploration of using Formative Assessment to promote STEM Education in early grades. By delving into the process of task development, its implementation, and subsequent impact, the paper offers valuable insights into the symbiotic relationship between Formative Assessment and STEM learning. The contributions of this research extend to both curriculum development and assessment practices, offering a compelling roadmap for educators and policymakers seeking to empower the next generation of STEM innovators for ***diverse policy decisions****.*

Keywords: STEM Education, Formative Assessment, Foundation-Level Literacy, Learning Poverty, Assessment Techniques and trends, Diverse policy decisions.

1. INTRODUCTION

STEM Education is serving a high deal of promoting 21st century features learning, and education spread across the globe and quite evidently in Pakistan. In order to implement STEM system many initiatives have been taken. Some research studies had been conducted but more of them were descriptive and a few interventional studies not encompassing all aspects of STEM i.e., omitting engineering factor in pertinent. The study shows downward trend of STEM Education in Pakistan. Some of the major factors leading to downward trends of STEM was non inclusive approach disregarding role of interdisciplinary approach or integrated STEM Education with implemented curriculum, classroom teaching and learning practices (Formative Assessment), teachers training, classroom models of consideration for teaching STEM, lack of efficacy and models to make STEM learning more connected, sustainable and relevant for students to outperform in future.

The Punjab Examination Commission (PEC) is a leading assessment body implementing assessment mechanisms in the province of Punjab. PEC is mandated to 'design, develop, implement, maintain, monitor and evaluate a system of assessment/examination for elementary education (Grade 1-8) (PEC Act 2010). Till 2019, PEC conducted annual Curriculum-Based examinations for Grades 5 and 8. In February 2020, the Government of Punjab replaced the examination system with the new assessment regime, the Assessment Policy Framework (APF) 2019. The APF introduces a set of three complimentary interlinked systems that cater to all tiers of the system; (1) Large- Scale Assessment: system level through provision of feedback for improved policy decisions (2) School- Based Assessment: school-level feedback for school-based changes and, (3) Formative Assessment: classroom-level consistent feedback for the teacher to continuously change and improve teaching and learning practices, promoting 21st century skills and ensures sustainable learning experiences for the students across all developmental levels. The APF is the overarching framework for assessments in the province focused on serving all purposes of a best practice educational assessment system: (i) tracking changes from one learning point to the other (ii) making informed choices for grade promotions (iii) helping teachers make informed decisions to refine teaching practices according to student learning needs and (iv) improving policy decisions (v) encompassing higher order critical

thinking skills for students improved learning (vi) Implementing PBL (Project Based learning) and PSM (Problem Solving Methods) (PESP III, 2019).

This paper will enable to identify integrated approach how Formative Assessment in Punjab can serve as a pivotal pillar to mitigate to downward trend of STEM and regulate emergence of its policy, practices and implementation in collaboration with Formative Assessment Policy in Punjab.

2. STUDY AIMS

Quality Science, Technology, Engineering, and Mathematics (STEM) education is vital for the future success of students. STEM instruction is transformed from conventional teaching, teacher-centered learning to active, student-centered learning. McDonald (2016)summarized the pedagogical instructions, including inquiry; argumentation and reasoning; digital learning; computer programming and robotics; integration of some STEM content; cooperative learning; student-centered; hands on, assessment; 21st-century skills, that were useful in developing student engagement and achievement in STEM disciplines. STEM instruction also referred to solving problems that described concepts and processes from science and mathematics while incorporating the teamwork and design methodology of engineering and using appropriate technology Smith and Karr-Kidwell (2000).

For sustainable learning experience there always is a need for a policy integrated with existing practices. The study aims to provide a comprehensive insight to integrate STEM Education with Formative Assessment Policy of Assessment Policy Framework (2020) implemented in Punjab and can serve as leading factor to meet the challenges to improve STEM Education from primary to higher education.

Research Questions

1. What are the contextual affordances of Formative Assessment Policy, principles and practices to identify fields to implement assessment trends and techniques to improve STEM Education.
2. How well tailored STEM Integrated items based on standardized instructions, and rubrics help students learn in the education system? Are they meeting specific learning standards?
3. What factors are associated with student achievement? To what extent does student achievement vary with the characteristics of the learning environment (teacher knowledge and preparation, school resources etc.) or with student's interest?

4. Is there any difference in the students' performance taught using formative assessment technique in science and mathematics higher order critical thinking concepts?

3. LITERATURE REVIEW

3.1. Major Determinants Conceding STEM Education

Public school system in Pakistan is facing multiple challenges in STEM Education sustainable learning performance rather witnessed to come up with downward trend(Aslam et al., 2022). The vital impacts identified comprise of absence of developed instructional technologies, integrated curriculum material, teachers training through professional development and effective implementation of the said factors in classroom teaching and learning practices.(Havice et al., 2018) Another study has shown that teachers provided with integrated curriculum, increased perception and understanding of STEM Subjects to their daily classrooms teaching by maintaining its consistency have shown significant trails of students' performance of 21st century skills.(Bal & Bedir, 2021; Foundation, 2023) Students; as a result of consistent implementation of aforementioned vital factors, showed increased confidence in critical thinking which is evident in terms of benefitting profoundly better than others.(Han et al., 2023) The STEM Education Policy however needs a revamp focusing existing successful policies and trends as mentioned for sustainable achievements of its goals.

3.2. Teaching at the Right Level (TaRL)

Teaching and learning at early grades foster a global consensus as a medium to set a sustainable foundation for children's development, learning and futuristic achievement. Early Primary level learning has a strong bearing on advanced grades rapid learning. (Ndijuye & Tandika, 2020). Academicians and psychologist have invested a dire need of introducing practical and theoretical concepts for these are the most receptive years of foundation level sustainable learning. (Palaiologou, 2021) Furthermore it is emphasized that STEM Education must be started from early years by ensuring STEM professional development for early education and care educators and program.

"Science, Technology, Engineering and Mathematics are not just disciplines to be mastered but are instead reflections of the whole child's development and evolving conversation with the world . . .. (Greg Nelson, President of MA Association of Early Childhood Teacher Educators)."

Figure 1. STEM Education in early years(Stone-MacDonald et al., 2011)

It is focused with adequate research studies that adults leading on to showing scientific disposition bear its roots in their early learnings. These sustainable conceptual and scientific dispositions enable the children respond in a specific manner instigating the critical thinking skills. (Edwards et al., 1998; Heckman, 2006; Lowe, 1988) Considering findings and implementation of the international STEM Education, there is a dire need to reform STEM education policy for Teaching at The Right Level (TaRL).(Havice et al., 2018)

Many studies have shown impacts of STEM Education in early grades and came up with advocacy for the stance. The foundation level learning leaves a lasting impact and minimizes learning gaps in developmental levels as it is considered a rapid learning and developing phase. (Çiftçi et al., 2022) Another study promotes integration of STEM in classroom practices 'assessment for learning', and to implement it in different learning environment.(Jiang, 2022) A successful model of 'assessment for learning' is opted in the local context of the Punjab and can

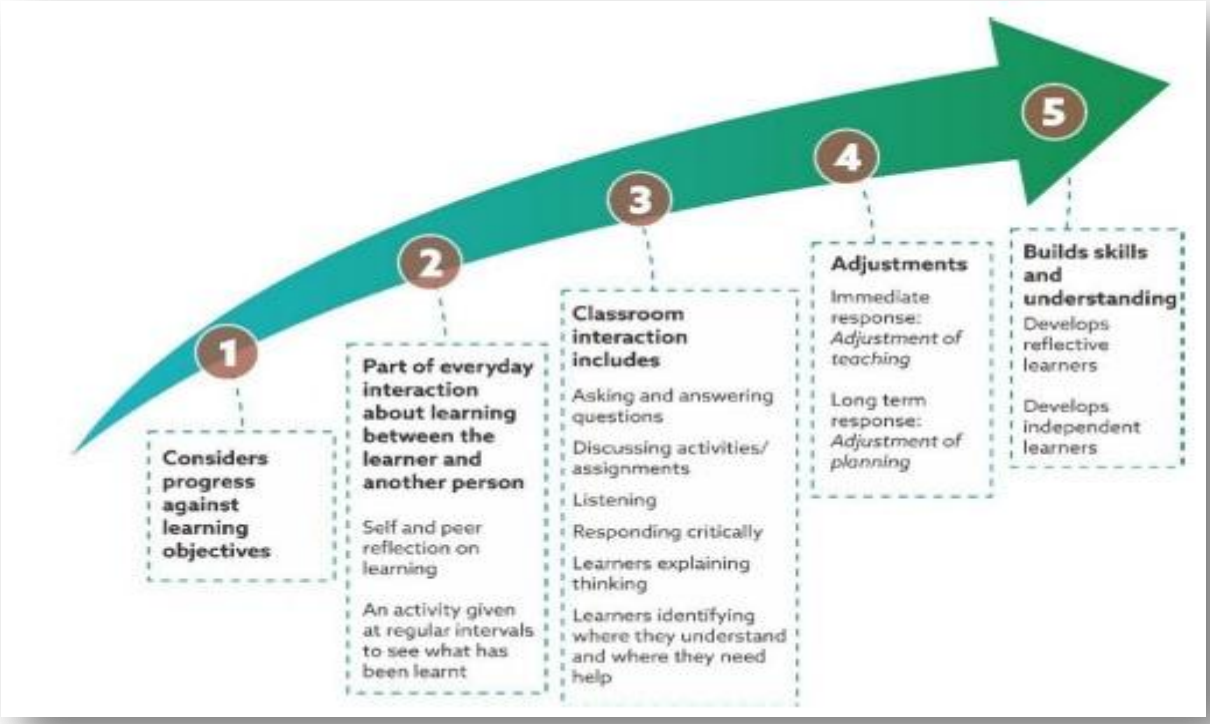

Figure 2: Assessment for Learning Supporting STEM Integrated Classroom Practice

efficiently serve STEM Education which emphasizes ***'easily read, think, prioritize, understand, plan, remember, and solve problems'*** in classroom learning. ((PSF), 2021-22)

3.3. Learning Achievements in Pakistan

Despite significant reforms and investment over the past decade, students in Pakistan are not achieving minimum levels of learning (ASER, 2019; Das et al., 2013; NEAS, 2014; NEAS-MoFEP, 2021). According to NEAS, in 2014, less than 50% of students in Grades 4 and 8 were competent in Urdu, while less than 40% of students in these grades were competent in mathematics. Five years later, in 2019, ASER results demonstrated that only 52% of students in grade 5 could read an Urdu story written at a grade 2 level. Similarly, Pakistan ranked 62 in both mathematics and natural sciences from 64 countries participating in TIMSS 2019. The consistent poor academic performance of the students in the STEM Subjects nationally and internationally is an alarming situation and needs integration with successful implemented policy, principles and practices through Formative Assessment Policy Framework in Punjab. (Punjab Examination Commission and Cambridge Education, 2021)

3.4. Formative Assessment Strategy in Punjab and STEM Education in the Classroom

Punjab Formative Assessment Strategy, an integral component of Formative Assessment Policy-2019 is serving as a significant stride in Punjab also serve as binding link among teachers, students, education, stakeholders and the allied departments. Punjab Examination commission (PEC) has profundity to support educational reforms e.g Single National Curriculum (SNC), teacher development under the Innovative Teacher Support Package (ITSP), Classroom Observation Tool (COT) and our new assessment system under the Assessment Policy Framework (APF)). Researches have shown successfully improve implemented models of STEM Education where it was made part of the everyday teaching and learning experience of the students, implementation of integrated curriculum to ensure inclusive approach of inclusion of 21st century knowledge and skills, teachers professional development programs aligned with best and smart classroom practices in local context to mitigate challenges, assessment frameworks aligned with international proficiency frameworks to support students improved academic achievement nationally and internationally and finally leading on to sharing of empirical facts stakeholders to draw better policies. Undeniably the fact which supports the determinants are comprehensively addressed in Punjab Formative Assessment Strategy which can efficiently implement STEM Education in real classroom teaching and learning culture through a cohesive system for sustainable evidence-based outputs leading 21st century

incremental changes integrating curriculum, training and assessment systems for improve education system.

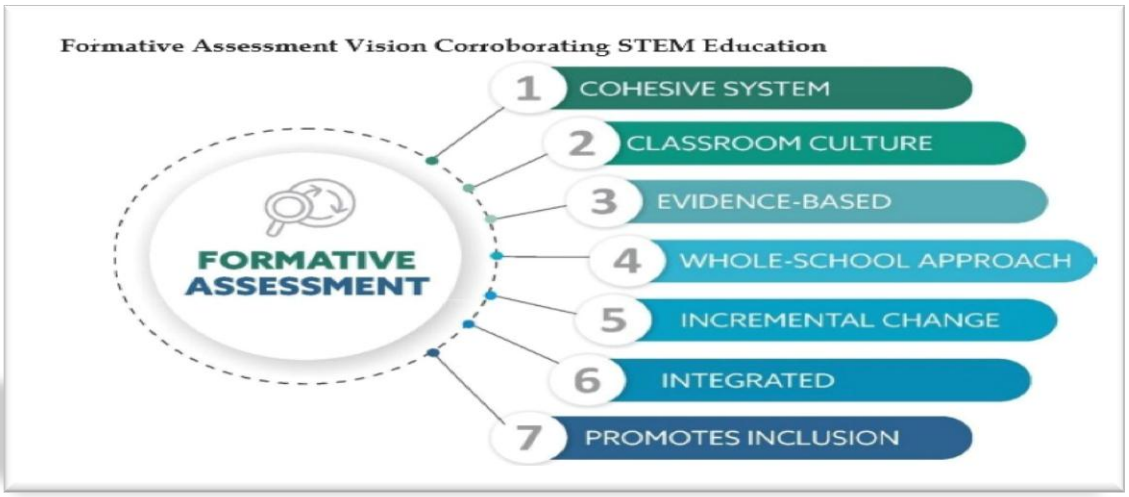

Figure 3. Formative Assessment supporting STEM Education Building Block

3.5. Policy, Institutional Arrangements, and Leadership Mechanism for SEM Education

A successful policy needs a cohesive approach bringing all implementing partners under one umbrella defining their roles and responsibilities to implement the Vision in true letter and spirit. The administrative liaison plays a vital role in bringing clarity of purpose, at all levels, aligning vision with policy directions and political commitments, buy-in from all stakeholders especially teachers, allocate adequate funds, provision of continuous training and support for implementation. (Havice et al., 2018; OSUMI et al., 2022; Punjab Examination Commission and Cambridge Education, 2021)

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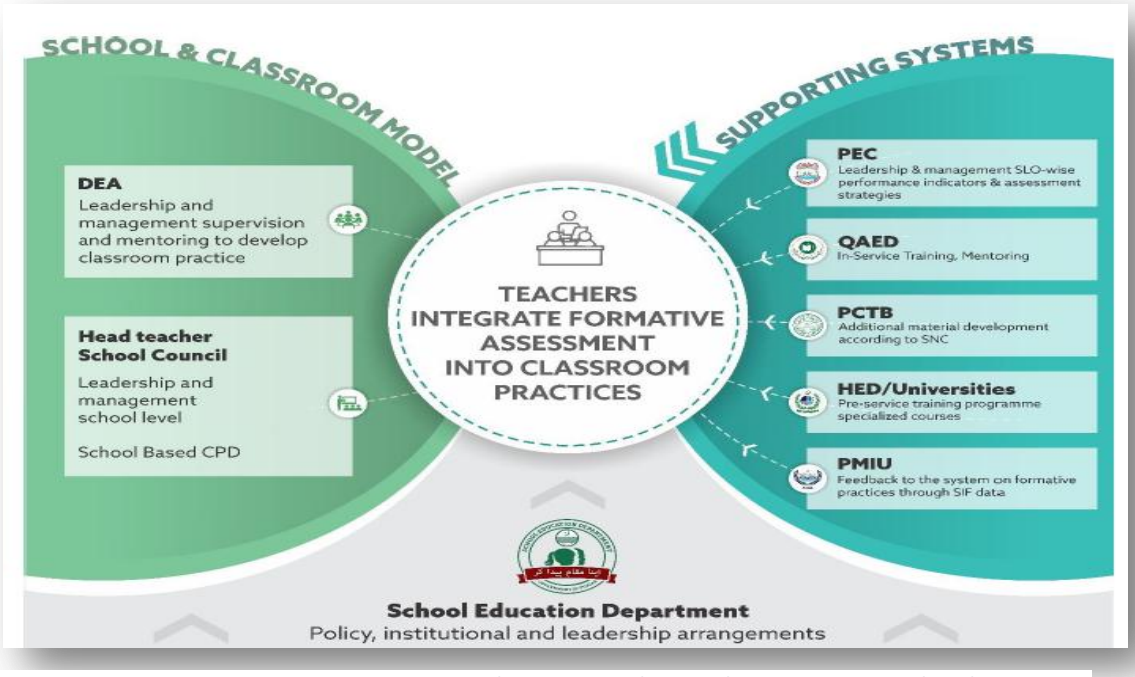

Figure 4. Formative Assessment Strategy Framework in Liaison with TEM Education Institutional Implementation.

Keeping into consideration local context a brief administrative system which is serving as a success story in Punjab in implanting School-Based and Large-Scale Assessments and heading effectively towards Formative Assessment Implementation in Punjab aligned with empirical evidence is worth considering for STEM Education effective implementation in Punjab. This model integrates classroom model supported by administrative intervention which lead on to delivery of empirical data for policy considerations.

4. Methodology

The study is based on a Mixed-Method Approach. The study includes:

- Gender (Boys and Girls)
- Type of Schools (Primary-Public Sector for SIC/Interview- Primary, Middle, High, Higher Secondary School)
- 10 Male female rural urban schools from each of 4 selected districts were taken for SII test.
- 10, 10 Male female rural urban schools from each of 4 selected districts were taken for Interview
- Location (Rural and Urban)

The data was comprised of:

- -Critical analysis of Formative Assessment Policy, Principles and Practices advocating STEM Education in classroom Formative Assessment practices aligned with international patterns for sustainable learning.
- -Analysis of secondary data from LSA through which the district showing highest performance trend in Science and Mathematics was included in sample to report best practices.
- -Qualitative Data from document analysis of LSA and interviews from teachers and students.
- -Composition of sample STEM Integrated items used during study interactive in nature based on Project Based and Problem-Solving Methods in the item particulars aligning it with the smart instructional technology and standardized rubrics meeting international standard of global proficiency framework and examples of lecture method samples.

4.1 Task Development Process

The task development process aimed at assessing higher order critical thinking scientific and mathematical concepts and those which align with STEM education tools as well. Selection of the Content and Concepts (learning outcomes) and alignment with the international benchmarks and framework was ensured in addition inclusion of performance level indicators along with scoring details and feedback. This collaborative approach makes an item standardized to support teaching and learning, identify learning gaps, revisit teaching techniques and ensure sustainable learning of science and mathematical concepts.

It is pertinent to mention that STEM Education aims at an effective way to engage students in high-level thinking and improve problem-solving skills by placing science and mathematics in the context. Consequent upon, it can be considered a collaborative approach for task development to be practiced by the teachers in classroom enriched with international trends of teaching and assessment.

Practicing teachers and assessment experts thoroughly went through the National Curriculum to identify learning concepts ensuring higher order scientific inquiry and mathematical concepts. The predefined concepts/benchmarks of the global proficiency frameworks were also aligned with the task to ensure improved learning leading to higher grades concepts and aligned with international assessment concepts to support teachers to prepare students for international assessments.

Following steps were adopted in brief:

1. Prioritization of higher order critical thinking learning outcomes from Single National Curriculum (SNC) aligned with STEM Education Tools preceding to basic concept in early grades-practicing teachers, assessment experts participated in this activity.
2. Alignment of selected learning outcomes with global proficiency framework by the experts of the said assessment.
3. Development of instructions promoting teaching process engaged with problem solving method which promotes cognitive skills must function well to efficiently and easily read, think, prioritize, understand, plan, remember, and solve problems as STEM EDUCATION mentions and aims for.((PSF), 2021-22)
4. Items promoting higher order critical thinking skills were supported by the development of performance levels as standardized international marking schemes for qualitative and quantitative feedback to improve learning.
5. Performance levels were tagged with performance descriptors to assist teachers in implementation of higher order critical thinking concepts in classroom making it inclusive by catering students of mixed ability groups, identifying their strengths and weakness and leading to help them improve their weaker learning areas.
6. The tools were added in Item Bank Software (IBS) to make them available for the teachers at one click generation and hard copy availability. IBS utility ensures provision of quality items, instruction, marking schemes and online monitoring for consistent classroom improved pedagogy.
7. Items developed and selected based on academic calendar to observe daily teaching practice and use of item developed with inclusive approach to support STEM Skills.

A brief structure of comparison of common concepts/topics, percentage of learning outcomes promoting higher order critical thinking skills, standardized framework and comparison of early grades concepts with their proceeding concepts in higher grades which enable the study to be executed in early grades and enforce the fact to implement STEM Education from early grades are being shared. It is vital that Science discipline follows the similar pattern of concepts to invest in Stem Education from early grades to ensure sustainable learning in foundation learning levels.

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Mathematics

Total Percentage Share of the Three Domains for Maths-Progression of Concepts Across Developmental levels

Domains	Share in Percentage Grade-1	Share in Percentage Grade-2
Cognitive	95%	98%
Affective	0%	0%
Psychomotor	5%	2%

Grade I & II Frameworks

Competency / Learning Domains	Numbers & Operations		Algebra (5%)		Measurements (25%)		Geometry (8%)		Statistics & Probability		Total 100%
	Grade 1 57%	Grade 2 51%	Grade 1 5%	Grade 2 5%	Grade 1 257%	Grade 2 27%	Grade 1 8%	Grade 2 14%	Grade 1 5%	Grade 2 3%	
Cognitive Domain											
Remember (38%)	7		-		4		3		1		38%
Understand (43%)	8		2		6		-		1		43%
Apply (12%)	5		-		-		-		-		12%
Analyze (2%)	1		-		-		-		-		2%
Evaluate (0%)	-		-		-		-		-		-
Create (0%)	-		-		-		-		-		-
Organizing (0%)	-		-		-		-		-		-

Figure 5: Early Grades Concepts, Taxonomical and Progression of Domains Comparison.(Punjab Examination Commission and Cambridge Education, 2021; VIII, 2022)

Total Percentage Share of the Three Domains for Math-Progression of Concepts Across Developmental levels (Grade I/II-VI/VII)

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The proceeding detail enables to corelate conceptual, taxonomical and topic wise progression introduced in early grades and included in higher grades with percentage variations and enable

Grade 1					
Unit	Title	Cogn	Affec	Psych	Weight
1	Number & Operations	44%	-	-	44%
2	Algebra	15%	-	-	15%
3	Measurements	8%	-	2%	10%
4	Geometry	15%	-	6%	21%
5	Statistics & Probability	8%	-	2%	10%
	Total Weightage (100%)	90%		10%	100%

Grade 2					
Unit	Title	Cogn	Affec	Psych	Weight
1	Number & Operations	52%	0%	5%	57%
2	Algebra	5%	0%	0%	5%
3	Measurements	25%	0%	0%	25%
4	Geometry	8%	0%	0%	8%
5	Statistics & Probability	5%	0%	0%	5%
	Total Weightage (100%)	95%	0%	5%	100%

Grade VI					
Unit	Title	Cogn	Affec	Psych	Weight
1	Number & Operations	34%	0%	0%	34%
2	Algebra	27%	0%	0%	27%
3	Measurements	14%	0%	0%	14%
4	Geometry	14%	0%	4%	18%
5	Statistics & Probability	6%	0%	1%	7%
	Total Weightage (100%)	95%	0%	5%	100%

Grade VII					
Unit	Title	Cogn	Affec	Psych	Weight
1	Number & Operations	32	-	-	32%
2	Algebra	34	-	-	34%
3	Measurements	7	-	-	7%
4	Geometry	9	-	6	15%
5	Statistics & Probability	9	-	3	12%
	Total Weightage (100%)	91%	-	9%	100%

Science

Total Percentage Share of the Three Domains for Science-Progression of Concepts Across Developmental levels

Domains	Share in Percentage Grade-1	Share in Percentage Grade-2
Cognitive	89%	90%
Affective	10	9%
Psychomotor	1%	1%

Grade I & II Frameworks

Competency / Learning Domains	Discovering Self and Immediate Environment		Life Sciences 15%		Physical Sciences 14%		Earth and Space Science 9%		Total 100%
	Grade 1 20%	Grade 2 51%	Grade 1 38%	Grade 2 15%	Grade 1 5%	Grade 2 14%	Grade 1 9%	Grade 2 9%	
Remember (38%)	7		-		4		3		38%
Understand (43%)	8		2		6		-		43%
Apply (12%)	5		-		-		-		12%
Analyze (2%)	1		-		-		-		2%
Evaluate (0%)	-		-		-		-		-
Create (0%)	-		-		-		-		-
Organizing (0%)	-		-		-		-		-

Figure 6: : Early Grades Concepts, Taxonomical and Progression of Domains Comparison (Punjab Examination Commission and Cambridge Education, 2021)

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the study to be rooted in initiation STEM Education from early grades to support higher grades sustainable learning for students improved performances.

Total Percentage Share of the Domains for General Knowledge/Science (Inclusive Science Domains)-Progression of Concepts Across Developmental levels (Grade I/II- VI/VII)

The proceeding detail enables to corelate conceptual, taxonomical and topic wise progression introduced in early grades (In Grade I/II, the subject is named General knowledge keeping multiple domains and concepts however it included higher grades concepts and domains as introductory information in it) and included in higher grades with percentage variations and

	Grade I				
No	Domain	Cogn	Affec	Psych	Weight
1	Discovering Self and Immediate Environment	15%	5%	-	20%
2	Ethics and Values	7%	4%	-	11%
3	Responsible Citizenship	7%			7%
4	Patriotism and Knowledge of the Country	4%	-	1%	5%
5	Goods and Services	5%	-	-	5%
6	Life Sciences	37%	1%	-	38%
7	Physical Sciences	5%	-	-	5%
8	Earth and Space Science	9%	-	-	9%
Total (100%)			89%	10%	1%

	Grade II				
No	Domain	Cogn	Affec	Psych	Weight
1	Discovering Self and Immediate Environment	6%			6%
2	Ethics and Values	16%	6%		22%
3	Responsible Citizenship	12%	3%		15%
4	Patriotism and Knowledge of the Country	11%		1%	12%
5	Goods and Services	7%			7%
6	Life Sciences	15%			15%
7	Physical Sciences	14%			14%
8	Earth and Space Science	9%			9%
Total (100%)			90%	9%	1%

	Grade VI				
No	Domain	Cogn	Affec	Psych	Weight
1	Domain A: Life Sciences	21%	2%	-	23%
2	Domain B: Physical Sciences	59%	-	12%	71%
3	Domain C: Earth and Space Science	6%	-	-	6%
Total (100%)		86%	2%	12%	100

	Grade VII				
No	Domain	Cogn	Affec	Psych	Weight
1	Domain A: Life Sciences	28%	1%	2%	31%
2	Domain B: Physical Sciences	57%	-	7%	64%
3	Domain C: Earth and Space Science	5%	-	-	5%
Total (100%)		90%	1%	9%	100

enable the study to be rooted in initiation STEM Education from early grades to support higher grades sustainable learning for students improved performances.

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Grade	1		Subject		Science
Unit	2	Unit Name	My Body	Page Number	05
SLO	Identify the sensory description of each of the five senses (Taste: sweet, sour, bitter, salty; Touch: Soft, hard, smooth, rough, cold, warm, hot; Hearing; loud, soft, high, low; Sight: Bright, dim and recognize colors; Smell; pleasant and unpleasant)				

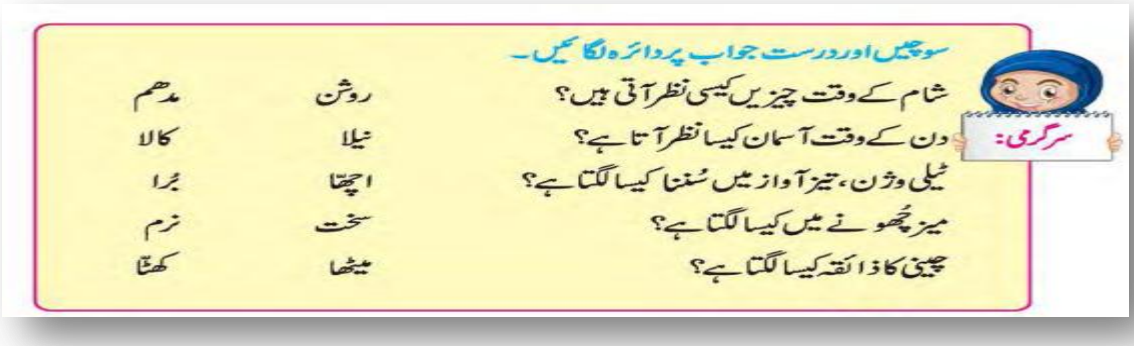
Tasks Aligned with STEM Skills and Interventions in Formative

Assessment Mode/Types of Instruments

Assessment Task 01: Think and circle the correct answer.

- How the objects look like in the evening?
  a) Bright b) Dim
- How the sky looks like in the day?
  a) Blue b) Black
- What does it feel like to listen to television at high volume?
  a) Good b) Bad
- How does it feel to touch the table?
  a) Hard b) Soft
- What does sugar taste like?
  a) Sweet b) Sour

Assessment Task 02: Observe the things from surroundings and note down on paper.



- Visit the different areas of your school and note which things you have seen, heard or felt.

Instructions:

1. Each student will be shown the activity of identification of sensory description of five senses (e.g., Taste: sweet, sour, bitter, salty; Touch: Soft, hard, smooth, rough, cold, warm, hot; Hearing; loud, soft, high, low; Sight: Bright, dim and recognize colors; Smell; pleasant and unpleasant etc.) from the textbook that is given on page no. 5.
2. Students must identify each sensory description of five senses from the textbook and able to understand different sensory description from environment.
3. Teachers are encouraged to assist only when necessary but should let the student attempt to identify and differentiate independently.
4. Homework will be given to those students who are approaching and below expectations.

Materials: Textbook, Lead pencil etc.

Rubric for Assessment:

Criteria	Exceeds Expectations (4 points)	Meets Expectations (3 points)	Approaching Expectations (2 points)	Below Expectations (1 point)
Identification of sensory description of five senses	Correctly identified sensory description of five senses	Correctly identified sensory description of three senses	Correctly identified sensory description of two senses but made several errors	Struggled to identify sensory description of all senses
Understanding from environment	Correctly understand sensory description of all senses from environment	Correctly understand sensory description of most senses from environment	Correctly understand sensory description of few senses from environment but made several errors	Struggled to understand sensory description of all senses from environment

Rubrics Explanation:

1. **Identification of sensory description of five senses:**

This criterion assesses the student's ability to accurately identify sensory description of five senses. A student who "Exceeds Expectations" will accurately identify all sensory descriptions, while a student who fails "Below Expectations" will struggle to do so.

2. **Understanding from environment:** This measures the student's ability to correctly understand sensory description of all senses from environment. A student who "Exceeds Expectations" will correctly understand sensory description of all senses from environment, while a student who is "Approaching Expectations" or "Below Expectations" will make some errors or struggle with this task.

Qualitative Analysis of Item in Context of STEM Skills and Interventions

Qualitative Dimension of Task	Task 1	Task 2	STEM Education Skills Alignment
Concept	Learning Outcome Based	Learning Outcome Based	Read and Think/Prioritize and Report
Cognitive Level	Comprehension	Application+	Creativity
STEM Skills	Soft Skills	Task Oriented	Innovation and Creativity
Marking Criteria	Performance Levels	Performance Levels	STEM Marking Standard
Modern Pedagogical Tools	Access to IBS	Access to IBS	Innovative Access Medium
Global Best Practices	Global Proficiency Framework (GPF)	Global Proficiency Framework (GPF)	Aims to align with national and international frameworks

Grade	1		Subject		General Knowledge
Unit	13	Unit Name	Plants and Animal	Page Number	43
SLO	Identify the differences between common domestic and wild animals in terms of physical features.				

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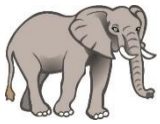
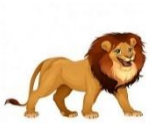
Assessment Task-1: Fill the box with red colour in front of wild animal and green colour in front of pet animals.

Cow ☐ Goat ☐

Elephant ☐ Lion ☐

Horse ☐

Assessment Task-2: Identify the animals in column A and match each animal to its physical features in column B.

Column A	Column B
	Some animals have hard skin.
	Some animals have sharp teeth.
	Some animals are big.

Instructions:

1. Each student will be shown the activity of various pet and wild animals and their physical features (e.g., big animal, small animal, have sharp teeth, have hard skin, have soft skin etc.) from the textbook that is given on page no. 43 and 46.
2. Students must identify each pet and wild animals and their physical features.
3. Teachers are encouraged to assist only when necessary but should let the student attempt to identify and match independently.

4. Write three physical features of animals as homework.

Materials: Textbook, Lead pencil etc.

Assessment for Rubrics:

Criteria	Exceeds Expectations (4 points)	Meets Expectations (3 points)	Approaching Expectations (2 points)	Below Expectations (1 point)
Identification of pet and wild animals	Correctly identified all pet and wild animals	Correctly identified most pet and wild animals	Correctly identified some pet and wild animals, but made several errors	Struggled to identify pet and wild animals
Matching of animals with their physical features	Correctly matched all animals with their physical features	Correctly matched most animals with their physical features	Correctly matched some animals with their physical features, but made several errors	Struggled to match animals with their physical features

Rubric Explanation:

1. **Identification of pet and wild animals:** This criterion assesses the student's ability to accurately identify different pet and wild animals. A student who "Exceeds Expectations" will accurately identify all animals, while a student who falls "Below Expectations" will struggle to do so.

2. **Matching of animals with their physical features:** This measures the student's ability to correctly match each animal with their physical features. A student who "Exceeds Expectations" will correctly match all animals with their physical features, while a student who is "Approaching Expectations" or "Below Expectations" will make some errors or struggle with this task.

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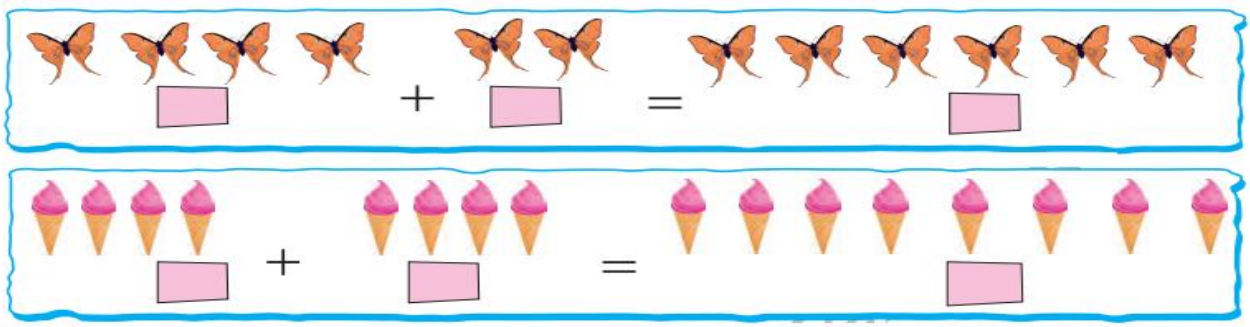
Qualitative Analysis of Item in Context of STEM Skills and Interventions

Qualitative Dimension of Task	Task 1	Task 2	STEM Education Skills Alignment
Concept	Learning Outcome Based	Learning Outcome Based	Read and Think/Prioritize and Report
Cognitive Level	Knowledge	Application+	Critical Thinking
STEM Skills	Soft Skills	Task Oriented	Innovation and Creativity
Marking Criteria	Performance Levels	Performance Levels	STEM Marking Standard
Modern Pedagogical Tools	Access to IBS	Access to IBS	Innovative Access Medium
Global Best Practices	Global Proficiency Framework (GPF)	Global Proficiency Framework (GPF)	Aims to align with national and international frameworks

Grade	1		Subject		Mathematics
Unit	2	Unit Name	Number Operations	Page Number	45
SLO	Add two, 1-digit numbers sum up to 9.				

Task 01: Count and add.



Instructions:

1) Ask the students to open page number 45 of the textbook.

2) The teacher asks the students to count the objects in each group and then add these two numbers together. They will write the result in the box.
3) Teachers are encouraged to assist only when necessary, but should let the student attempt to count and add independently.
4) Teacher will assign homework to students who are approaching expectations or below expectations.

Materials: Textbook, Pencil, Notebook.

Rubrics for Assessment:

Criteria	Exceeds Expectations (4 points)	Meets Expectations (3 points)	Approaching Expectations (2 points)	Below Expectations (1 point)
Counting Accuracy	Counted objects in all sets accurately	Counted objects in most sets accurately	Counted objects in some sets accurately	Struggled to count objects accurately
Addition Skills	Correctly added all sets of numbers	Correctly added most sets of numbers	Correctly added some sets of numbers, but made several errors	Struggled to add sets of numbers

Rubric Explanation:

1) **Counting Accuracy:** This criterion assesses the student's ability to accurately count the number of objects in each set. A student who "Exceeds Expectations" will accurately count the objects in all sets, while a student who falls "Below Expectations" will struggle to count accurately.
2) **Addition Skills:** This measures the student's ability to correctly add the two numbers they have counted. A student who "Exceeds Expectations" will correctly add all sets of numbers, while a student who is "Approaching Expectations" or "Below Expectations" will make some errors in addition or struggle with the concept of addition.

Qualitative Analysis of Item in Context of STEM Skills and Interventions

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Qualitative Dimension of Task	Task 1	Task 2	STEM Education Skills Alignment
Concept	Learning Outcome Based	Learning Outcome Based	Think and Solve Problems
Cognitive Level	Knowledge	Application+	Critical Thinking leading to meaningful learning
STEM Skills	Soft Skills	Task Oriented	Critical Thinking
Marking Criteria	Performance Levels	Performance Levels	STEM Marking Standard
Modern Pedagogical Tools	Access to IBS	Access to IBS	Innovative Access Medium
Global Best Practices	Global Proficiency Framework (GPF)	Global Proficiency Framework (GPF)	Aims to align with national and international frameworks

Grade	1		Subject		Mathematics
Unit	6	Unit Name	Geometry	Page Number	108
SLO	Classify 2-D shapes according to the number of sides and corners.				

Task 03: Write the correct name, number of sides and corners of these daily life objects.

Instructions:

1) Students must identify the basic shape (circle, square, triangle, rectangle, etc.) that best matches each object. They should write the name of the shape under the picture.

2) Students must write the number of sides and corners of every picture in the given boxes.
3) Students are also asked to draw at least two objects from their own daily life and identify the shapes. They will write the number of sides and corners of these shapes.
4) Teachers are encouraged to assist only when necessary, but should let the student attempt to recognize the shapes independently.
5) (Given Homework as remedial): The students will draw the shapes of circle, square, triangle and rectangle on notebook. They will also write the name of each shape, number of sides and corners.

Materials: Textbook, whiteboard, marker, pencils and space for students to draw and write.

Rubrics for Assessment:

Criteria	Exceeds Expectations (4 points)	Meets Expectations (3 points)	Approaching Expectations (2 points)	Below Expectations (1 point)
Shape Identification	Correctly identified the shapes in all pictures	Correctly identified the shapes in most pictures	Correctly identified the shapes in some pictures, but made several errors	Struggled to identify shapes in pictures
Sides Identification	Correctly identified number of sides in all pictures	Correctly identified the number of sides in most pictures	Correctly identified the number of sides in some pictures, but made several errors	Struggled to identify number of sides in pictures
Corners Identification	Correctly identified number of corners in all pictures	Correctly identified the number of corners in most pictures	Correctly identified the number of corners in some pictures, but made several errors	Struggled to identify number of corners in pictures

Rubric Explanation:

1) **Shape Identification:** This criterion assesses the student's ability to accurately identify the basic shape that matches each pictured object. A student who "Exceeds Expectations" will accurately identify the shapes in all pictures, while a student who falls "Below Expectations" will struggle to do so.
2) **Sides Identification:** This measures the student's ability to apply their knowledge of shapes to identify the number of sides in the shapes in personal objects. A student who "Exceeds Expectations" will identify the number of sides in all personal objects, while a student who is "Approaching Expectations" or "Below Expectations" will make some errors in identifying number of sides in shapes, or struggle with this task.

Corners Identification: This measures the student's ability to apply their knowledge of shapes to identify the number of corners in the shapes in personal objects. A student who "Exceeds Expectations" will identify the number of corners in all personal objects, while a student who is "Approaching Expectations" or "Below Expectations" will make some errors in identifying number of corners in shapes, or struggle with this task.

Qualitative Analysis of Item in Context of STEM Skills and Interventions

Qualitative Dimension of Task	Task 1	Task 2	STEM Education Skills Alignment
Concept	Learning Outcome Based	Learning Outcome Based	Think and Solve Problems
Cognitive Level	Knowledge	Application+	Critical Thinking leading to meaningful learning
STEM Skills	Soft Skills	Task Oriented	Critical Thinking
Marking Criteria	Performance Levels	Performance Levels	STEM Marking Standard
Modern Pedagogical Tools	Access to IBS	Access to IBS	Innovative Access Medium
Global Best Practices	Global Proficiency Framework (GPF)	Global Proficiency Framework (GPF)	Aims to align with national and international

			frameworks

Implementation in classroom

Items were developed taking into consideration the standardized assessment technique aligned with STEM Education skills. However, a set of key principles were required to assist in effective teaching practice in the classroom. This model is retrieved from Formative Assessment School and Classroom Model from Punjab given in Formative Assessment Strategy. This model promotes inquirey stance from the teachers who invest in essentatial teaching teachniques enabling to fostreing 21st century skills in the learners.

> *"True formative assessment requires teachers to take **an inquiry stance**, understanding that instruction and assessment are inextricably linked and often times inseparable." (Shepard, 2000). "When a teacher assumes a formative assessment stance—i.e., consistently asks questions to discover what students know and are ready to learn—every tool or activity that occurs in the classroom is formative in nature, and frequent checks for understanding aren't an "add-on" to teaching—they are the heart of teaching (Genishi & Dyson, 1984)"*(NCTE 2021)[38]

Another component which provides arena for diverse kind of teaching and learning practices to promote effective classroom experiences investing in preparation of miscellaneous assessments nationally and internationally. STEM Education aims at teachers training and Formative Assessment Classroom and School Model in Punjab supports the aim realistically.
The step wise approach dissects the information to be understood in brief given below.

i. **Step 1:** Planning which relates activities to learning outcomes and performance indicators
ii. **Step 2:** Supporting students to develop understanding, skills, and disposition
iii. **Step 3:** Regularly checking for understanding and providing feedback
iv. **Step 4:** Reinforcing concepts through specific interventions

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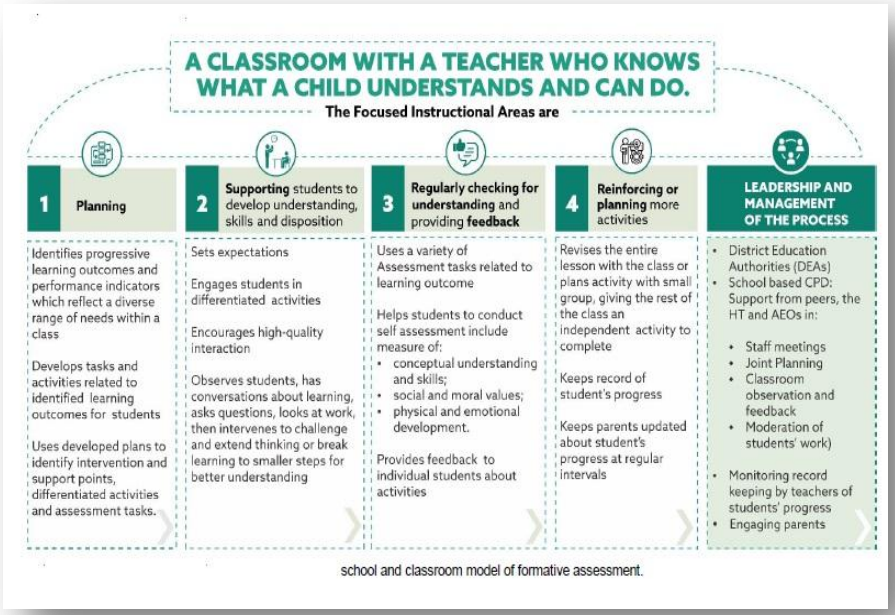

school and classroom model of formative assessment.

The scientific approach of the implementation is School Model promotes critical thinking, prioritizing, problem solving etc. as given in STEM Education.

Figure 7. Formative Assessment Classroom Model.(Punjab Examination Commission and Cambridge Education, 2021)

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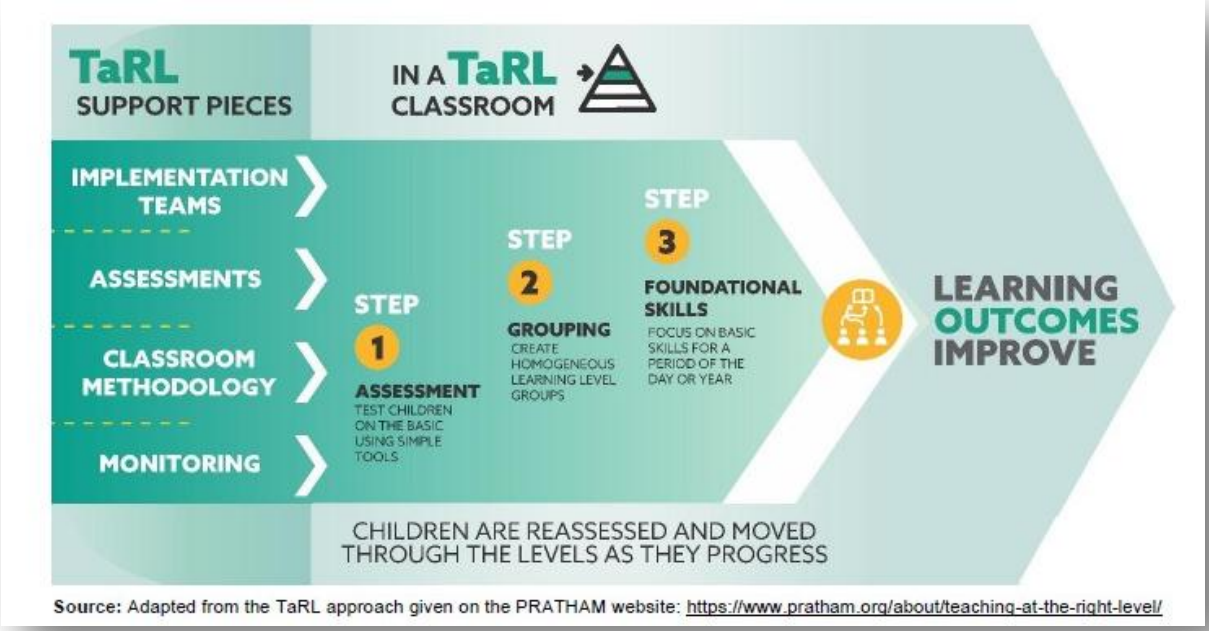
In order to implement the effective teaching strategies an approach mentioning 'Teaching at the Right Level', is a comprehensive Formative Assessment Model including the major determinants to effectively help promote STEM Education in classroom encompassing implementation teams, classroom methodology, assessments and monitoring mechanism which seem devoid in STEM Education Policy.



Source: Adapted from the TaRL approach given on the PRATHAM website: https://www.pratham.org/about/teaching-at-the-right-level/

Figure 8TaRl Model Adapted from Formative Assessment Punjab(Punjab Examination Commission and Cambridge Education, 2021)

MATHS		SCIENCE	
Muzaffargarh	80	Muzaffargarh	82
Khanewal	78	Narowal	81
Narowal	78	Multan	78
Jhang	73	D.G. Khan	77
Multan	71	Toba Tek Singh	77
D.G. Khan	70	Sialkot	77
Layyah	69	Khanewal	77
Rajanpur	69	Sheikhupura	76
Toba Tek Singh	69	Rajanpur	75
Sialkot	69	Lodhran	75
Bahawalpur	68	Nankana Sahib	75
Sheikhupura	68	Layyah	74
Lodhran	67	Sargodha	74
Sargodha	67	M.B. Din	74
Faisalabad	67	Kasur	73
Kasur	66	Faisalabad	73
Nankana Sahib	66	Jhang	72
Vehari	66	Okara	72
Chakwal	65	Bahawalpur	72
Gujranwala	65	Chakwal	72
Okara	65	Vehari	72
R.Y. Khan	64	Bahawalnagar	71
Mianwali	63	Mianwali	70
Khushab	63	Sahiwal	70
M.B. Din	63	Khushab	70
Rawalpindi	61	R.Y. Khan	68
Pakpattan	61	Rawalpindi	67
Hafizabad	61	Attock	67
Bhakkar	60	Hafizabad	67
Jhelum	59	Pakpattan	66
Sahiwal	59	Bhakkar	64
Chiniot	57	Gujranwala	64
Bahawalnagar	55	Jhelum	63
Lahore	54	Lahore	63
Attock	52	Chiniot	62
Gujrat	49	Gujrat	59

Data Collection and Analysis

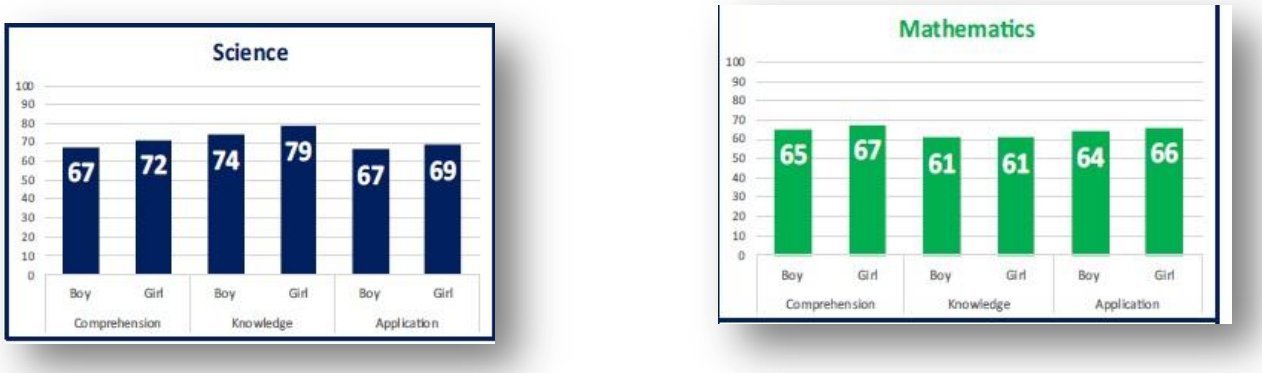
District Data Collection

The primary data was collected on students performance including high performing district in Mathematics and Science Grade-4 Large Scale Assessment 2023 and furthermore

including regional representation of districts based on Large Scale Assessment results.

Muzaffargarh performed best in both science and Mathematics. Representation of south, North and central are added in the study.

Figure 9: LSA Grade 4 District Ranking Based on Students' Achievement of Science and Math .



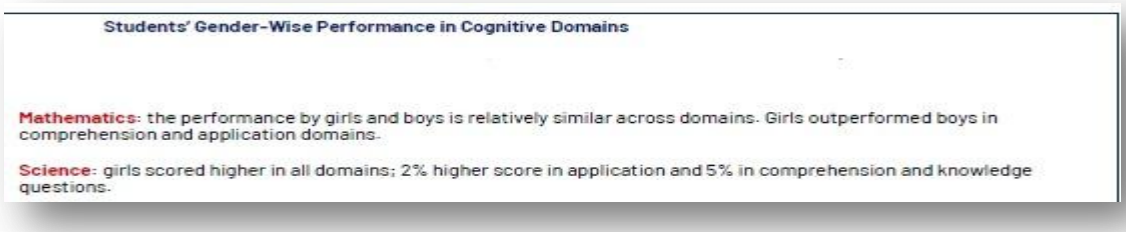


Figure 10. Higher order Critical Thinking Skills Inclusion through Assessment Policy Framework-SBA and Formative concluding improved learning in students.(PEC, 2023)

Quality Assurance parameters included the following:

- Ensuring alignment of tasks with academic calendar schedule for classroom observation.

- Teachers training on using items based on critical thinking, problem solving, and task oriented keeping in mind the process steps of classroom model serving as effective teaching modelling.
- The quality assurance was ensured by PEC team itself conducting the study and ensuring validity and reliability of the conduct under quality assurance parameters and protocols.
- Students interviews were also conducted after the conduct of the class on the aforementioned item. The interview was conducted by the expert subject person to qualitatively report on students learning experience based on specialized developed concept on higher order critical thinking aligned to STEM Education sustainable performance were investigated about.

Data Analysis

The data of the study had been analyzed using appropriate techniques relevant to the variable:

Descriptive Analysis is used to report on data collected from the teachers and students underlying the context of teachers' perception on effectiveness of specialized content techniques followed by specialized instructions and empirically supported feedback and feedforward mechanism in the classroom to implement STEM Education in early grade to promote and outreach standardized results as it aims for.

However, it is pertinent to mention that only significant results were added here for brief deliberation.

Findings

Given below are the STEM Integrated items related to Science and Math grade I/II. Please tick the most relevant.

Key:

SD = Strong Disagree = 1, D = Disagree = 2, N = Neutral = 3, A = Agree = 1, SA = Strong Agree = 5

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		Frequency	Percent	Valid Percent	Cumulative Percent	
Valid		53	46.5	46.5	46.5	
	1	6	5.3	5.3	51.8	The table is showing teachers' responses trend which has detailed deliberation with each response in upcoming tables.
	2	1	.9	.9	52.6	
	3	7	6.1	6.1	58.8	
	3,A	2	1.8	1.8	60.5	
	3.A	1	.9	.9	61.4	
	3A agree	1	.9	.9	62.3	
	4	1	.9	.9	63.2	
	5	22	19.3	19.3	82.5	
	A	4	3.5	3.5	86.0	
	A=1	1	.9	.9	86.8	
	Agree	4	3.5	3.5	90.4	
	N	1	.9	.9	91.2	
	ok	1	.9	.9	92.1	
	Sa	1	.9	.9	93.0	
	SA	1	.9	.9	93.9	
	Sd	1	.9	.9	94.7	
	SD	3	2.6	2.6	97.4	

I have been given training to teach through PBL/PSM.

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	Strong Agree:5	1	.9	.9	98.2	
	Strong agree=5	1	.9	.9	99.1	
	Strongly agree	1	.9	.9	100.0	
	Total	114	100.0	100.0		

The environment of our school is comfortable for students to learn through PBL/PSM for Science and Maths.

		Frequency	Percent	Valid Percent	Cumulative Percent	
Valid		3	2.6	2.6	2.6	Modern teaching techniques like **PBL/PSM** are considered appropriate teach Science and Mathematics as of 53.5 % by the relevant subject teachers.
	Agree	61	53.5	53.5	56.1	
	Disagree	9	7.9	7.9	64.0	
	Neutral	23	20.2	20.2	84.2	
	Strongly Agree	14	12.3	12.3	96.5	
	Strongly disagree	4	3.5	3.5	100.0	
	Total	114	100.0	100.0		

		Frequency	Percent	Valid Percent	Cumulative Percent	
Valid		5	4.4	4.4	4.4	A large number of teachers with 50.9 % are well aware pf PBL/PSM in the STEM Disciplines in particular Science and Maths.
	Agree	58	50.9	50.9	55.3	
	Disagree	21	18.4	18.4	73.7	
	Neutral	15	13.2	13.2	86.8	
	Strongly agree	8	7.0	7.0	93.9	
	Strongly disagree	7	6.1	6.1	100.0	
	Total	114	100.0	100.0		

I have been given training of Student Learning Outcomes (SLOs) related to teach in classroom.

		Frequency	Percent	Valid Percent	Cumulative Percent	
Valid		3	2.6	2.6	2.6	Teachers have received concept-based teaching in the classroom.
	Agree	69	60.5	60.5	63.2	
	Disagree	6	5.3	5.3	68.4	
	Neutral	9	7.9	7.9	76.3	
	Strongly agree	26	22.8	22.8	99.1	
	Strongly disagree	1	.9	.9	100.0	
	Total	114	100.0	100.0		

Students have interest in studying through observation method.

		Frequency	Percent	Valid Percent	Cumulative Percent	
Valid		3	2.6	2.6	2.6	Teachers reported that
	Agree	71	62.3	62.3	64.9	

	Disagree	1	.9	.9	65.8	students take more interest while involved through observation method especially in Science phenomenon.
	Neutral	7	6.1	6.1	71.9	
	Strongly Agree	29	25.4	25.4	97.4	
	Strongly disagree	3	2.6	2.6	100.0	
	Total	114	100.0	100.0		

Content of the textbook aligned with the STEM.

		Frequency	Percent	Valid Percent	Cumulative Percent	
Valid		3	2.6	2.6	2.6	Content of the texts books are aligned with the STEM Education as of reported by 67.5%
	Agree	77	67.5	67.5	70.2	
	Disagree	3	2.6	2.6	72.8	
	Neutral	12	10.5	10.5	83.3	
	Strongly Agree	19	16.7	16.7	100.0	
	Total	114	100.0	100.0		

Content of the textbook related to STEM is easy to understand.

		Frequency	Percent	Valid Percent	Cumulative Percent	
Valid		3	2.6	2.6	2.6	The content of the text books aligned with the STEM Education is easily understood.
	Agree	82	71.9	71.9	74.6	
	Disagree	7	6.1	6.1	80.7	
	Neutral	5	4.4	4.4	85.1	
	Strongly agree	17	14.9	14.9	100.0	
	Total	114	100.0	100.0		

Pictures in the textbook related to STEM are interesting.

		Frequency	Percent	Valid Percent	Cumulative Percent	
Valid		3	2.6	2.6	2.6	Illustration, graphical representations are comprehended easily and related to STEM Education.
	Agree	77	67.5	67.5	70.2	
	Disagree	4	3.5	3.5	73.7	
	Neutral	10	8.8	8.8	82.5	
	Strongly agree	20	17.5	17.5	100.0	
	Total	114	100.0	100.0		

I use feedback technique in my classroom every day.

		Frequency	Percent	Valid Percent	Cumulative Percent	
Valid		3	2.6	2.6	2.6	Teachers are providing feedback to students in the classroom every day which may support them to improve learning.
	Agree	81	71.1	71.1	73.7	
	Disagree	2	1.8	1.8	75.4	
	Neutral	8	7.0	7.0	82.5	
	Strongly agree	20	17.5	17.5	100.0	
	Total	114	100.0	100.0		

Students understand higher order and critical thinking question better through lecture method.

		Frequency	Percent	Valid Percent	Cumulative Percent	
Valid		5	4.4	4.4	4.4	Techniques like PBL/PSM etc are explicitly effective than lecture method.
	Agree	64	56.1	56.1	60.5	
	Disagree	11	9.6	9.6	70.2	
	Neutral	16	14.0	14.0	84.2	
	Strongly Agree	16	14.0	14.0	98.2	

	Strongly disagree	2	1.8	1.8	100.0	
	Total	114	100.0	100.0		

Inclusiveness of STEM and Formative Assessment techniques in classroom model is highly effective for my class.

		Frequency	Percent	Valid Percent	Cumulative Percent	
Valid		22	19.3	19.3	19.3	Trend showing teachers' priority on considering Formative Assessment Techniques serving highly effective for sustainable STEM Education.
	Option 1	92	80.7	80.7	100.0	
	Total	114	100.0	100.0		

Collaborative techniques of formative assessment assist in regular reinforcement to improve students performance on STEM framework.

		Frequency	Percent	Valid Percent	Cumulative Percent	
Valid		4	3.5	3.5	3.5	Teachers' support the notion of adaptation of collaborative techniques where formative assessment is
	Agree	75	65.8	65.8	69.3	
	Disagree	3	2.6	2.6	71.9	
	Neutral	20	17.5	17.5	89.5	
	Strongly Agree	11	9.6	9.6	99.1	
	Strongly disagree	1	.9	.9	100.0	

	Total	114	100.0	100.0		made part of daily classroom experiences for improved learning.

STEM and Formative Assessment Classroom model is highly effective for sustainable learning and improved 21st century skills.

		Frequency	Percent	Valid Percent	Cumulative Percent	
Valid		5	4.4	4.4	4.4	The Formative Assessment Classroom Model introduced and implemented through Formative Assessment Strategy in Punjab.
	Agree	73	64.0	64.0	68.4	
	Disagree	2	1.8	1.8	70.2	
	Neutral	13	11.4	11.4	81.6	
	Strongly agree	21	18.4	18.4	100.0	
	Total	114	100.0	100.0		

Feedback on supportive material to implement modern teaching techniques was also included and added at annexure-A. The trend shows the unavailability of modern teachers aid however, basic low cost AV Aids are available. Need is felt to equip schools with state-of-the-art teaching aids to implement 21st century skills learning experiences.

Students Interviews

- Male- Female students of both rural and urban strata were asked questions on the STEM Integrated items taught in specialized techniques to evaluate the level of understanding of concepts.

- As the study conducted keeping academic calendars activity, students in other sections taught same concept but with lecture method were also asked recap questions to evaluate learning sustainability.
- Students taken STEM Education were made part of the interview.
- Students conducted research study on Science Teaching were included in the study.

Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		1	1.1	1.1	1.1
	Female	46	51.1	51.1	52.2
	Male	43	47.8	47.8	100.0
	Total	90	100.0	100.0	

Area

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		2	2.2	2.2	2.2
	Rural	57	63.3	63.3	65.6
	Urban	31	34.4	34.4	100.0
	Total	90	100.0	100.0	

Type of school

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Elementry	41	45.6	45.6	45.6
	High	23	25.6	25.6	71.1
	Higher secondary	4	4.4	4.4	75.6
	Primary	22	24.4	24.4	100.0
	Total	90	100.0	100.0	

Students aptness to deliver understanding of the concept taught in specialized manner was comprehensive as compared to those taught through lecture method. However. Students learnt through lecture method couldn't perform as of treatment group.

Students were asked questions of science at the end of lecture method and responded correctly.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		2	2.2	2.2	2.2
	Agree	38	42.2	42.2	44.4
	Disagree	9	10.0	10.0	54.4
	Neutral	19	21.1	21.1	75.6
	Strongly agree	19	21.1	21.1	96.7
	Strongly disagree	3	3.3	3.3	100.0
	Total	90	100.0	100.0	

Students were asked questions about the items taught through formative assessment technique and were able to understand the concept. and reproduce knowledge after the teacher.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		1	1.1	1.1	1.1
	Agree	52	57.8	57.8	58.9
	Disagree	7	7.8	7.8	66.7
	Neutral	11	12.2	12.2	78.9
	Strongly agree	17	18.9	18.9	97.8

	Strongly disagree	2	2.2	2.2	100.0
	Total	90	100.0	100.0	

Students were taught higher order critical thinking concepts by the teacher and shown better reflection of the learning as compared to students taking routine lecture.

Students were asked questions of Math at the end of Problem-Solving method and responded correctly.

		Frequency	Percent	Valid Percent	Cumulative Percent	
Valid		1	1.1	1.1	1.1	Students displayed better understanding when problem solving method used in classroom learning and responded accurately on the concepts taught to them.
	Agree	48	53.3	53.3	54.4	
	Disagree	11	12.2	12.2	66.7	
	Neutral	14	15.6	15.6	82.2	
	Strongly agree	14	15.6	15.6	97.8	
	Strongly disagree	2	2.2	2.2	100.0	
	Total	90	100.0	100.0		

Students were displayed images/models of science during lecture. Enabled them to comprehend concept better.

		Frequency	Percent	Valid Percent	Cumulative Percent	
Valid		4	4.4	4.4	4.4	Trend shows use of teaching
	Agree	43	47.8	47.8	52.2	
	Disagree	5	5.6	5.6	57.8	

Students replied confidently while taught through feedback and feedforward method and shown clear concept comprehension.

	Neutral	13	14.4	14.4	72.2	supported
	Strongly agree	21	23.3	23.3	95.6	aids proved
	Strongly disagree	4	4.4	4.4	100.0	better in learning
	Total	90	100.0	100.0		experiences.

Students given answers on concepts of number and operation after learning through practical method.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		1	1.1	1.1	1.1
	Agree	46	51.1	51.1	52.2
	Disagree	7	7.8	7.8	60.0
	Neutral	10	11.1	11.1	71.1
	Strongly Agree	22	24.4	24.4	95.6
	Strongly disagree	4	4.4	4.4	100.0
	Total	90	100.0	100.0	

Concept of number and operation is starting from Grade I and is present till highest grades. Students performed explicitly better when general examples and problem-solving method was adopted as compared to lecture method.

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		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Agree	42	46.7	46.7	46.7
	Disagree	6	6.7	6.7	53.3
	Neutral	14	15.6	15.6	68.9
	Strongly agree	27	30.0	30.0	98.9
	Strongly disagree	1	1.1	1.1	100.0
	Total	90	100.0	100.0	

Qualitative evidence of STEM Integrated Items

Teachers were engaged in using Formative Assessment techniques and STEM Integrated items to teach in the class for feedback and feedforward which enables clarity of concepts and sustainable comprehension which was evident in students' conclusive answers session. Evidence of daily classroom tasks were also used in comparison to STEM Integrated Items.

Sample 1:

Illustration based items were used as these called to engage identification and classification which lead from basic to higher order thinking skills. In lecture method classroom teacher didn't even check students' work as every teacher doesn't invest in taking feedback during teaching in the classroom. In specialized class teacher followed given STEM Integrated Item, followed instructions and marked worked as of given rubrics. In concept ladder, student was given remedial on weak performing area which serve as improved and sustainable learning technique.

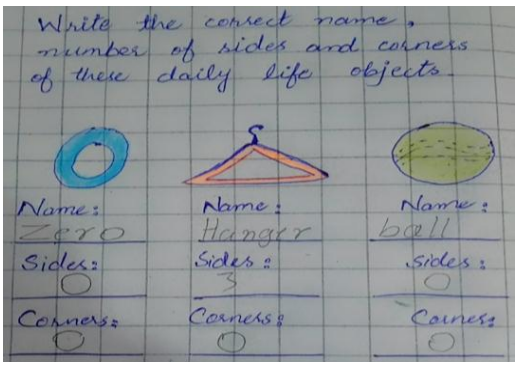

Figure 11. Lecture Method Classroom.

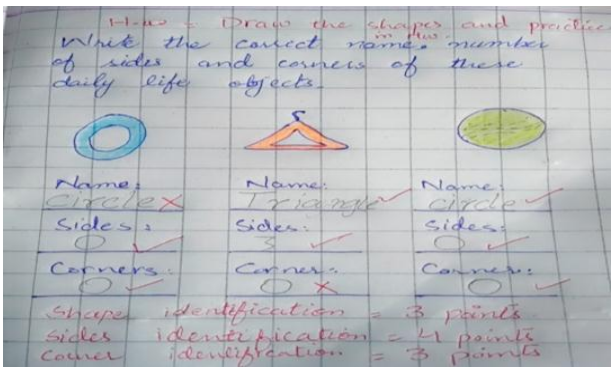

Figure 12. Stem Integrated Formative Assessment Classroom.

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Sample 2:

In lecture method classroom, classwork is checked where question of mathematics is solved through problem-solving method, but absence of feedback would lead to hinder learning the concept. In SIC (Stem Integrated Classroom) student is provided feedback on standardized rubrics.

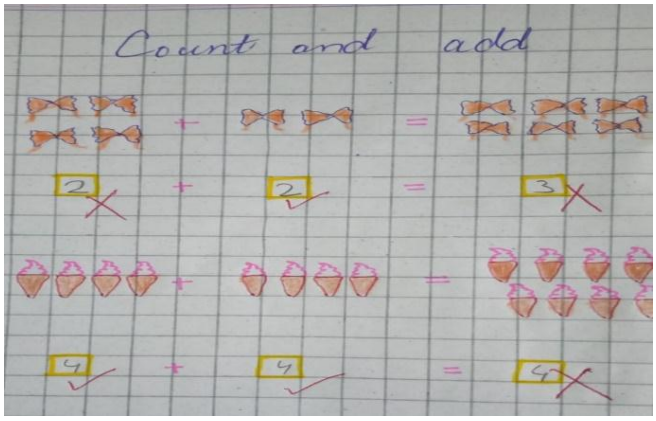

Figure 13. Lecture Method Classroom.

Figure 134. Stem Integrated Formative Assessment Classroom.

Sample 3:

Classification on animals based on their habitat is higher order critical thinking question. Teacher in Lecture method classroom just marked the response incorrect and didn't provide any feedback which may only add learning gap. However, in SIC (Stem Integrated Classroom using Formative Assessment teacher marked the response on provided standardized rubrics.

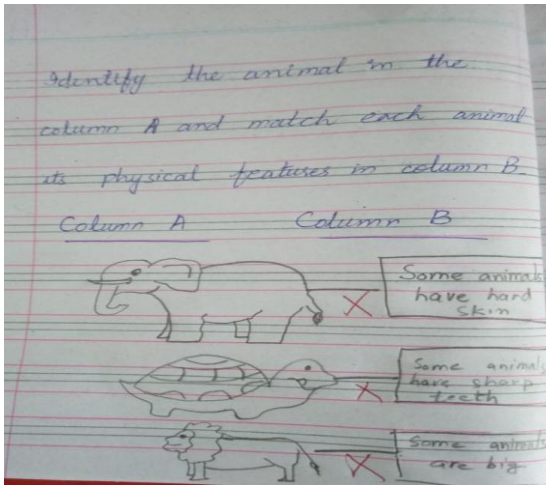

Figure 15. Lecture Method Classroom.

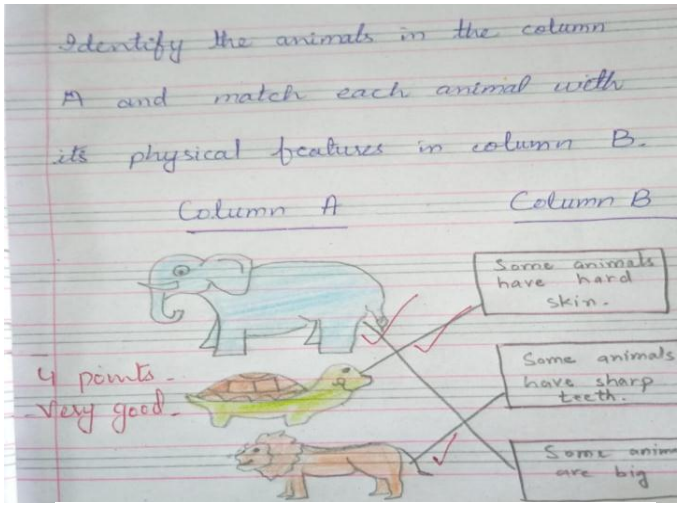

Figure 146. Stem Integrated Formative Assessment Classroom.

Practical Implications

The fact supporting the evidence lead on to the trend that teachers are well informed about the suitable teaching methodologies to teach Science and Mathematics and invest in their trust in Formative Assessment practice in classroom envision to lead critical thinking skills in the students and be able to perform better in diverse kind of assessment competitions.

Early years curriculum is developed to promote all the 21st century skills relevant to the development level and upgrading to higher education. Maths and Science curriculum supports the notion STEM Education aims for however the culminating factor is systematic implementation policy for sustainable learning.

Teachers do practice Formative Assessment in classroom, formal or informal manner, need is however felt for information technology integration to keep a track of the feedback and feedforward techniques adding upto students sustainable learning.

Teachers' professional development model on a large scale is part of Formative Assessment Strategy yet STEM Education need to integrate with PEC to build stable learning platforms where PEC in leading role id working with QAED for Formative Assessment Strategy Implementation.

TaRL is critical and raising a question on the implementation strategy of STEM Education aimed at initiating in HSS whereas the successful STEM Education models in Australia and America are promoting and initiated from early grades to ensure sustainable learning from foundation learning years.

STEM Education seems to revamp policy, principles and practices in local context respecting and addressing the challenges public schools face at large. Furthermore, the idea of selected schools venture may be effective as pilot project but does not ensure population based improved, sustainable and holistic improvement of Education system at large.

STEM Education Assessment Tools are in need to align with the curriculum driven percentages of all cognitive domains for fundamental concept learning leads on to higher order critical thinking skills which is focused learning area of STEM Education.

The allied departments in Punjab are working in collaboration and following many successful examples to work hand in hand to support implement STEM Education in Punjab. Successfully

implemented policy as of Assessment Framework provides ample opportunity to collaborate and support in diverse determinants of STEM Education.

Challenges and Limitation

This is an ongoing study and can be expanded with many diverse contextual variables to investigate in depth. We had discussed some emerging findings from Grade I and II in terms of grass root level prospect initiation of STEM Education for a holistic education improvement. The scope of the study can engage in future correlative concepts lineage among curriculum, textbooks, teachers' proficiency on STEM Subjects Teaching, role and impact of Formative Assessment Strategy involving academicians, experts from assessment field, training experts and stakeholders from the allied departments. Integrated curriculum approach involving modern assessment and teaching aids provision at large scale may ask for a user interface utility, data entry mechanism and utilization. Multigrade teaching is a challenge in this context.

Conclusion

Punjab is highly important in terms of nature of its educational reforms and implementations and had given many successful examples from Single National Curriculum (SNC) implementation, teachers professional training on the curriculum, textbooks development and conduct of assessment in all grades. Consequent upon the following strengths of Punjab and PEC Assessment Policy Framework 2019 will guide in constructing manner to upgrade STEM Education in Punjab.

The study is concluded with the following details:

1. The fundamental factor to uplift STEM Education 21st century skill set and sustainable learning is to make higher order critical thinking concepts a part of daily teaching and learning experiences of the students followed by evidence based feedback and feedforward techniques.
2. Practicing teachers of Mathematics and Science should involve in determining specialized instructions followed by standardized. rubrics to help implement effective teaching techniques.
3. STEM Education in collaboration with Formative Assessment Strategy can implement revamped policy, principles and practices in line with successful classroom and school models, roles and responsibilities of allied departments, implementation of framework

and quality assurance mechanism. The policy includes all the allied departments work together in their due diligence and mandate for curriculum development, textbooks development, teachers professional development and quality assessment to provide feedback to the system and stakeholders to lead on to empirical policy decision for sustainable learning.

4. The detrimental features Formative Assessment Strategy Punjab which can support STEM Education principles are as followed:
    - A Change Mechanism Process-System wise shift
    - Implementation Framework-Professional Development Programs (Short-Long Term)
    - Quality Assurance Monitoring Mechanism
5. Enabling user friendly access to the smart teaching material, low cost, no cost resources can be mitigated by integrating STEM Resources provision with Formative Assessment item bank already in development phase and will be available to all the teachers in the Punjab.

To conclude it can be mentioned that STEM Education is leading with a futuristic approach of 21st century skills improvement to help built a better nation outperforming in the fields of Science, Technology, Engineering and Mathematics. In previous years limited research studies which were more of descriptive nature identified downward trend in of STEM Education in Pakistan. The critique made part of this study provides ample evidence that importance of STEM education is undeniable to meet international standards, yet STEM Education is devoid of incorporating system level policy, principles and practices and in dire need to have improved and practical implementation steps for sustainable and impactful reforms at the granular level which are already internationally in practice in STEM System.

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