Modes of Engagement and Learner Roles While Doing Mathematics: A Study of Vigyan Pratibha Learning Units

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Abstract

Honey and Mumford refined Kolb's learning cycle and proposed four distinct learning styles in adult learning context. Our study evaluates the structural alignment of two mathematics learning units from the Vigyan Pratibha program with experiential learning modes derived from Honey & Mumford in a school-based learning context. Through a qualitative analysis of the learning units' architecture, we identified consistent opportunities for students to engage across the four modes of the experiential learning cycle (activist, reflector, theorist, and pragmatist). Furthermore, as an emerging, proof-of-concept finding, our analysis and facilitator accounts suggest two additional learner roles, "creator" and "co-constructor", that reflect mathematical participation and practice. To illustrate this structural analysis, the study incorporates facilitator narratives regarding student-task interactions, offering further insights into how student engagement corresponds to the identified learning modes. The findings indicate that this framework illustrates how co-curricular materials can intentionally design balanced opportunities for diverse forms of mathematical participation.

Keywords: *Co-curricular materials, learning styles, school learning*

1. Introduction

Experiential learning is seen as an evolving process wherein learners develop knowledge by participating in cycles of experience, reflection, conceptualisation, and experimentation. Building upon Kolb's (1984) foundational model, Honey and Mumford (1986) categorised these stages into four distinct learning styles - activist, reflector, theorist, and pragmatist - offering a behavioral perspective for comprehending individual approaches to learning tasks. Although their framework was initially intended for adult learners, current research has started to explore its applicability in school-based contexts, where students are still fostering metacognitive awareness and autonomy. This raises the crucial question of whether co-curricular instructional materials, especially in the field of mathematics education, can be designed to offer balanced opportunities for students to adopt different learning modalities and roles during mathematical activity, without presupposing that learners possess static, pre-determined learning styles.

Against this backdrop, the present study examines the Vigyan Pratibha (VP) program's mathematics learning units to evaluate their alignment with Honey and Mumford's experiential learning modes. The study aims to figure out whether co-curricular instructional materials can effectively scaffold diverse learning modalities by examining the pedagogical architecture of these

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units and incorporating facilitators' narratives. At a broader level the study seeks to address the following research questions:

RQ1: How do the Vigyan Pratibha mathematics learning units, when viewed as co-curricular materials, offer opportunities for students to engage in modes corresponding to Honey and Mumford's four learning styles?

RQ2: What emerging learner roles or forms of mathematical participation appear beyond the original four categories?

RQ3: How can insights from these mathematics learning units inform the design of co-curricular resources that promote student-centered learning in school contexts?

2. Conceptual Framework

This section explores the theoretical underpinnings that inform the study, referencing known theories of experiential learning and learning modes. Specifically, it discusses Kolb's Experiential Learning Cycle and Honey & Mumford's Learning Styles and explores their relevance for the design of co-curricular instructional materials at the school level.

Kolb's experiential learning cycle

Experiential learning is commonly described as the process through which knowledge is constructed by transforming experience (Kolb, 1984). This perspective perceives learning not as the simple collection of static information or a sequence of behavioral outcomes, but as a constantly evolving, malleable process in which ideas are continuously formed and reformed. The concept is centered around a four-stage cycle that requires learners to engage in four different kinds of processes. It shows how humans gather data from their surroundings and convert it into purposeful, higher order actions. The four interrelated stages of Kolb's (1984) cycle are:

Concrete Experience (CE): This phase entails engaging in immediate, present-moment personal experiences. To thrive in this stage, learners must engage completely, openly, and impartially in new experiences. This acts as the focal point for learning and offers the foundational facts for the remainder of the cycle.

Reflective Observation (RO): Following an experience, learners are required to step back to gather data, look at, and reflect the experience from various angles.

Abstract Conceptualisation (AC): In this stage, learners synthesise their reflections and observations to generate abstract concepts and coherent theories. Through this process, the observations are given meaning and a hypothesis for future action is formed.

Active Experimentation (AE): Lastly, students apply their developed ideas and concepts to solve problems and make decisions. They invariably create new tangible experiences by putting their ideas to the test in new settings, which repeats the cycle.

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Honey & Mumford learning styles

Building upon the foundational work of Kolb's cycle, Honey and Mumford (1986) transitioned the theoretical cycle into a behavioral framework. Acknowledging the broader critical debate concerning "learning styles" as fixed personal traits, we utilise Honey and Mumford's taxonomy not as an assessment of innate learner traits, but as an analytical lens for categorising distinct pedagogical modes of engagement and learner roles afforded by curriculum design:

• *Activist* engagement involves immediate, direct immersion in novelty, hands-on trial, and intuitive exploration (e.g., actively sketching paths, manipulating physical or visual models).

• *Reflector* engagement entails pausing to observe, compare multiple representations or solutions, and examine variations from different angles before drawing conclusions.

• *Theorist* engagement involves integrating observations into logical structures, identifying overarching rules, formulating conjectures, and abstracting general mathematical principles or formal statements.

• *Pragmatist* engagement is distinguished from mere decorative context: it entails applying mathematical ideas to solve concrete problems, testing whether an abstract rule or strategy works in practical application, or using real-world constraints to validate a mathematical method.

Learning modes for the design of instructional material

Kolb's (1984) experiential learning cycle was conceptualised as a universal framework for all learners, while Honey and Mumford's (1986) learning styles model was explicitly tailored for adult learners. The latter argues that only a minority of learners use all four styles for learning, whereas the majority have the potential to apply all four but lack the opportunity to do so (Honey and Mumford, 1986). Limited research has explored the connection between the instructional design of learning materials and individual learning styles (Bearneza, 2023; McLoughlin, 1999). The majority of the learning styles studies based on Honey & Mumford pertain to adult learning contexts (Aljaberi, 2015; Woolhouse & Blaire, 2003) with some focused on school-based learning contexts (Krisyani et al., 2024; Liline et al., 2026). Adult learning contexts, where the majority of current research has been undertaken, generally presuppose higher metacognitive awareness, increased autonomy in pace of learning, and more consistent domain specific motivation. In contrast, school-based learners are frequently engaged in the development of these competencies.

In this scenario, can we employ Honey & Mumford's (1986) learning modes as a framework for developing co-curricular instructional materials at the school-level? Although the learning modes were developed for adult learning, their behavioral orientation offers a useful perspective for school-based contexts, where learners are still developing these competencies and benefit from structured opportunities to engage in diverse learning modalities. Thus, employing this framework in co-curricular instructional materials at the school level can act as a scaffold to foster balanced learning methodologies.

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3. Methods

Context: The Vigyan Pratibha (VP) project is a national-level initiative which aims to foster inclusive spaces in Indian schools where students of diverse abilities and underserved backgrounds can explore science and mathematics. It develops evolving, high-quality resources for classes 8-10, developed collaboratively by science and mathematics educators. These resources nurture observation, analysis, critical thinking, and collective learning, while inspiring excitement and deep understanding of the subjects. The project is structured around Learning Units (LUs), which are mostly curriculum-linked activities designed for teachers to engage interested students in exploring science and mathematics beyond textbooks. Each LU has two versions: Student Version (SV) and Teacher Version (TV). TV contains additional pedagogical notes (for teachers) along with the content of the SV to support the facilitation. In our context, we are considering both students and teachers as learners. The consideration of teachers as learners is primarily because they first try out the LUs as learners in VP workshops, and the TV also guides them in facilitation.

For our study, we have chosen two mathematics LUs:

1) Finding The Right Path [Finding-the-right-path] - The LU is aimed at exploring using graphs, switching between different representations for the same problem, to gain experience in forming conjectures, testing with examples and counterexamples, and developing foundational knowledge of concepts and techniques in graph theory.

2) Mathematical Neighbours [Mathematical Neighbours] - This LU is aimed at motivating students about the “Four Color Theorem” through puzzles, introduces a new way of representing maps, and explores the technique of node colouring. It enables students to represent problems mathematically using graphs and the concepts of colouring.

The LUs were not written by considering learning styles/modes frameworks. We coded instances in the LUs which give opportunities for students to experience the four learning modes. Our unit of analysis was theme blocks, defined as a coherent pedagogical episode or task prompt in the text (such as an introductory scenario, an investigative prompt, or a synthesis question) designed around a specific mathematical action. Both authors participated in the coding process using the operational definitions of the engagement modes and confirmed consensus on the finalised version. There were instances in which multiple modes of engagement were observed and systematically documented.

We also interviewed two facilitators, one of whom is a co-author of both LUs and has conducted and observed both LUs. The other, a teacher who conducted Mathematical Neighbours at her school. Transcripts were analysed thematically to identify how facilitators observed student engagement interacting with the designed tasks, serving as supporting illustrative evidence. The facilitator discussions highlighted broader pedagogical affordances within the Vigyan Pratibha ecosystem, extending across multiple LUs.

4. Results and Discussion

The following tables provide a structured analysis of the alignment between the two Vigyan Pratibha mathematics learning units and Honey and Mumford’s four learning modes. They present

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empirical evidence that the units are effectively integrated with opportunities for diverse learner engagement. Only selected instances from the broader analysis are presented in the tables.

Table 1 highlights tasks, including sketching paths in the Konigsberg Bridge problem and experimenting with Network Diagrams. These instances immerse learners into new experiences, confirming that the LUs encourage active exploration and ensure novelty. Presentation of mathematics through stories and the mode of problem posing in these LUs can stimulate curiosity and engagement.

Activists		
Learning Unit	**Section/Task (Page)**	**Pedagogical Instances**
Finding The Right Path	Page No. 1-2	Using history connection (Konigsberg Bridge Problem) to bring out the idea of paths; presentation of mathematics as a story; encourage the learners to sketch the possible paths.
Finding The Right Path	Page No. 5	Guiding the learners to trace the graph from different starting points; introduction to the concept of graphs and related terminologies (vertices, edges, degree, etc.)
Mathematical Neighbours	Page No. 3	Introduction to the concepts like Network Diagram, nodes, and links; explaining how to draw a Network Diagram.
Mathematical Neighbours	Page No. 12	Posing a question to find (if possible) Network Diagrams where it is impossible to draw it without the links crossing each other; determine the number of colours needed to colour the Network Diagram.

Table 1: Instances Where Students Can Take the Role of Activists

Table 2 shows opportunities for reflective practice, including the comparison of solutions and analysing differences between tasks. Such activities prompt learners to pause, observe, and critically evaluate multiple perspectives. The deliberate integration of structured reflection within the units affirms the pedagogical design as a supportive for deeper metacognitive engagement.

Reflectors		
Learning Unit	**Page Number(s)**	**Pedagogical Instances**
Finding The Right Path	Page No. 3	Comparison of learners present solutions

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		with the case of Konigsberg Bridges; reflecting on whether the factors (width, distances) of bridges matter; discussion on whether a simpler drawing makes it easier to work with the problem.
Finding The Right Path	Page No. 9-10	Observation of the relationship between 'position' and 'degree' of the node in the path; connecting the learners' ideas with concepts in graph theory (Eulerian path and Eulerian cycle)
Mathematical Neighbours	Page No. 2	Comparison of tasks (1A, 1B, and 1C) to see if there is any difference between them; Follow up by asking if they could draw the maps of all the tasks and prompting the discussion of their results with other learners.
Mathematical Neighbours	Page No. 13	Asking the learners to think and describe a Network Diagram which will require 10 colours to colour it.

Table 2: Instances Where Students Can Take the Role of Reflectors

Table 3 illustrates opportunities for pragmatist engagement. Rather than treating realistic narratives as mere background framing, these tasks invite students to test and apply mathematical representations under authentic or simulated constraints (e.g., using network properties to solve historical bridge traversal problems or applying coloring rules to practical map-partitioning problems). We recognise that narrative context alone does not constitute pragmatist engagement unless students actively apply mathematical models to negotiate concrete problem constraints.

Pragmatists		
Learning Unit	**Section/Task (Page)**	**Pedagogical Instances**
Finding The Right Path	Page No. 1	Connecting it with a real world scenario of Konigsberg bridges.
Finding The Right Path	Page No. 10	Inclusion of a realistic context (and using a diagram), where Euler and the citizens of Konigsberg attempted to solve the problem.
Mathematical Neighbours	Page No. 1	Creating a context of the king and his children where the kingdom has to be divided among the children upon some conditions.

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Mathematical Neighbours	Page No. 12-13	Mentioned the real life examples of images on a 2-D surface (such as maps).

Table 3: Instances Where Students Can Take the Role of Pragmatists

Table 4 illustrates instances in which learners can formulate conjectures/statements and connect them to established principles of graph theory. This process highlights the LUs' capacity to promote abstraction and synthesis, guiding students beyond specific examples toward the development of generalisable theories. It also points to the incorporation of higher-order cognitive processes within the instructional design.

Theorists		
Learning Unit	**Section/Task (Page)**	**Pedagogical Instances**
Finding The Right Path	Page No. 7	Making statements of learners' conjectures.
Finding The Right Path	Page No. 9-10	Mapping the learners' ideas/patterns to the theoretical statement that "conditions for a connected graph to have a Eulerian path is that the graph must have exactly two vertices whose degree is odd".
Mathematical Neighbours	Page No. 11-12	Opportunity for learners to come up with a statement similar to Four Color Theorem.
Mathematical Neighbours	Page No. 14	Mapping the learners' ideas/patterns to the theoretical concept that "every planar Network Diagram can be coloured using four or less colours such that no adjacent nodes have the same colour".

Table 4: Instances Where Students Can Take the Role of Theorists

Mathematical thinking is a dynamic process that enhances the ability to comprehend increasingly complex ideas, thereby broadening our understanding (Stacey et al., 1982). Stacey et al. (1982) offer a structured framework for developing mathematical thinking by focusing on the processes of specialising, generalising, conjecturing, and convincing. A challenge, a surprise, a contradiction, or a perceived gap in understanding provokes mathematical thinking. These instances can help students to adopt the role of "creator". Follow-up interviews with the facilitators identified some instances that resonate with this in another LU related to Patterns in Square Numbers [Patterns in square numbers]:

F1: *I keep on saying that 'Ulta L' [upside down L, Figure 1], I mean, that will stay with me. That was the first time I had taken that session and then the kid said that a*

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number, a number next to it and it's square, if you add, you get the square of the next number and when the kid said it, I was shocked.

Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Square	1	4	9	16	25	36	49	64	81	100	121	144	169	196	225	256	289	324	361	400

Figure 1: An Example of 'Ulta L' Pattern, Where A Number (2), Its Next Number (3), and Its Square (4) Will Give the Square of the Next Number (9)

In our context, we frame 'creator' not as a stand-alone, rigid learning style, but as an emerging learner role or mathematical practice wherein the student generates original representations, sub-problems, or unexpected structural conjectures (such as the student-generated 'Ulta L' pattern in Figure 1).

The concept of co-construction emerges from social constructivism and sociocultural theory. It emphasises the collaborative engagement between facilitators and students and among students in the learning process. But, how can this collaboration be ensured in a classroom? One of the ways is to incorporate tasks which need collaboration and co-construction to move ahead. Thus, considering "co-constructor" as a learning mode and including tasks that promote it in the instructional materials can enrich students' interactions and learning. Presence of such tasks in another VP learning unit [Is-your-polygon-the-same-as-mine] has been mentioned by the facilitator in the following narrative:

> *F1:* *So, is your polygon the same as mine?, is a learning unit where what you do is… you divide into 6 groups. And so, you do all these combinations of angles and sides, each of them [each group does a different set of drawings of triangles]… And all of the 6 have to come together to get all the tests of congruence for triangles. So, each of them is not enough. So, as one group can say, AAA is not a test of convergence. One group can say SAS is a test of congruence. But to get the entire list, they have to work together and kind of. So, that I would say as it is a co-construction, where the unit itself forces co-construction on you [learners].*

Rather than asserting that "creator" and "co-constructor" constitute distinct, fixed learning styles parallel to the original Honey and Mumford dimensions, we interpret them as proof-of-concept participatory roles: forms of mathematical practice that are not comfortably subsumed under individual processing categories.

The facilitators' narratives also highlighted the alignment of the LUs with the four learning modes. One facilitator, who was also a co-author, pointed out that students' role as reflectors helped improve the content of the LUs. For example, the initial draft of Mathematical Neighbours began with a task involving five kingdoms, but a student's question – '*What is so special about five?'* - prompted the authors to reflect on and revise their writing of the LU. She emphasised that the units provide opportunities that encourage the '*tenacity of trying and questioning'*. She also mentioned

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that '*one of the things that is always in the forefront of some of us writing things [LUs] was the framework of mathematical processes*'.

The teacher facilitator pointed out that students were primarily taking on the roles of activists and reflectors. She also observed that "*those who do not perform well or do not show interest in the class were showing more interest in that learning unit and were able to answer the questions that we have*". She added:

> *F2: So, they [students] are thinking that we are all at the same pace. Nobody is intelligent here. We can also answer. They are getting that confidence.*

This may be due to the minimal prerequisites required for the learning units, which another facilitator also noted, emphasising that "*mathematical knowledge needed for these LUs is minimal*". She also distinguished between "mathematical knowledge" and "mathematical understanding".

The facilitator narratives provided illustrative support for how these task opportunities unfold dynamically in classroom settings. While these reflections cannot formally validate student psychological modes, they provide qualitative accounts indicating that students actively engaged across diverse modes and took on ownership when tasks lowered formal prerequisite barriers.

Although we distinguish between different engagement modes, we recognise that they are interdependent and frequently overlap during authentic mathematical inquiry. Rather than establishing a revised six-style theoretical model or confirming student learning effectiveness, this study offers an exploratory proof-of-concept demonstrating how co-curricular materials can design structured opportunities for diverse learner roles. More such research needs to be conducted by considering all LUs and exploring their interconnections, so as to establish a comprehensive model that enhances pedagogical effectiveness and supports diverse learner needs.

5. Declarations

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Ethics Approval

The work has received institutional ethical review board approval (IRB office/2024/OR/16).

Responsible Use of AI

All research, analysis, and writing in this paper were conducted by the author(s) without the assistance of artificial intelligence tools.

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Competing Interests

The authors declare no competing interests.

Authors' Contributions

Author 1 conceptualised the study, curated the data, performed the formal analysis and investigation, developed the methodology, conducted the visualisation, and wrote the original draft. Author 1 also reviewed and edited the manuscript. Author 2 curated the data, performed the formal analysis and investigation, conducted the visualisation, and reviewed and edited the manuscript.

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