Title	iSTEM classroom observation protocol version 5.3
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Integrated STEM Classroom Observation Protocol (iSTEM protocol) version 5.3

Information for Protocol Users

Context of Protocol Use

The iSTEM protocol is designed for use in primary and secondary STEM classrooms for analysing: (a) the extents to which students demonstrate **P**roductive **I**nterdisciplinary **E**ngagement (**PIE**) while solving a STEM problem and (b) the extents to which design principles for fostering students' PIE–problematizing, resources, accountability, and authority–were present in the learning environment i.e., **enacted** during observed lesson.

A STEM activity or unit of work may include several STEM lessons. Complete one set of iSTEM protocol for each STEM lesson observed.

Suitable STEM Activities for Observation

Any STEM unit of work observed using the iSTEM protocol should have the aim of students **designing a solution to a real-life STEM problem**. Students generally follow engineering design, design thinking, science inquiry and/or computational thinking approaches, and draw upon conceptual knowledge, procedural skills/methods, and/or practices in at least one other STEM discipline to solve the problem.

A STEM unit of work should broadly comprise 3 **STEM phases**: Problem Definition, Research, and Development. Each STEM phase comprises various **STEM tasks**. A STEM lesson could also open with a **Recap** of the previous lesson and close with **Reflection** of the overall STEM lesson/activity.
Thus, a STEM lesson could include the following **Lesson Features:** Recap, Problem Definition, Research, Development, and Reflection. Any lesson feature could be repeated and may not appear in the above listed sequence.

How to Use the Protocol

The protocol comprises 4 parts.

Parts	To Do
README: commonly used terms, STEM Task definitions, and Design Principles descriptions	Read the definitions and descriptions before the lesson observation. Be familiar with what the STEM phases and tasks refer to and what observation notes to take.
Part A: Overview of Observed STEM Lesson	Fill in during Lesson Observation. Fill in Table 1 at the end of the observation. Ensure the sequence of lesson features and STEM tasks correspond to sequence of tables in Part B.
Part B: Observation Notes	Fill in during Lesson Observation. Copy and insert a new table for each Lesson Feature as needed e.g., when Lesson Feature is repeated, STEM Tasks in a Lesson Feature are non-concurrent.
Part C: Design Principles	Give ratings after lesson observation. Cite evidence from Part B: Observation notes.
Part D: Productive Interdisciplinary Engagement	Give ratings after lesson observation. Cite evidence from Part B: Observation notes.

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README (read before Lesson Observation)

Descriptions of Commonly Used Terms

Term	Definition / Examples
STEM problem	The STEM problem could be presented as a problem to be solved, a challenge to overcome, or a product to be produced (either in a concrete, physical form or as a drawing or other mode of representation) by the end of the STEM activity or unit of work.
Success criteria for final solution	What the final solution to the STEM problem needs to fulfil or be able to do (i.e., its function) to be considered successful.
Constraints of final solution	Limitations on the final solution that restrict the possible solutions e.g., types and amount of materials to use, size of solution.
Sound disciplinary concepts:	Examples: mathematically or scientifically accurate concepts/facts.
Disciplinary practices/ways of thinking and doing (WOTD)	Practices valued by disciplinary communities. Examples of scientific practices: Asking questions, planning and carrying out investigation, analysing and interpreting data, modelling, constructing explanations, argumentation, obtaining, evaluating and communicating information Examples of technological practices: Design thinking, sketching, woodwork/metalwork, prototyping, weighing impacts of technology on society and the environment Examples of engineering practices: Defining problems, determining/defining success criteria and constraints, brainstorming for solutions, evaluating existing responses/solutions to problem, weighing tradeoffs and optimizing solution, making, testing (including the use of digital analysis tools/simulations to test design), iteratively redesign solution, communicating ideas to clients. Examples of mathematical practices: Making sense of the problem, modelling the problem using appropriate mathematical concepts and tools, looking for patterns and mathematical structures, reasoning abstractly and quantitatively, persevering in solving problems, using appropriate tools strategically to solve problems, attending to accuracy and precision, applying computational thinking to simulate scenarios and solve problems, constructing and critiquing mathematical arguments, representing and communicating mathematical ideas and solutions. References for disciplinary practices: American Association for the Advancement of Science (AAAS) (1993). *The nature of technology*. Project 2061: Benchmarks for Science Literacy. The nature of technology. http://www.project2061.org/publications/bsl/online/index.php?chapter=3 National Governors Association Center for Best Practices & Council of Chief State School Officers. (2010). *Common Core State Standards for Mathematics.* https://learning.ccsso.org/wp-content/uploads/2022/11/ADA-Compliant-Math-Standards.pdf. NGSS Lead States. (2013). *Next Generation Science Standards*: For States, By States. https://www.nextgenscience.org/.

STEM Task Definitions

* Lesson Feature	^STEM Task Definition
Recap	Recap of previous STEM lesson where **previously known/shared ideas are repeated** to class.
STEM Phase: Problem Definition	(i) **Context**: Introduce context that gives rise to STEM problem e.g. background of problem including who, where, when, etc. (ii) **Problem**: Identify or state the STEM problem/challenge within the given context that students are required to solve. May include statement or identification of success criteria or solution constraints to be fulfilled by the final STEM solution.
STEM Phase: Research	Gather information and/or empirical data to inform solution design. May include: (i) **Search** • Search for existing information in online sources, given texts, etc. • Search for and/or evaluate existing responses (i.e., current products) or possible solutions to problem. (ii) **Investigate** Gather empirical data to inform solution, such as: • Gather information from potential users to understand/specific problems pertinent to users (e.g,. through interviews, surveys). • Carry out investigations using control of variables (COV) approach or utilise given data to identify relationships among factors [Scientific inquiry].
STEM Phase: Development	Development of solution to STEM problem. May include: (i) **Generate** • Describe (e.g., list of requirements or specifications) and/or create a visual representation (e.g. drawing, diagram, flowchart) of possible solution(s) [Technology/Design]. • Scaling and optimisation to determine resources required, size of product etc. [Mathematics]. • Includes iterative re-generation of ideas. (ii) **Concretize/Make** • Create or revise a design, model, prototype or other product (physical or computer-based) that can be tested [Technology]. • Includes iterative re-concretize/re-make. (iii) **Test** • Put design, prototype, model, or other product to tests and analyse data from tests to evaluate whether the success criteria of the final STEM solution are met. Testing of design could utilise digital analysis tools such as simulations. Testing may also involve potential users. (iv) **Feedback** • Present design solution (including final STEM solution) to other peers (not involved in one's solution design) or whole class for feedback • Reflect on recommended changes or improvements to design solution. • May occur after any other task.
Reflection	Summary of lesson or STEM activity; reflection on what is learnt from lesson or STEM activity.

PIE Design Principles and Outcomes Descriptions

Design Principles	**Detailed Description**	**Observation Notes to Take (where observed)**
Problematizing	*Extent to which the STEM learning experience is meaningful for students and STEM communities.* This is based on the STEM learning experience presented to students within the observed lesson.	The STEM learning experience, including the STEM problem and its context, where relevant.
Resources	*Extent to which resources are provided to support students in solving the STEM problem*. Resources include: 1) **Material resources** (e.g., information sources/readings; physical materials; tools) to complete STEM task. These include: • **Materials**: e.g., hyperlinks to information sources, readings, videos etc. on context or problem • **Tools**: instruments for measurements or making product; apparatus for carrying out investigations; personal learning devices for making sketches. 2) Students are provided **support from teacher** (or other adults) **or written scaffold** in worksheet (e.g. instructions or template for steps/procedures) to complete STEM task. Support can be in the form of: • Teacher does part of STEM task for student or demonstrates procedures/steps • Teacher gives verbal or written instruction on how to complete part of STEM task (e.g. certain procedures/steps) without showing how it is done • Verbal or written options for how to proceed with or complete part of the STEM task but students are not told what to do or choose • Structured worksheet e.g. to record engineering design processes (e.g. Ask, Plan, Create, Test, Improve).	**What and how** materials, tools, or form of support are given to students. Note down if it is observed that students are given resources but do not use them.
Authority	*Extent to which students are given epistemic authority to construct the final solution to the STEM problem.* This depends on: • Opportunities for students to propose own ideas for STEM task. • How teacher follows-up on students' reported ideas. • How success criteria/solution requirements for evaluating final solution to STEM problem are decided	**What happens after a student proposes an idea** related to the STEM task at hand or solution to STEM problem: **who says what** • Include examples of **critique instances: who says what** What **success criteria**/constraints and **how they come about**. An instance = talk around a decision to be made for the STEM task at hand or contributes to solution of STEM problem. An instance begins when a new decision is being discussed and ends when a decision is reached (including agreement to postpone decision-making or agree to disagree)
Accountability	*Extent to which students' ideas and actions are held accountable to STEM disciplinary concepts, ways of thinking and doing (WOTD) and norms, by self and others (peers, teacher).* This depends on: • Who critiques students' ideas put forward during STEM task. • Nature of critique (verbal, written or checklist): based on STEM disciplinary concepts or WOTD, request for evidence/reasoning, or practical reasons (e.g., easy to do; someone knows how to) • Nature of success criteria or constraints for the final solution to the STEM problem.	
Outcomes	**Description**	**Observation Notes to Take**
Productive Interdisciplinarity Engagement	*Extent to which students are cognitively engaged in group-based interdisciplinary decision-making to progress towards a final solution to the STEM problem.*	**How decisions** related to the STEM task at hand or solution to the STEM problem **are reached by the group,** including how groups **justify their decisions**.

Part A: Overview of Observed STEM Lesson

School: _____ Level / Stream or band: _____ Class: _____ No. of students: _____ Teacher(s): _____

STEM lesson topic _____ Lesson no. (e.g. 1) _____ Date: _____ Time: _____

Table 1. Fill in sequence of lesson feature and STEM tasks for observed lesson. Insert columns as needed.

Time	E.g. 0815 – 0845						
***Lesson Feature** – ^concurrent Task(s)	Problem definition – Context & Problem						

Observer's Notes on Overall Alignment

Alignment between	Response (Please check)	Elaboration (highlight what is problematic and/or how to improve)
(i) Lesson objectives and overall STEM problem Whether lesson objectives (achieved by the end of the observed lesson) directly contribute to solving the overall STEM problem.	☐ Yes ☐ No	
(ii) STEM Tasks and lesson objectives Whether STEM tasks implemented in the observed lesson are aligned and logically connected to the lesson objectives.	☐ Yes ☐ No	

Part B: Observation Notes **[Note: Insert table for respective Lesson Feature as needed]**

Lesson Feature	**Recap**	**Start time:**		**End time:**	

STEM Task (check all boxes that apply):

☐**Context**: Introduce context that gives rise to STEM problem e.g., background of problem including who, where, when etc.

☐**Problem:** Identify or state a problem/challenge within the given context that students are required to solve. May include statement or identification of success criteria or constraints.

☐**Research**: Gather information and/or empirical data to inform solution. May include search and/or investigate

☐**Development**: Development of solution to STEM problem. May include generate, concretize/make, test, and/or feedback.

Instructional Activity (check all boxes that apply) **Seat work involves documentation of ideas/responses e.g. with worksheet*

☐Class: teacher instruction
☐Class: discussion/critique
☐Class: group presentation
☐Inter-group: discussion/critique
☐Group: members-only discussion
☐Group: teacher-involved discussion
☐Group: hands-on
☐Group: seat work*
☐Individual: hands-on
☐Individual: seat work*

Lesson Observation Notes

- Persons involved: Teacher (tr). Students (ss) or (S1, S2, S3…) if distinguishable. • Content of action and speech, including questioning and responses.

Include descriptions of the following. Highlight parts of notes that serve as evidence for each design principle (according to assigned colour).

- Context and nature of STEM problem **(Problematizing)**
- Materials provided, if any **(Resources)**
- Success criteria and how they came about, if any **(Accountability)**
- What happens after students propose an idea related to the STEM task or solution to STEM problem; who says what **(Authority)**
    - Include examples of critique instances **(Accountability)**. Critique may be verbal, written, or a checklist.

Problematizing

Resources

Authority

Accountability

Lesson Feature	**STEM Phase 1: Problem Definition**	**Start time:**		**End time:**	

STEM Task (check all boxes that apply):

☐ **Context**: Introduce context that gives rise to STEM problem e.g. background of problem including who, where, when etc.

☐ **Problem:** Identify or state a problem/challenge within the given context that students are required to solve. May include statement or identification of success criteria or constraints.

Instructional Activity (check all boxes that apply)

☐Class: teacher instruction
☐Class: discussion/critique
☐Class: group presentation
☐Inter-group: discussion/critique

**Seat work involves documentation of ideas/responses e.g. with worksheet*

☐Group: members-only discussion
☐Group: teacher-involved discussion
☐Group: hands-on
☐Group: seat work
☐Individual: hands-on
☐Individual: seat work

Lesson Observation Notes

- Persons involved: Teacher (tr). Students (ss) or (S1, S2, S3…) if distinguishable. • Content of action and speech, including questioning and responses.

Include descriptions of the following. Highlight parts of notes that serve as evidence for each design principle (according to assigned colour).

- Context and nature of STEM problem **(Problematizing)**
- Materials provided, if any **(Resources)**
- Success criteria and how they came about, if any **(Accountability)**
- What happens after students propose an idea related to the STEM task or solution to STEM problem; who says what **(Authority)**
  - Include examples of critique instances **(Accountability)**. Critique may be verbal, written, or a checklist.
- How students discuss and make decisions; what issues were encountered; what decisions are reached **(PIE)**

Problematizing **Resources** **Authority** **Accountability**	**PIE [Record Group Talk]**

Lesson Feature	**STEM Phase 2: Research**	**Start time:**		**End time:**	

Concurrent STEM Tasks (check all boxes that apply) **[Note: Insert new Research table if tasks are non-concurrent]**

☐ **Search**

- Search for existing information in online sources, given texts, etc.
- Search for and/or evaluate existing responses to problem.

☐ **Investigate**

Gather empirical data to inform solution, such as:

- Gather information from potential users to understand/specific problems pertinent to users (e.g. through interviews, surveys).
- Carry out investigations using control of variables (COV) approach or utilise given data to identify relationships among factors [Scientific inquiry].

Instructional Activity (check all boxes that apply)

**Seat work involves documentation of ideas/responses e.g. with worksheet*

☐Class: teacher instruction
☐Class: discussion/critique
☐Class: group presentation
☐Inter-group: discussion/critique
☐Group: members-only discussion
☐Group: teacher-involved discussion
☐Group: hands-on
☐Group: seat work
☐Individual: hands-on
☐Individual: seat work

Lesson Observation Notes

• Persons involved: Teacher (tr). Students (ss) or (S1, S2, S3…) if distinguishable. • Content of action and speech, including questioning and responses.

Include descriptions of the following. Highlight parts of notes that serve as evidence for each design principle (according to assigned colour).

- Context and nature of STEM problem **(Problematizing)**
- Materials provided, if any **(Resources)**
- Success criteria and how they came about, if any **(Accountability)**
- What happens after students propose an idea related to the STEM task or solution to STEM problem; who says what **(Authority)**
  - Include examples of critique instances **(Accountability)**. Critique may be verbal, written, or a checklist.
- How students discuss and make decisions; what issues were encountered; what decisions are reached **(PIE)**

Problematizing **Resources** **Authority** **Accountability**	**PIE [Record Group Talk]**

Lesson Feature	**STEM Phase 3: Development**	**Start time:**		**End time:**	

Concurrent STEM Tasks (check all boxes that apply) **[Note: Insert new Development table if tasks are non-concurrent]**

☐ **Generate (includes iterative re-generation of ideas)**

- Describe (e.g., list of requirements or specifications) and/or create a visual representation (e.g. drawing, diagram, flowchart) of possible solutions [Technology/Design].
- Scaling and optimisation to determine resources required, size of product etc. [Mathematics].

☐ **Concretize/Make (includes iterative re-concretize/re-make)**

- Create or revise a design, model, prototype or other product (physical or computer-based) that can be tested [Technology].

☐**Test (includes iterative re-test)**

- Put design, prototype, model, or other product to tests and analyse data from tests to evaluate whether the success criteria/constraints. are met. Testing of design could utilise digital analysis tools such as simulations. Testing may also involve potential users.

☐ **Feedback**

- Present design solution (including final solution) to other peers (not involved in one's solution design) or whole class for feedback
- Reflect on recommended changes or improvements to design solution.

Instructional Activity (check all boxes that apply)

**Seat work involves documentation of ideas/responses e.g. with worksheet*

☐Class: teacher instruction
☐Class: discussion/critique
☐Class: group presentation
☐Inter-group: discussion/critique
☐Group: members-only discussion
☐Group: teacher-involved discussion
☐Group: hands-on
☐Group: seat work
☐Individual: hands-on
☐Individual: seat work

Lesson Observation Notes

• Persons involved: Teacher (tr). Students (ss) or (S1, S2, S3…) if distinguishable. • Content of action and speech, including questioning and responses.

Include descriptions of the following. Highlight parts of notes that serve as evidence for each design principle (according to assigned colour).

- Context and nature of STEM problem **(Problematizing)**
- Materials provided, if any **(Resources)**
- Success criteria and how they came about, if any **(Accountability)**
- What happens after students propose an idea related to the STEM task or solution to STEM problem; who says what **(Authority)**
  - Include examples of critique instances **(Accountability)**. Critique may be verbal, written, or a checklist.
- How students discuss and make decisions; what issues were encountered; what decisions are reached **(PIE)**

Problematizing **Resources** **Authority** **Accountability**	**PIE [Record Group Talk]**

Lesson Feature	**Reflection**	**Start time:**		**End time:**	

Instructional Activity (check all boxes that apply)

**Seat work involves documentation of ideas/responses e.g. with worksheet*

☐Class: teacher instruction
☐Class: discussion/critique
☐Class: group presentation
☐Inter-group: discussion/critique
☐Group: members-only discussion
☐Group: teacher-involved discussion
☐Group: hands-on
☐Group: seat work
☐Individual: hands-on
☐Individual: seat work

Lesson Observation Notes

- Persons involved: Teacher (tr). Students (ss) or (S1, S2, S3…) if distinguishable. • Content of action and speech, including questioning and responses.

Include descriptions of the following. Highlight parts of notes that serve as evidence for each design principle (according to assigned colour).

- Context and nature of STEM problem **(Problematizing)**
- Materials provided, if any **(Resources)**
- Success criteria and how they came about, if any **(Accountability)**
- What happens after students propose an idea related to the STEM task or solution to STEM problem; who says what **(Authority)**
    - Include examples of critique instances **(Accountability)**. Critique may be verbal, written, or a checklist.

Problematizing **Resources** **Authority** **Accountability**	**PIE [Record Group Talk]**

Part C: Design Principles (Complete based on Part B: Observation Notes)

Cite evidence gathered from lesson features in observed STEM lesson to rate extent to which each design principle is met.

Problematizing Lesson STEM learning experience in relation to STEM problem is meaningful for students and communities.				
	Evidence absent **0**	**Minimal evidence** **1**	**Reasonable evidence** **2**	**Compelling evidence** **3**
(i) Nature of STEM learning experience (**check all that applies**): ☐ **Complex**: Requires concepts/skills from more than one STEM discipline to solve. ☐ **Authentic:** Relevant to students' lives or real-life situations, including historical events. ☐ **Open-ended**: Has more than one possible solution. ☐ **Extended***: Involves applying, analysing, evaluating, or creating ideas/artifacts. ☐ **Persistent**: Problem continues to exist although there are already solutions available. E.g., traffic jams, recycling, food security. *Note: All except Extended follows definition of a STEM problem in the S-T-E-M Quartet (Tan et al., 2019) Tan, A.-L., Teo, T. W., Choy, B. H., & Ong, Y. S. (2019). The S-T-E-M Quartet. *Innovation and Education*, *1*(1), 1–14. https://doi.org/10.1186/s42862-019-0005-x	STEM problem is not meaningful: no criteria met.	STEM problem is minimally meaningful: 1 to 2 criteria met.	STEM problem is fairly meaningful: 3 to 4 criteria met.	STEM problem is highly meaningful: all five criteria met.

Design Principle: Problematizing	**Evidence**	**Rating**
(i) Nature of STEM learnng experience	State the STEM problem. Describe the STEM learning experience	Choose an item.

Resources

Adequate resources are provided to support students in solving STEM problem during observed **STEM phase(s):** Problem definition, Research, Development.

	Evidence absent 0	Minimal evidence 1	Reasonable evidence 2	Compelling evidence 3
(i) Material Resources Extent to which students are provided needful materials and tools to complete STEM task. Examples of materials: hyperlinks to information sources, readings, materials to make product Examples of tools: instruments for measurements or making product; apparatus for carrying out investigations; personal learning devices for making sketches.	No **required** materials and tools are provided, and students are **unable** to source for such materials to complete all the STEM tasks. E.g. Students search for information and source for materials and tools to complete all the STEM tasks.	**Some** required materials and tools are provided, and students are **unable** to source for other/alternative materials/tools such that they cannot complete all the STEM tasks. E.g. Students given readings with information and tools to use, but are unable to source for other materials/tools they need to complete all the STEM tasks.	**Some** required materials and tools are provided, and students are **able** to source for other/alternative materials/tools such that they can complete all the STEM tasks. E.g. Students given readings with information and tools to use, and source for other materials/tools of their own to complete all the STEM	**All** required materials and tools to complete all the STEM tasks are **provided**. E.g. Students given readings with information, materials and tools/apparatus to complete all the STEM tasks.
(ii) Support Extent to which students are provided support from teacher (or other adults) or written scaffold in worksheet (e.g. instructions or template for steps/procedures) to complete STEM task.	**No support** provided by teacher or worksheet.	**Two or more** instances of verbal or written **options** for how to proceed with/complete STEM task but students are not told what to do/choose. May Include structured worksheet to record engineering design processes.	**Two or more** instances of **verbal or written instruction** on how to complete **part** of STEM task (e.g. procedures/steps) **without showing** how it is done. May Include structured worksheet to record engineering design processes.	**Two or more** instances of **teacher demonstrating procedures/steps** to complete part of the STEM task or **doing part** of STEM task for student. Repeated demonstration of same procedure/step counts as one instance. May Include structured worksheet to record engineering design processes e.g. Ask, Plan, Create, Test, Improve.
(iii) Time Extent to which students have sufficient time to work on the STEM problem within the lesson.	STEM tasks are **not spontaneously modified** and some STEM tasks could **not be completed**. E.g., Part/All of a STEM task, especially towards end of lesson, was abruptly ended/skipped over.	STEM task is **spontaneously modified due to insufficient time,** but some STEM tasks could **not be completed**. E.g., Teacher reduced the number of variables to investigate but some groups could not complete investigations.	STEM task is **spontaneously modified due to insufficient time** and STEM tasks were **completed**. E.g., Teacher calls on some groups to present their solution but not others.	Lesson was completed as planned with no evidence of STEM task modification due to insufficient time.

Design Principle: Resources	**Evidence (Give evidence from observed lesson features from Observation Notes)**	**Rating**
(i) Material resources		Choose an item.
(ii) Support		Choose an item.
(iii) Time		Choose an item.

Authority

Students are given epistemic authority to construct solution to STEM problem.

	Evidence absent 0	Minimal evidence 1	Reasonable evidence 2	Compelling evidence 3
(i) Idea proposal Who proposes ideas during Problem Definition, Research, and Development phases and whether ideas are acknowledged.	Students mostly **do not** propose their own ideas.	Students mostly propose ideas that are not acknowledged by peers for discussion.	Students mostly propose ideas with teacher support for discussion.	Students mostly propose ideas that are acknowledged by peers for discussion.
(ii) Student-driven ideas Extent to which ideas for the STEM solution are driven by students.	Teacher mostly **tells** students what modification to make or what to do/use instead. Teacher uses command words or gives instruction.	Teacher mostly **suggests** alternative/modification/ improvement for students to consider. Use of phrases such as "Why don't you…? Have you tried…? How about…?	Teacher mostly critiques or highlights good points **without suggesting modification or improvement**	Students' ideas are **fully driven by them** with no intervention by the teacher.
(iii) Determination of success criteria/solution requirements How success criteria or solution requirements for evaluating final solution to STEM problem are decided.	Given by teacher and **accepted by students** with or without explaining choice of criteria OR no criteria given.	**Selected by students from a given list** (e.g., by majority vote) without discussing reasoning behind choice.	**Negotiated between students and teacher** (E.g. teacher provides some criteria/requirements which are discussed to reach class consensus).	**Additional criteria are proposed by students** at the group level for their solution with justifications.

Design Principle: **Authority**	**Evidence (Give evidence from observed lesson features from Observation Notes)**	**Rating**
(i) Idea proposal		Choose an item.
(ii) Student-driven ideas	Note: This item has a relatively lower percent agreement among raters. Please review the descriptions carefully when deliberating this item rating.	Choose an item.
(iii) Determination of success criteria		Choose an item.

Accountability

Students' ideas and actions are held accountable to STEM disciplinary concepts and practices or ways of thinking and doing (WOTD), by self and others (peers, teacher).

- **Sound disciplinary concepts**: e.g., mathematically/scientifically accurate concepts/facts.
- Critiques involving **disciplinary practices/WOTD** consider, for example: (i) validity and reliability of processes to gather and/or analyse data; (ii) coherence of reasoning and with evidence (if relevant); (iii) agreement of data/evidence/claims with others' data/evidence or established disciplinary ideas/facts, (iv) norms for 2D/3D drawings to communicate ideas.
- **Request for evidence or reasoning**: e.g., "Why do you say that?"; "What's your evidence?"; "How do you know that?"
- **Practical reasoning**: e.g., reasoning based on what is easy, convenient, or fast to do.

	Evidence absent **0**	**Minimal evidence** **1**	**Reasonable evidence** **2**	**Compelling evidence** **3**
(i) Critique by others Who critiques students' ideas put forward during STEM tasks.	No opportunities for critique. Group/Class discussion or presentation does not involve critique.	Most critiques are made by own group members.	Most critiques are made by teacher.	Most critiques are made by teacher and students beyond own group members.
(ii) Nature of critique How students' ideas are held accountable.	No opportunities for critique or only one critique instance.	**Two or more**-critique instances involve **practical reasons not part of success criteria or constraints** (e.g., time it takes to do so; whether someone knows how to do it)	**Two or more** critique instances involve **request for evidence or reasoning** without considering soundness of STEM disciplinary concepts or practices/WOTD (which includes meeting of success criteria or constraints).	**Two or more** critique instances involve **soundness of STEM** disciplinary concepts or practices/WOTD, including meeting of **success criteria or constraints.**
(iii) Nature of success criteria or constraints for the final solution	**No success criteria** are made explicit to students OR STEM tasks do not involve holding students accountable to the success criteria.	All success criteria/constraints are based on **non-STEM related concepts/practices.**	Criteria/constraints include **sound** STEM concepts/practices involving **only 1 STEM discipline**.	Criteria/constraints include **sound** STEM concepts/practices involving **two or more STEM disciplines**.

Design Principle: Accountability	**Evidence (Give evidence from observed lesson features from Observation Notes)**	**Rating**
(i) Critique by others		Choose an item.
(ii) Nature of critique		Choose an item.
(iii) Nature of success criteria or constraints	Note: This item has a relatively lower percent agreement among raters. Please review the descriptions carefully when deliberating this item rating.	Choose an item.

Part D: Productive Interdisciplinary Engagement (Complete based on Part B: Observation Notes)

Note: Judgement of Productive Interdisciplinary Engagement should be done either for observed group or at Class level, for all three dimensions.

One instance = discussion of a decision (to be) made during **STEM Phases** (Problem definition, Research or Development) that affects quality of solution to STEM problem.

Dimension	Evidence absent 0	Minimal evidence 1	Reasonable evidence 2	Compelling evidence 3
Engagement (i) Cognitive engagement: Students are cognitively engaged during the STEM lesson.	Students demonstrate mostly **exposition**. Exposition means teacher or one student shares/elaborates on his/her idea(s) most of the time. May include quick confirmation or acknowledgement/agreement by others. E.g., Making egg-drop device [**Exposition**] S1: Let's put newspaper around the egg. We can use all of it. S2: All? [**confirmation**] S1: Yeah, just wrap all of it around the egg. But crumple it first. S2: Okay. [**acknowledgement/agreement**]	Students demonstrate mostly **information-seeking** discourse**.** Information-seeking means some students **ask questions to seek information or clarification** of idea while mainly one student responds. E.g., [**Information-seeking**] S1: Let's put newspaper around the egg. S2: How much do we use? S1: All of it. S3: Just wrap around the egg? S1: Crumple it first.	**Two or more** instances of **idea-building** discourse. Idea-building means students **build on** an idea (by elaborating, adding details, providing examples, etc.), **without identifying errors/issues or critiquing** the idea. Idea-building must involve students other than the idea proposer. E.g., [**Idea building**] S1: Let's put newspaper around the egg. S2: Okay, we can use all of it. S1: Crumple it first. Then wrap around the egg. S2: How do we secure it? S3: Use the tape. Wrap the tape all around so the newspaper won't fall off.	**Two or more** instances of **critical discussion.** Critical discussion means students **build on and critique** an idea with justification (e.g., justify why an idea would not work or has an issue) OR students **discuss/compare multiple ideas.** E.g., [**Critical discussion**] S1: Let's put newspaper around the egg. S2: Why? S1: The newspaper will cushion the egg when it hits the ground. S3: But the egg will still fall very fast. We will need a lot of newspaper. I don't think there's enough newspaper [**critique**]. S2: We can make a parachute. It will slow down the egg [discuss another idea]. Excludes isolated instances of quick identification of error/issue based on facts: Eg.. 1 S1: Let's use the glass. S2: This is plastic. E.g. 2 S3: We'll make it blue. S4: We don't have blue paint.
Engagement (ii) Students work in group or individually during the STEM lesson.	Lesson involves mostly **individual work OR** students are **not on task** during group or individual work.	Students mostly work **individually** during group work.	Students mostly work **within subgroups** of the group during group work.	Students mostly work **within the group** during group work.

Dimension	Evidence (Give evidence from observed lesson features from Observation Notes)	Rating
Engagement (i) Cognitive engagement		Choose an item.
Engagement (ii) Group vs individual work		Choose an item.

One instance = discussion of a decision (to be) made during **STEM Phases** (Problem definition, Research or Development) that affects quality of solution to STEM problem.

Dimension	Evidence absent 0	Minimal evidence 1	Reasonable evidence 2	Compelling evidence 3
Interdisciplinarity Students take a systematic and disciplinary-based approach to make and justify decisions that affect the quality of the solution to the STEM problem.	Students demonstrate mostly **random decision-making or unjustified decision-making.** Reasons for decision are not made explicit or not given.	Students demonstrate mostly **poor decision-making** based on **satisficing** (i.e., agree with first idea that appears to meet success criteria/constraints) or **practical reasons NOT tied to success criteria/constraints.** OR Students only demonstrate systematic disciplinary or non-disciplinary decision making with teacher involvement.	Students demonstrate **two or more instances** of **systematic but non-disciplinary-based decision-making**. Decisions are based on weighing benefits and tradeoffs, evidence (researched/given information or data from investigation/test), and **practical reasons tied to success criteria/requirements**. Do NOT include disciplinary reasonings.	Students demonstrate **two or more instances** of **systematic and disciplinary-based decision-making**. Decisions are based on weighing benefits and tradeoffs, evidence (researched/given information or data from investigation/test), and **disciplinary reasonings** tied to success criteria/requirements.

Dimension	Evidence (Give evidence from observed lesson features from Observation Notes)	Rating
Interdisciplinarity Rate based on highest level observed.	Note: This item has a relatively lower percent agreement among raters. Please review the descriptions carefully when deliberating this item rating.	Choose an item.

Dimension	Evidence absent 0	Minimal evidence 1	Reasonable evidence 2	Compelling evidence 3
Productivity (i) Students make progress towards the solution to the STEM problem, from start to end of the STEM lesson.	It is unclear whether students reach an initial decision/solution that addresses the STEM problem or meets *success criteria/constraints* by end of lesson.	Issue(s) with initial decision/solution are identified (by students or teacher), which makes it inadequate for meeting success criteria/constraints, but subsequent modifications still do not meet success criteria/constraints.	Students successfully defend decision/solution against critiques without modifying it OR solution satisfies all tests and thus does not require modification.	Students reach a new or improved decision/solution that addresses an identified issue with the previous decision/solution or meets more *success criteria/constraints* by end of lesson (compared to their initial idea).
Productivity (ii) Quality of final solution to STEM problem.	Most students' final solution does not meet any success criteria OR There is no approach to determine if students' final solution met any success criteria. OR No final solution is produced.	Most students' final solution meets **fewer than half** of the success criteria OR satisfies fewer than half of the constraints.	Most students' final solution meets **more than half** of the success criteria AND satisfies more than half of the constraints.	Most students' final solution meets **all** of the success criteria. AND satisfies all constraints.

Dimension	Evidence (Give evidence from observed lesson features from Observation Notes)	Rating
Productivity (i) Progress towards solution		Choose an item.
Productivity (ii) Quality of final solution	Only applicable for lesson involving final STEM solution. Summarize quality of final solution by various students/groups and most frequently met success criteria/requirements	Choose an item.