

Facilitator guide - separate from student copies

Free teacher and homeschool key for Fair, Repeated Trials (OBML-006), worksheet version 1. Middle-school has MS01-MS06; high-school has HS01-HS06. Distribute the appropriate student copy first. All scenarios are planning or hypothetical reasoning, not reported experiments. No claimed curriculum alignment, tested duration or learning-effectiveness result.

Observable learning goals and preparation

Middle-school: name the changed factor and observed response, retain every outcome and identify one limitation. High-school: justify a comparison, distinguish agreement from accuracy, and bound a transfer claim. Prerequisites: compare two situations and explain a reason. No equation, marble apparatus or internet access is needed. Read the student explanation and this key before facilitating; prepare printed copies or plain paper and pencil.

Vocabulary in context

Factor: a condition deliberately changed. Response: an observed outcome. Comparable conditions: aspects kept as steady as feasible for the intended comparison. Variation: differences among repeated observations. Repeatability concerns agreement under specified same conditions; accuracy concerns agreement with the quantity being measured. Systematic error is a persistent component of measurement error, which repetition alone does not remove. Do not label every changed condition a systematic measurement error.

Paper activity - complete without equipment

Materials: student worksheet or paper and pencil. Setup: read the invented A/B planning scenario aloud or independently. Steps: (1) record the first decision before reading the supporting explanation; (2) label the changed factor, response and comparable conditions; (3) sketch the revised plan; (4) prepare a blank record for both settings, with outcome and changed-condition notes; (5) reason about a shifted track, a misplaced ruler zero, and a study-note transfer. Observations here are the learner's annotations and explanations, not physical outcomes. Compare plans and ask what another observer would need to know. Limitation: paper reasoning cannot show that a marble remains in a particular cup or that a note arrangement improves searching.

Safety and access

This activity requires no marbles, tools, heights or track construction. Work seated with ordinary paper and pencil; do not convert the diagram into instructions for a tall run, stairs or roads. If an adult separately chooses the lesson's physical option, its complete low-stable-track and small-part limits still apply; no physical option is needed here. Oral responses, a dictated sketch or large-print copying can replace handwriting without changing the central reasoning.

Middle-school answer guidance

MS01 | Record both the catch and the miss, with a note that the track shifted. Reason: leaving out an inconvenient outcome conceals relevant conditions. Accept: a full record that flags the shift and separates changed-condition trials when interpreting the intended comparison. Misconception: "a miss is not a real trial"; ask, "What changed, and would the next observer know?" The key supplies reasoning after the prediction.

MS02 | Changed factor: release mark A or B. Response: whether the marble stays in or misses/leaves the cup, using one agreed observation rule. Comparable conditions: the same marble, track, cup position and let-go method. Any three plus an explanation are acceptable. Holding these steady reduces competing explanations for a difference; it does not guarantee perfect control. Misconception: only the number of repeats matters.

MS03 | Accept a sketch or description with the same cup position, marble, track and release method in A/B, and different labelled release marks. The original plan confounds release mark with cup position: an outcome difference could involve either. Accept a narrowed claim that honestly compares whole setups, but that alone does not answer the requested release-mark question. Misconception: changing more things makes the intended explanation clearer.

MS04 | A complete blank record includes trial/setting, stayed or missed and condition notes, with space for repeated A and B observations. Accept another layout with equivalent fields and both settings repeated. A shifted trial stays in the full record and is flagged; report its changed conditions and plan fresh comparable trials rather than treating it as unchanged. Do not require a particular number of repeats as a universal standard. Misconception: delete misses to clean up the results.

MS05 | No. Closely agreeing readings do not establish agreement with the actual length; the misplaced zero can persist on every reading. Accept "repetition can show consistency while a tool stays wrong." A proposed zero/reference check is useful but is not a reported result. Misconception: agreement means accuracy.

MS06 | Accept a justified paper plan: change note arrangement; observe whether or how the named topic is found under a stated rule; keep content, reader, target difficulty and search instructions comparable as feasible; repeat both arrangements and keep every outcome. Other well-defined responses are valid. Limitations can include familiarity, unequal topics or the narrow reader/task scope. No method advantage is established. Misconception: one successful search proves the arrangement works for everyone.

High-school answer guidance

HS01 | Cup position is a competing explanation because it changes with the release setting. Keep the cup position and other stated conditions comparable while changing the release mark; repeat both settings. Accept a design that separately investigates cup position, with a clear narrower claim. The supplied comparison cannot isolate the release mark. Misconception: a clear outcome identifies its cause automatically.

HS02 | Accept a planned response rule, comparable marble/track/cup/release method, repeats at both marks, and a record of every outcome and exception. A shifted-track trial is retained and annotated; interpret it separately from unchanged-condition trials and obtain fresh comparable observations if needed. Explain any exclusion from a particular comparison while retaining the full record. No actual experiment or minimum universal repeat count is supplied. Misconception: recording a shift makes the shift harmless.

HS03 | Repeated readings expose observed spread and agreement under stated conditions. A consistently misplaced zero can leave closely agreeing readings consistently offset; agreement alone does not certify accuracy. Accept a proposed check of zero alignment or comparison with an appropriate independent reference, with a stated purpose and honest limitations. The check is proposed, not performed. Misconception: all errors disappear with enough repetition; or all variation identifies one known error cause.

HS04 | Accept a defined note-arrangement factor and response such as finding a specified topic under one observation rule; keep content, task difficulty, reader and instructions comparable where feasible. Repeat both conditions and record exceptions. Familiarity must be acknowledged: record prior exposure, choose comparable unfamiliar tasks, or qualify the comparison. Accept any justified design that makes this influence visible rather than pretending it vanished. Remaining limits include different readers/tasks and imperfect comparability. No psychological effect or best-method result is claimed.

HS05 | Two gaps: agreement does not establish accuracy; observations in one set of conditions do not establish universality. Accept: "The repeated readings agreed under the stated conditions. We still need to check possible systematic error and investigate different conditions before making a broader claim." Equivalent reasoned wording is valid. Misconception: replacing "accurate" with "reliable" repairs both claims without explaining the boundary.

HS06 | Relocating the cup changes the arrangement, so previous catches do not establish what the new setup does. The story illustrates retesting. A useful record identifies release setting, apparatus conditions, every outcome and changed-condition notes across repeated trials. Accept additional relevant setup details. Narrative catches are authored events, not an experimental dataset that proves a quantitative or universal prediction. Misconception: the story supplies measured proof for another apparatus.

Teaching routes and next questions

One learner: make the first decision privately, then use the explanation and key to revise it. A nonspecialist adult can ask, "What would stay the same?", "What would count as the outcome?", and "What would this record still fail to tell us?" Invite reasons before showing key answers. No adult is needed to invent measurement results.

Siblings or mixed experience: each proposes a plan independently, then compare what they chose to hold steady. An experienced learner can challenge the causal claim without announcing the younger learner's answer. Keep a shared blank record, with each person explaining one possible limitation. An oral or paper route teaches the same planning relationship; it cannot supply physical evidence.

Simpler route: use only one A/B change and the blank record; prompt with "change / observe / keep comparable." Allow oral explanations or a labelled sketch. Deeper route: ask whether a change in observer, tool or location still counts as the same measurement conditions, then ask how that changes the claim. Several-factor designs exist; this worksheet intentionally uses a bounded simple comparison rather than defining all science as one-factor testing.

Discussion prompts and takeaways

Prediction: which parts of a record would you keep before knowing the desired answer? Explanation: what competing cause would a changed cup position introduce? Application: what does repetition reveal in the note-search plan, and what remains untested? Likely temptation: keeping successful outcomes makes the story cleaner. Respond by asking what information the discarded observation carried. Another temptation: consistency feels like correctness. Ask what independent check could address a persistent tool error.

Takeaway: define the question, plan what changes and what is observed, keep conditions comparable, repeat both settings, preserve every outcome, and state remaining limits. If answers differ, check whether the learner defined a different valid response or comparison before correcting them. A new question is how much evidence a particular claim would need; this package gives no universal number of trials.

Optional connected reading

Fair, Repeated Trials offers the focused explanation. One More Take demonstrates Quinn repeating releases and checking a changed arrangement before filming. Use the direct return to its repeated-trial passage; the story supplies an application illustration, not laboratory measurements. All central learning content is already included here.

Source notes (all activities here are paper planning)

NIST experimental design - planned factors, responses and uncontrolled influences
<https://www.itl.nist.gov/div898/handbook/pri/section1/pri11.htm>

NIST variability - differences among repeated measurements
<https://www.itl.nist.gov/div898/handbook/mpc/section1/mpc114.htm>

NIST measurement terminology - agreement, accuracy and systematic error (D.1.1.1-6)
<https://www.nist.gov/pml/nist-technical-note-1297/nist-tn-1297-appendix-d1-terminology>