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Carnegie Learning MATHia 2019-2020 DataShop Documentation

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Problem-Solving in MATHia Workspaces

MATHia (formerly Cognitive Tutor; Ritter et al., 2007) content is divided into two types of topical "workspaces,[1]" concept builders and mastery workspaces. Concept builders present a fixed sequence of questions associated with content intended to build conceptual understanding. Mastery workspaces present multi-step problems on which students demonstrate mastery of fine-grained skills or knowledge components (KCs). Both types of workspace provide assistance in the form of context-sensitive hints and just-in-time (JIT) feedback. Figure 1 provides a screenshot from a mastery workspace called "Using Scale Factor."

Figure 1. A screenshot of problem-solving in the MATHia workspace "Using Scale Factor."

Each mastery workspace contains a large set of problems, of which each student will complete a subset. When MATHia estimates that students have mastered all KCs associated with a workspace, the student is moved on to the next workspace in

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[1] Some existing datasets and research use the term "section" for what we call "workspace."

their curriculum sequence. KC mastery is estimated using Bayesian Knowledge Tracing (BKT; Corbett & Anderson, 1994). Progress toward skill or KC mastery is displayed to the student via the Skillometer (see Figure 2). If a student fails to reach mastery of all KCs before reaching a fixed maximum number of problems, they are also moved onto the next workspace, but without mastery (Fancsali et al., 2020). We sometimes call this latter case a "promotion." See Ritter et al., 2016 for details on this approach to mastery learning.

Figure 1 illustrates multi-step problem-solving in a problem within the MATHia mastery workspace "Using Scale Factor." In the partially completed problem in Figure 1, the student has completed four steps of the problem, as entering the "scale" requires providing values and units for both the numerator and denominator. The student has chosen to do an optional task, which introduces four more problem-solving steps that may not always appear in data for this problem (or similar problems within this workspace).
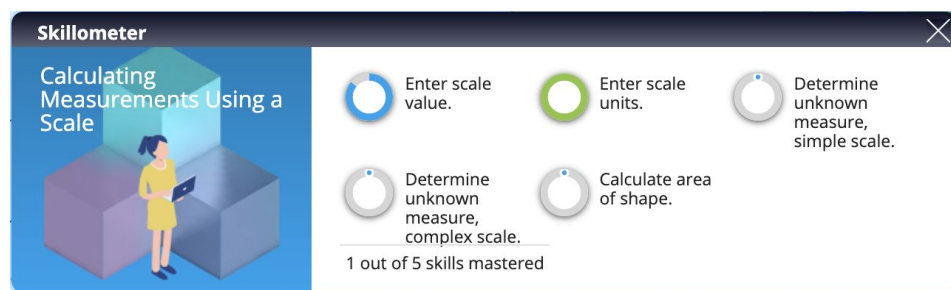

Figure 2. "Skillometer" display for the five KC tracked by "Using Scale Factor." After completing the first four problem steps (see Figure 1), the student is estimated to have mastered the KC "Enter scale units" and has made progress toward mastery of "Enter scale value."

Column Documentation & Notes

Notes: Possible values are often provided in {}; CF = DataShop "Custom Field" associated with transaction-level data.

Anon Student Id: anonymous student identifier

Session Id: {no_session_tracking}; These data do not track login sessions within MATHia, but this is a required field for DataShop, so all values are "no_session_tracking."

Time: Timestamp in UNIX epoch time.

Level (Workspace Id): identifier for the workspace

Problem Name: identifier for the problem

Step Name: identifier for the problem-step

Selection: {Done Button}; This field is typically blank as the selection is usually the "Step Name," but there are entries with the value "Done Button" when the student's action is "Done" (see next column), indicating that they are pressing the "Done Button" in MATHia to proceed to the next problem.

Action: {Attempt, Done, Hint Request, Hint Level Change}
- Attempt: Student made a problem-solving attempt (see input)
- Done: Student clicked the "Done" button required to complete a problem
- Hint Request: Student requests a hint
- Hint Level Change: Student requests a hint at a "deeper" level (see helplevel)

Input: student input at the problem-step (sometimes interpretable a la the actual number/text, etc., input value; other times more difficult to interpret)

Outcome: {OK, OK_AMBIGUOUS, JIT, FREEBIE_JIT, ERROR, INITIAL_HINT, HINT_LEVEL_CHANGE}
- OK + OK_AMBIGUOUS = correct (OK_AMBIGUOUS is re-coded as OK in some DataShop-imported datasets).
- JIT = error that is tracked for just-in-time, context-sensitive feedback (e.g., a known misconception, a number as input that appears in the problem but is incorrect, etc.). JIT is re-coded as ERROR in some DataShop-imported datasets.
- FREEBIE_JIT = JIT (see above) that does not impact student KC mastery estimates like an error or JIT typically does, and so a "freebie." FREEBIE_JIT is re-coded as ERROR in some DataShop-imported datasets.

- ERROR = error that isn't specifically tracked for JIT feedback
- INITIAL_HINT = first-level hint is provided
- HINT_LEVEL_CHANGE = a "deeper" level hint is provided

Help Level: {0, 1, 2, 3, ...}; Generally (but not always), there are three levels of hints, corresponding to the following (also, in general):
- 0 = not a hint request
- 1 = first-level hint = "goal setting hint" – generally a re-statement of the goal/question relevant to the current problem-step
- 2 = second-level hint = "teach hint" – provides more in-depth insight into how to solve the current problem-step without giving the answer
- 3 = third-level hint = "bottom out hint" – provides the correct answer to the problem-step

Attempt At Step: count of attempts on this step for this problem (or problem-step) (e.g., 1 = first attempt at this problem-step for this problem; 2 = second attempt, etc.; 0 = not an attempt)
- DataShop re-calculates this column during import. See DataShop documentation for datasets that aren't attached as files to the project.

KC Model(MATHia): The skill or knowledge component (KC) tracked by MATHia for this problem-step; the KC is only provided for transactions in which the student's action impacts the BKT estimate of KC mastery. The change in this BKT estimate is tracked in custom fields CF (Skill Previous p-Known) & CF (Skill New p-Known).

CF (Ruleid): sub-skill related to KC with some problem-solving context encoded; used, e.g., to determine what hint or just-in-time (JIT) feedback is appropriate; not always interpretable.

CF (Etalon): The correct value for a particular problem-step that MATHia is expecting.

CF (Skill Previous p-Known): BKT skill estimate prior to this action (i.e., semantic event)

<u>CF (Skill New p-Known)</u>: BKT skill estimate after this action (i.e., semantic event)

<u>CF (Workspace Progress Status)</u>: {GRADUATED, NOT_COMPLETED, PROMOTED}
This is repeated for every entry that corresponds to work in a workspace.
- GRADUATED = The student eventually masters all skills/KCs in this workspace and moves on to the next workspace of content (or finishes the last workspace of assigned content).
- PROMOTED = The student reached the maximum number of problems allowed in this workspace without having mastered all skills/KCs. Student is moved on ("promoted") to the next workspace of content despite a lack of mastery.
- NOT_COMPLETED = The student's work for this workspace is incomplete (i.e., they neither graduated nor were promoted from this section). This could happen for any number of reasons. Given the bevy of factors that might lead a student to not complete a workspace, *it is worth considering filtering out this student work in many analyses.*

<u>CF (Semantic Event Id)</u>: a unique id for a semantically meaningful student action/click/input; could have multiple rows associated with it (e.g., when multiple skills are updated for a single student attempt).

Additional Note

1.) In mastery workspaces, the KC that is mapped to a problem-step is only included in a transaction's data when MATHia updates its BKT estimate of the probability of knowledge (p_known) of that KC (e.g., on most, but not all, first attempts at that KC). There are circumstances in which non-first-attempts provide for p_known updates (e.g., if a student gets a "FREEBIE_JIT" outcome on the first attempt, in which the student makes a relatively innocuous error that isn't counted "against" the student's p_known value for that KC). There are lots of places where a problem-step is associated with a KC but you'll not see a KC in the "KC Model (MATHia)" column because the student's action doesn't affect the p_known estimate. The prior and updated p_known values

are tracked in custom fields associated with the transactions where updates occur (see Column Documentation & Notes).

References

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