Writing Classroom Assessment Items

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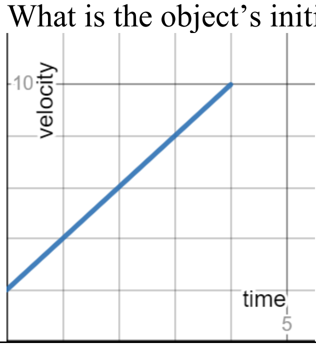
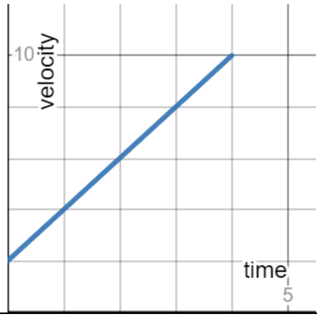
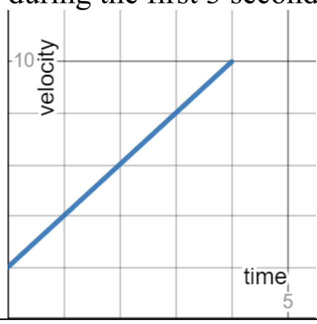
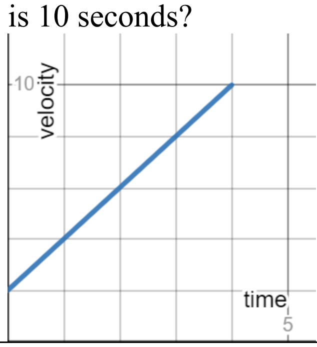
While multiple-choice, summative exams, when carefully designed, can provide a valid and reliable measure of student understanding in STEM subjects (Mitra, 2022), other assessment types are needed if we want to measure student skills rather than just learning outcomes (Yakob et al., 2021). Hence, this paper will describe the design of multiple assessment types for a one-week physics unit on the topic of accelerated motion. Representative examples of each of the assessment types suggested in the unit curriculum map (summative, multiple-choice exam, formative assessment, and performance task) will be presented and discussed.

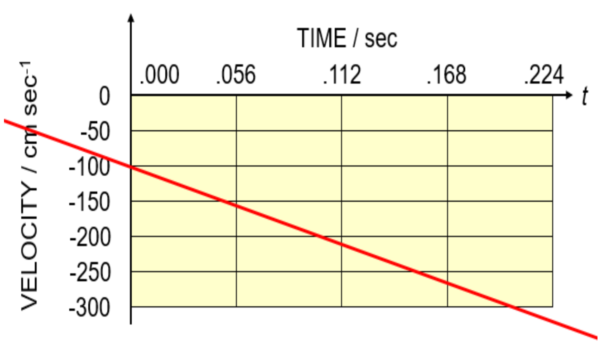
Summative Test

The questions in the 10-item multiple-choice, summative exam (Table 1) were selected to align with the table of test specifications for the unit of study described above. As suggested by Brame (2013), care was taken to ensure that all distractors were plausible answers. According to Jovanovska (2018), correct options should be randomly distributed, and this was done using Random.org's Random Integer Generator (n.d.). A list of 10 random integers between 1 and 4 (inclusive) was generated, and options A-D were then mapped to the numbers 1-4.

Table 1: 10-item multiple-choice, summative exam for the selected unit of study

#	Question Stem	Answer Choices
1	The velocity-time graph of an object is shown below. The units of the velocity values on the graph are metres per second (ms^{-1}) and the units of the time values on the graph are seconds (s). What is the object's initial velocity? 	A. 1 ms^{-1} **B. 2 ms^{-1}** C. 5 ms^{-1} D. 10 ms^{-1}

2	The same velocity-time graph from Question 1 is shown below. What is the object's acceleration? 	A. 0.5 ms^{-2} **B. 2 ms^{-2}** C. 1 ms^{-2} D. 2.5 ms^{-2}
3	The same velocity-time graph from Question 1 is shown below. How far did the object travel during the first 3 seconds? 	**A. 15 m** B. 24 m C. 30 m D. 40 m
4	The same velocity-time graph from Question 1 is shown below. Assuming acceleration remains constant, what will its velocity be when the time is 10 seconds? 	A. 10 ms^{-1} B. 20 ms^{-1} **C. 22 ms^{-1}** D. 50 ms^{-1}
5	A car accelerates from rest at a constant rate of 2ms^{-2}. What is its velocity after it has travelled 100m?	A. 50 ms^{-1} **B. 20 ms^{-1}** C. 100 ms^{-1} D. 400 ms^{-1}
6	A spaceship travelling at 100ms^{-1} is slowed down by a rocket motor to a final velocity of 10ms^{-1} in 20 seconds. What is the acceleration of the spaceship?	**A. -4.5 ms^{-2}** B. -5 ms^{-2} C. 10 ms^{-2} D. -90 ms^{-2}

<table>
<tr><td>7</td><td>A ball is thrown upwards with a velocity of $+10ms^{-1}$. Taking the acceleration due to gravity to be $-10ms^{-2}$, what will its velocity be after 2 seconds?</td><td>A. $-10\ ms^{-1}$
B. $5\ ms^{-1}$
C. $0\ ms^{-1}$
D. $+10\ ms^{-1}$</td></tr>
<tr><td>8</td><td>A ball is thrown upwards with a velocity of $+10ms^{-1}$. Taking the acceleration due to gravity to be $-10ms^{-2}$, what maximum height will it reach?</td><td>A. 5 m
B. 10 m
C. 20 m
D. 1 m</td></tr>
<tr><td>9</td><td>Displacement and time data for a falling golf ball are shown below. According to the data, the acceleration due to gravity is:
<table>
<tr><th>Time
t /s</th><th>Average Displacement
s / m</th></tr>
<tr><td>1.0</td><td>5</td></tr>
<tr><td>2.0</td><td>20</td></tr>
<tr><td>3.0</td><td>45</td></tr>
<tr><td>4.0</td><td>80</td></tr>
<tr><td>5.0</td><td>125</td></tr>
</table></td><td>A. $5\ ms^{-2}$
B. $9.8\ ms^{-2}$
C. $25\ ms^{-2}$
D. $10\ ms^{-2}$</td></tr>
<tr><td>10</td><td>An experiment tracking the motion of a falling apple produced the following velocity-time graph. According to the graph, the acceleration due to gravity is approximately:

</td><td>A. $10\ ms^{-2}$
B. $100\ ms^{-2}$
C. $980\ ms^{-2}$
D. $9.8\ ms^{-2}$</td></tr>
</table>

Note. Correct answers are highlighted in blue.

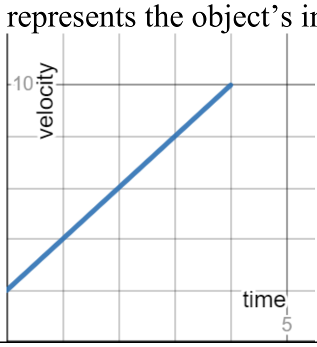
Pre-Administration Analysis

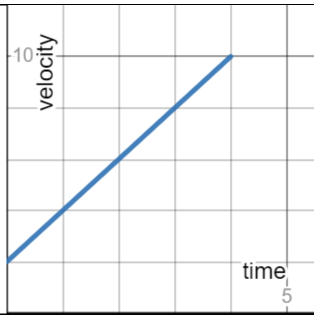
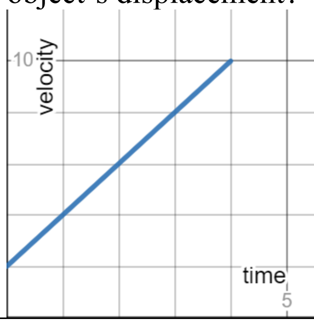
A Pre-Administration Item Analysis was carried out using a checklist adapted from Izard (2004). The question item contexts were all either purely mathematical or drawn from common, culturally neutral examples of accelerated motion. Significant revisions were made to items 1-4 to make it explicitly clear what the values on the axes represented, and item 4 was rephrased from “Assuming acceleration remains constant, what will its velocity be after 10 seconds?” to its current form, to avoid any possible misinterpretations of the word “after”.

Formative Assessment

The questions in the formative assessment for Day 2 of the one-week unit of study (Table 2) were selected to both familiarise students with the format of the summative exam and gauge conceptual understanding of motion graphs. This would allow for instruction to be adjusted or key concepts to be revisited before introducing the algebraic forms of the graphs on Day 3. The formative assessment will be used as an exit ticket (Dixson & Worrell, 2016).

Table 2: formative assessment (exit ticket) for Day 2 of the selected unit of study

#	Question Stem	Answer Choices
1	The velocity-time graph of an object is shown below. The units of the velocity values on the graph are metres per second (ms^{-1}) and the units of the time values on the graph are seconds (s). What information on the graph represents the object’s initial velocity? 	A. The y-intercept B. The area under the graph C. The gradient of the graph D. Not enough information given
2	The same velocity-time graph from Question 1 is shown below. What information on the graph represents the object’s acceleration?	A. The y-intercept B. The area under the graph C. The gradient of the graph D. Not enough information given

		
3	The same velocity-time graph from Question 1 is shown below. What information on the graph represents the object's displacement? 	A. The y-intercept B. The area under the graph C. The gradient of the graph D. Not enough information given
4	Describe or sketch what the velocity-time graph of an object falling under the influence of gravity (starting from rest) looks like. Specific number values are not required in your response.	Answers will vary but should include either a description of a straight-line graph with a negative gradient starting at the origin, or an equivalent sketch.
5	Explain how the velocity-time graph for a marble rolling down a straight track with a slight incline would differ from the velocity-time graph of an object falling under the influence of gravity. Assume both objects start from rest.	Answers will vary but should include reference to the marble still having constant acceleration (and thus a straight-line velocity-time graph of the same shape, but with a less negative slope), or words to that effect (or equivalent sketch).

Performance Task

Performance assessments are a necessary part of the assessment mix in Science and STEM Education if we are to assess students' skills and not just learning outcomes or products (Yakob et al., 2021). Therefore, a performance task (see Table 3) was planned for the final two days of the unit of study that would allow students to practice authentic scientific skills and to exercise higher cognitive levels than those required by a multiple-choice assessment.

Table 3: description of performance task

State one performance outcome and the indicators for the performance (specific descriptors that clarify the outcome).	Analyse the motion of objects in freefall in order to predict their future positions and velocities. Calculate an estimate of the acceleration due to gravity from a graph that was created with primary experimental data.
Describe the performance task.	Students will design and carry out an experiment that allows them to collect data with which they can derive an experimental value for acceleration due to gravity (g) using a graphical method. They will use the uncertainties in their measurements to suggest an uncertainty range for their derived value of g.
Who will view the product or performance?	Science department teachers and lab assistant.
What is the real-world context for the task?	Much scientific work in the real-world involves verifying theoretical values via experimental results.
List the step-by-step process for task completion.	1. Choose an appropriate theoretical model of accelerated motion under the influence of gravity that can be verified experimentally. 2. Discuss choice of independent and dependent variables and feasibility of experimental setup with a teacher 3. Once approved, collect required equipment and carry out data collection. Collect data for at least 5 different values of the independent variable with at least 3 repeated trials for each value. 4. Process your data and present it on an appropriate graph from which an experimental value of the acceleration due to gravity can be derived, with an appropriate uncertainty range.
List process criteria.	• Students can manipulate the independent variable to produce an appropriate range of values • Students can control appropriate variables to produce valid results

	• Students can measure the dependent variable using an appropriate measuring instrument and record results to an appropriate degree of precision • Students can use appropriate digital tools to process and present data
List final product criteria.	• The data collected has been processed and plotted in a way that allows for comparison of experimental results with the chosen theoretical model • Uncertainties in measurements are included with all measured results, calculated values and on the graph • The graph is appropriately presented with labelled axes including units, a title and figure reference and appropriate choice of x- and y-axis scales • All numerical data is presented with an appropriate number of significant figures and all equations and mathematical symbols are correctly presented with an equation editor

Rubric

To evaluate the performance task, an analytic rubric (Table 4) was chosen to align with the reason for using the performance task; that is, to enable the assessment of skills that cannot be explicitly evaluated (and thus only implied) by assessing a final product. An analytic rubric is more appropriate for assessing skills that need to be observed by an instructor because levels of performance are stated for each individual criterion (which corresponds to a particular skills), while a holistic rubric does not (Mueller, 2018), suggesting that holistic rubrics are more useful for assessing student products that do not need to be evaluated in "real time". Equal weighting was assigned to all criteria, and generic level descriptors (for the degree of skill proficiency) were used since the details of each task are included in the criteria descriptors.

Table 4: analytic rubric for performance task

	Description of Performance on Each Criterion			
Criteria/Level:	1 (Beginning)	2 (Developing)	3 (Proficient)	4 (Mastery)
Students can manipulate the independent variable to produce an appropriate range of values	Requires close supervision and step-by-step instruction to perform the task	Performs the task correctly with assistance OR requires intervention to correct errors	Performs the task correctly without assistance	Performs the task correctly without assistance AND helps others to correct mistakes
Students can control appropriate variables to produce valid results	Requires close supervision and step-by-step instruction to perform the task	Performs the task correctly with assistance OR requires intervention to correct errors	Performs the task correctly without assistance	Performs the task correctly without assistance AND helps others to correct mistakes
Students can measure the dependent variable using an appropriate measuring instrument and record results to an appropriate degree of precision	Requires close supervision and step-by-step instruction to perform the task	Performs the task correctly with assistance OR requires intervention to correct errors	Performs the task correctly without assistance	Performs the task correctly without assistance AND helps others to correct mistakes
Students can use appropriate digital tools to process and present data	Requires close supervision and step-by-step instruction to perform the task	Performs the task correctly with assistance OR requires intervention to correct errors	Performs the task correctly without assistance	Performs the task correctly without assistance AND helps others to correct mistakes

Conclusion

By designing a summative, multiple-choice assessment according to a table of test specifications and supporting it with appropriate formative assessments and a performance task, a balanced variety of cognitive levels and learning objectives can be assessed. Moreover, the use of an analytic rubric for the performance task allows students' experimental science skills to be assessed (in addition to the learning objectives). Implementing this plan in the science classroom would require daily lessons of at least one hour's duration and multiple teachers to observe and support students during the performance task; however, it could easily be implemented within a normal school timetable and with one teacher over the course of 2-3 weeks.

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