# DEVELOPMENT AND VALIDATION OF A PHYSICS CONCEPT TEST IN KINEMATICS FOR SENIOR HIGH SCHOOL STUDENTS

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## ABSTRACT

*Kinematics, a fundamental structure in Mechanics is a critical concept that needs to be realized by students for a more complex analysis of subsequent topics in Physics. One way to determine the effectiveness of Physics teachers in teaching at these trying times is to measure the conceptual understanding of Grade 12-Senior High School (SHS) students in Science, Technology, Engineering, and Mathematics (STEM) track. With the goal of establishing a valid and reliable test questionnaire in Kinematics that can be administered either in a paper-and-pencil approach (asynchronous learning) or online approach (synchronous learning); this study focused on the development and validation process of a 45-item conceptual test in Kinematics. Adhering to the Most Essential Learning Competencies (MELC) set by the Department of Education (DEPED), the initial pool of items was pilot tested using a Google form to 110 SHS students after the items had undergone face and content validation by a panel of experts. Furthermore, Classical Item Analysis by calculating the difficulty and discrimination indices was examined to establish test validity. Reliability analysis was also conducted using Cronbach's Alpha ($\alpha$ =0.758) and the Kuder-Richardson formula, (KR-20 = 0.761) which resulted in a deletion of 15 items. In general, this Physics concept test in Kinematics showed an acceptable standard of measurement for classroom use which can be utilized by teachers as a form of diagnostic, formative, and summative tests.*

*Keywords: Physics education, Kinematics conceptual test, Development and Validation, Senior High School (STEM), Philippines*

## INTRODUCTION

Learning the basics is an essential step for a better understanding of complex tasks in the future. To measure how one has learned, the use of assessments in education is an integral part of instruction. The trying times caused by Covid-19 have greatly challenged and affected the education sector worldwide. In effect, the demand for distance learning has paved the way for continuing the learning process of the education system. As most of the methods are performed online, assessment tasks must likewise, adapt to it. Hence, this study aimed to develop and validate a standardized test in Kinematics using the online approach of collecting data.

The basic topics usually tackled by Senior High School (SHS) Physics teachers in General Physics 1 are in Kinematics, and in most cases due to the different school-related activities faced by teachers (Miraňa, 2019), this can, unfortunately, be the last topic discussed in the semester. According to Buabeng, et al., (2016), most Physics teachers felt more qualified and prepared when they teach Mechanics compared to other Physics areas. This was expected because of its basic concepts and involvement in most Science-related curricula in the country. However, despite this, students still found difficulties in understanding the Physics concepts underlying the concepts of displacement, velocity, acceleration, and algebraic sign interpretations using kinematical graphs of motion that according to Cagande & Jugar (2018), there should be interventions needed to address these difficulties. According to Ayop and Ayop's (2019) review paper on education studies in Kinematics, the Test of Understanding Graphs in Kinematics (TUG-K) developed by Beichner (1994) is a lone assessment tool that adheres to mere kinematics. However, if one attempts to answer it without a strong foundation in interpreting graphs, conceptual difficulty is expected.

In a recent study conducted by Miraňa (2019), the conceptual knowledge in Physics of most students in Junior High School in the Philippines was found to be at a *very low mastery level* when compared to the standards determined by the Department of Education (DepEd). This result is different from what is expected in the Spiral Progression scheme intended by the K to 12 curriculum that aims to deepen the understanding of the students as they progress to a higher level. Due to the poor level of conceptual understanding of students in Physics (Miraňa, 2019) and with the limited studies addressing K-12 students' performance in the country (Almerino, et al., 2020), a test instrument that is aligned to the Most Essential Learning Competencies (MELC) of the DepEd was developed and validated to serve as a diagnostic, formative, and summative assessment tool by Physics teachers. Unlike the TUG-K of Beichner (1994) which primarily focused on interpreting graphs, this conceptual kinematics test involves other essential topics set by DepEd, which could be of great help to other science teachers in reducing their tasks to come up with a teacher-made test related to Kinematics. In this way, they can discuss other content standards in the learning competencies that are vital in the subsequent topics in General Physics 2 for the next semester.

## OBJECTIVES OF THE STUDY

The main goal of this study was to: (1) develop and (2) validate a standardized conceptual test for Kinematics anchoring on the MELC, as determined by DepEd. Specifically, this test instrument was designed and intended for use by Grade 12 - Senior High School (SHS) students under the Science, Technology, Engineering, and Mathematics (STEM) academic track.

## METHODOLOGY

### Preparation and Development Stage

After reviewing the literature and acquiring the updated learning competencies from DepEd as bases for the item constructions, this stage begins with the preparation of the Table of Specification (TOS) anchored on the K to 12 Most Essential Learning Competencies. Content topics in General Physics 1 were used as guidelines to craft the items. With the test items focusing on the conceptual understanding in Kinematics of the Grade 12 Level under the Science, Technology, Engineering, and Mathematics (STEM) curriculum, the initial draft constituted a 45-item multiple-choice test. Moreover, each item was classified into groups based on Bloom's taxonomy of the cognitive domain called Higher-Order Thinking Skills (HOTS) and Lower-Order Thinking Skills (LOTS). According to Bloom's taxonomy, *remembering and understanding* levels of questions belong to LOTS while *applying, analyzing, evaluating, and creating* are part of HOTS. As a matter of fact, the items were distributed based on their cognitive domains. Sixty-two percent (62%) of the 45 items exhibited the HOTS domain while the remaining 38% manifested LOTS.

### Validation Stage

According to Colton and Covert (2007), the process of any instrument construction involves constant revision, hence this iterative cycle of rewriting some items based on the feedback obtained from content experts was carried out to refine the test instrument. Four (4) content experts in Physics were selected to evaluate the content and face validity of the test. All of these experts who are Physics majors in their Bachelor's and Master's degrees have established significant years in teaching the discipline. One of the experts has a Ph.D. degree in Physics Education while the other two content experts are currently pursuing their Ph.D. degrees in Science Education. The fourth expert, on the other hand, was an MS Physics degree holder. Using a quantitative content validation consisting of a 20-item validation checklist adopted from Morales (2003), this Likert evaluation scale of 1-5 (e.g., 1 = Strongly disagree, 5 = Strongly agree) denotes the characteristics of a good and valid test. After obtaining feedback from experts, the conceptual test instrument in Kinematics for SHS was constructed in Google form for online pilot testing.

Using a convenience sampling method to pilot test the test instrument, the researcher collected data from 110 SHS students. Inclusion criteria for a STEM track, Grade-12 student includes enrolment in the school year 2020-2021, from either a modular or online distance learning modality. Taking advantage of technology through the Messenger application, the researcher was able to ask for assistance from friends and colleagues who are SHS Physics teachers to circulate the Google form to their respective students. Likewise, the researcher also tapped some help from other science teachers who may know someone in their respective schools to share the said form with their Grade 12 SHS students. Once the Google form was accessed by a student, a letter of consent was presented to inform them of the purpose of the pilot testing and how it can provide information for the analysis of the study. With the use of a timestamp feature that records the length of time an individual can finish the questionnaire; an SHS student can finish the test for approximately 30 minutes. Overall, most of the respondents (94%) came from public schools comprising 10% from Region IV-A (CALABARZON), 11% from Region VII (Central Visayas), and the rest (79%) belonged to one of the provinces in Region VI (Western Visayas). Meanwhile, only 6% of the test takers came from private schools. Most of the private schools communicated by the researcher were not responsive to the letter of request; hence a few respondents were recorded.

Furthermore, this low response rate using online surveys is typically expected because as pointed out in Saleh & Bista's study (2017), this is an increasing phenomenon that needs to be addressed, accordingly. This can also be attributed to several factors, such as student engagement, and incentives. Moreover, it was reported that participants prefer to complete an electronic survey when they personally or professionally know the proponent (Saleh & Bista, 2017). Since the researcher relies on the few known Physics teachers handling SHS under the STEM track; multiple contacts with students that contribute to an increased response rate is dependent on the teachers' encouragement and incentives or extra credit approach (Magro, et al., 2015). Likewise, possible apprehensions of the students to answer the test may be a factor because Kinematics were taken in the previous semester leading to lower student engagement and interest (Saleh & Bista, 2017) in answering the test.

## RESULTS AND DISCUSSION

The following stages were observed to perform the test in Kinematics for SHS: (a) development of a multiple-choice test, and (b) validation process to construct a standardized paper-and-pencil and/or online test.

### 1. Item Development

The topics that were included in General Physics 1 were based on the Department of Education's K to 12 MELC for Grade 12 Level. In this study, only topics in Kinematics were considered. Each item includes four (4) choices that gave the best answer while the other remaining choices served as distracters. According to Morales (2012), this 4-choices format is the predominant style in standardized and teacher-made tests in the secondary education system of the Philippines. This format has been used in the National Elementary Achievement Test (NEAT) and the National Achievement Test (NAT) which are considered standardized assessments of DepEd. Additionally, total item numbers and sample questions that correspond to the requirements of learning competencies were also presented in the TOS.

## 2. Content Validation and Pilot Testing

Content validation of the experts was requested to ensure that the purpose of the study was achieved. Therefore, the 45-item test was assessed for face validity and quantitative content validation. Regarding face validity, descriptive validation was used in terms of its incomprehensibility, simplicity, and relevance of the items to the MELC. Based on the common comments and suggestions of experts, the following points were addressed*: (i) changing the items into question form rather than using the missing statement method (ii) alternatives must be arranged from shortest to longest fragments or sentences or vice versa, and (iii) providing stems in the items where graphs are presented.*

The quantitative content validation was evaluated using the 20-item checklist designed to validate the characteristics of a good and valid test (Morales, 2003). After revising the items based on the suggestions of the experts, and retaining the number of items to 45, the test was subjected to content validity calculation using Aiken's (V) content validity coefficient. The use of Aiken's V value pertains to the degree of agreement among experts. Usually, the V value ranges from 0 to 1, and when the value approaches 1, the better and higher content validity an item becomes (Aiken, 1985). This can be calculated using the following equations:

$$V = \frac{\sum s}{n(c-1)} \quad \textbf{(1)}$$

$$s = r - lo \quad \textbf{(2)}$$

where **s** pertains to the scores assigned by each rater minus the lowest score in the used category (**r** = rating by an expert and **lo** = the lowest possible validity rating); n is the number of raters and experts; and c is the number of categories that raters can choose. According to the table recommended by Aiken (particularly on four (4) number of experts and raters and using five (5) number of rating categories -- see table V, Aiken, 1985:134), the content validity coefficient (V value) of all the items in the checklist must be falling at 0.88 or higher to effectively reach a significant standard (Ole, 2020). Consequently, as reflected in Table 1, experts found that the items were valid because of a content coefficient value close to 1.00 (*V= 0.94*). This implies that the experts considered the items of the test with high content validity.

**Table 1**
*Results of content validity coefficient (V value) using Aiken's equation*

| Checklist Items | V |
|---|---|
| 1 | 0.94 |
| 2 | 0.94 |
| 3 | 0.94 |
| 4 | 1.00 |
| 5 | 1.00 |
| 6 | 1.00 |
| 7 | 0.94 |
| 8 | 0.94 |
| 9 | 0.94 |
| 10 | 0.88 |
| 11 | 0.88 |
| 12 | 0.88 |
| 13 | 0.94 |
| 14 | 0.94 |
| 15 | 0.88 |
| 16 | 1.00 |
| 17 | 0.94 |
| 18 | 0.88 |
| 19 | 0.94 |
| 20 | 1.00 |
| **Average** | **0.94** |

## Item Analysis

According to Ferketich as cited by Albano (2018), the best-case scenario when administering an initial pool of candidate test items must at least be twice as large as the final number of items needed. With the 45 items generated in the Kinematics test, the 110 respondents were satisfied, and therefore, can be considered suitable for item analysis. Furthermore, another relevant procedure for item analysis is to ensure the appropriateness of the items by categorizing the items based on difficulty and discrimination index.

*A. Item difficulty*

To assess the difficulty of the items as not being too easy or too difficult, *item difficulty (DI)* must be determined. This can be computed by obtaining the percentage of SHS students who answered the specific item correctly out of the 110 students who answered the test.

$$DI = \frac{number\ of\ SHS\ students\ who\ got\ correct\ answers}{total\ number\ of\ SHS\ who\ took\ the\ test} \times 100 \quad (3)$$

As shown in equation 3, this method of computing the proportion of students who answered the test item accurately can be interpreted using Table 2

**Table 2**
*Item Difficulty of the 45-item test in* Kinematics

| Item Difficulty Interpretation | Range | Number of Items | Percentage |
|---|---|---|---|
| Very Easy (VE) | 0.81 - above | 8 | 18 |
| Easy (E) | 0.61 - 0.80 | 7 | 16 |
| Moderately Difficult (MD) | 0.41 - 0.60 | 17 | 38 |
| Difficult (D) | 0.21 - 0.40 | 11 | 24 |
| Very Difficult (VD) | 0.00 - 0.20 | 2 | 4 |
| *Total* | | 45 | 100 |
| ***Test Difficulty*** | | 0.53 | |

*Source: Ebel, 1972; http://fcit.usf.edu/assessment/selected/responsec.html (as cited in Morales, 2012)*

As noted in Table 2, most items (38%) were moderately difficult, followed by difficult level items which garnered 24%. Only 2 items (4%) of the 45 items were labeled as very difficult. However, the remaining 15 items (34%) were found to be easy and very easy items, respectively. Moreover, calculating the over-all test difficulty (*D* = *0.53*) by taking the mean suggests that the test items were categorized as moderately difficult.

*B. Item Discrimination*

**Table 3**
*Item Discrimination*

| Item Discrimination Interpretation | Range | Number of Items | Percentage |
|---|---|---|---|
| Questionable (Q) | -1.00 - -0.60 | 0 | 0 |
| Not Discriminating (ND) | -0.59 - 0.09 | 7 | 16 |
| Moderately Discriminating (MDs) | 0.10 - 0.20 | 8 | 18 |
| Discriminating (Ds) | 0.21 - 0.60 | 26 | 58 |
| Very Discriminating (VDs) | 0.61 - 1.00 | 4 | 9 |
| *Total* | | 45 | 100 |

*Source: Ebel, 1972; http://fcit.usf.edu/assessment/selected/responsec.html (as cited in Morales, 2012)*

The discrimination index (R) can be computed using equation 4 by comparing the performance of the top 27% of test takers and the bottom 27% of test takers to an item. Using Table 3 as a guide, the following items were interpreted, accordingly.

$$R = \frac{(H-L)}{27\%\ of\ Total} \quad \textbf{(4)}$$

where:

H = number of correct answers from top 27% of students

L = number of corrects answers from bottom 27% of students

As shown in Table 3, 26 out of the 45 items (58%) were measured as discriminating items, followed by 18% and 9% which were found to be moderately discriminating and very discriminating, respectively. This indicates that high-performing students tend to select the correct and best answer in an item compared to low-performing students. Based on classical test analysis, a discrimination index is an essential assessment that differentiates high scorers from low scorers. Accordingly, a positive discrimination index (values between 0.00 and 1.00) means that high scorers in a particular item choose a more correct answer than the low scorers. However, if more of the low scorers got a specific item correctly, a negative discrimination index (values between -1.00 and 0.00) is recorded. Consequently, 7 items (16%) were found to exhibit a not discriminating assessment, and none of the items was found questionable. Therefore, upon matching the difficulty index with the discrimination index as shown in Table 4, the items were classified as: (1) *accept;* (2) *revise*; and (3) *reject* the items (Table 5).

**Table 4**
*Item Analysis Standards (Decision table)*

| | Discriminating Level | | |
|---|---|---|---|
| Difficulty Level | Not Discriminating | Moderately Discriminating | Discriminating |
| Very Difficult | Reject | Reject | Reject |
| Difficult | Discarded | May Need Revision | Accept |
| Moderately Difficult | Discard | May Need Revision | Accept |
| Easy | Reject | Needs Revision | Needs Revision |
| Very Easy | Reject | Reject | Reject |

*Source: Ebel, 1972; http://fcit.usf.edu/assessment/selected/responsec.html (as cited in Morales, 2012)*

**Table 5**
*Item Classification Based on Item Analysis*

| Classification | Number of Items | Percentage |
|---|---|---|
| Accept | 19 | 42 |
| Revise | 11 | 25 |
| Reject/Discard | 15 | 33 |
| Total | 45 | 100 |

The resulting percentage distribution of the 45-item multiple-choice conceptual test in Kinematics after pairing it with the difficulty and discrimination indices led to 19 items (42%) that were accepted, 11 items (24%) were labeled as needing revisions, and 15 items (33%) were rejected. As a result, the new version of the Kinematics conceptual test for SHS resulted in 30 multiple-choice items.

**Reliability**

Reliability, as described by Colton and Covert (2015), pertains to the degree of consistency an instrument can establish over a period. It is an extent to which a test is dependable, self-consistent, and stable. There are different methods for establishing reliability evidence like parallel forms, test-retest, and internal consistency reliability. But when a test is only administered one time, the most appropriate method is using internal consistency reliability. Hence, utilizing Kuder-Richardson formulas (such as KR-20 and KR-21) and Cronbach's Alpha were the suggested proper equations for a dichotomous scored test (i.e. yes or no, agree or disagree, correct or incorrect). Calculating the KR-20 using Excel, and Statistical Package for Social Sciences (SPSS) software for the computed reliability of Cronbach's Alpha, the 45-conceptual test in Kinematics acquired values of approximately 0.76 for both methods of reliabilities (Table 6).

**Table 6**

*Reliability Values*

| Number of Items | KR-20 | Cronbach's Alpha |
|---|---|---|
| 45 | 0.761 | 0.758 |
| 30 | | 0.779 |

**Table 7**

*SCOREPAK Standard Interpretation of Reliability*

| Reliability (α) | Interpretation |
|---|---|
| .90 and above | Excellent reliability; at the level of the best standardized tests |
| .80 – .90 | Very good for a classroom test |
| .70 – .80 | Good for a classroom test; in the range of most. There are probably a few items which could be improved. |
| .60 – .70 | Somewhat low. This test needs to be supplemented by other measures (e.g., more tests) to determine grades. There are probably some items which could be improved. |
| .50 – .60 | Suggests need for revision of test unless it is quite short (ten or fewer items). The test needs to be supplemented by other measures (e.g., more tests) for grading. |
| .50 or below | Questionable reliability. This test should not contribute heavily to the course grade, and it needs revision. |

Source:*https://www.washington.edu/assessment/scanningscoring__trashed/scoring/reports/item-analysis/* (as cited in Morales, 2012)

Anchoring on the standards of SCOREPAK in interpreting reliability, cited by the University of Washington (Table 7), the α= 0.758 value indicates a good classroom test, with few items needed for improvement. Cortina (as cited in Ole, 2020) also explains that a reliability coefficient of 0.70 or higher is considered "acceptable" in most educational research situations. Based on the SPSS' item-total statistics table, even if an item was deleted the Cronbach's alpha (α) of all the 45 items were still found to be of good reliability value which ranged between 0.740 to 0.768. This suggests that all items were reliable. However, after removing the items that were classified as either *reject or discard*, another reevaluation of reliability analysis was administered using the SPSS. It was found that the alpha value, α, for the 30-item test increased to 0.779 or approximately at 0.80. It was also noted based on the item-total statistics table that deleting any item out of the 30 items yielded Cronbach's alpha values ranging from 0.761 to 0.790, indicating reliable values of all items.

## CONCLUSIONS

Through the application of reliability and validity methods, the following conclusions are drawn:

1. The results suggested an acceptable standard of developing and validating a Physics concept test in Kinematics for all Senior High School students in the Philippines, as for its classroom use. The rate of content experts using Aiken's content validation coefficient (V=0.94) indicated a high content validity value. Likewise, face validity in terms of comprehensibility, simplicity, and relevance of the items to the MELC was also employed based on their comments and suggestions before it was pilot tested to the SHS students.
2. As a result, the 110 collected responses using convenience sampling method were used for item and reliability analysis. The 45 items using a difficulty index formula were found to be 18%-*Very Easy*, 16%-*Easy*, 38%-*Moderately Difficult*, 24%-*Difficult,* and 4%-*Very Difficult* items. The 45-item test was considered *Moderately Difficult* based on its 53% test difficulty value. For its item discrimination index, none of the 45 items was classified as a Questionable item, however, 16% were found to be *Not Discriminating*, 18% was *Moderately Discriminating*, 58% and 9% were considered as *Discriminating* and *Very Discriminating*, respectively. Therefore, pairing the discrimination and difficulty indices led to 19 (42%) out of 45 items as accepted items, 11 (25%) items needed revisions and 15 items (33%) were rejected and discarded because of its effect as either being too easy or too difficult, and for not being able to discriminate between high and low scorers.
3. A reliability analysis was also utilized employing Kuder-Richardson formula (KR-20) and Cronbach's Alpha to the initial pool of test items. As shown in the results, a 0.76 coefficient of reliability index for both methods were computed, and thus an indicative of being a good instrument for classroom test, provided some of the items will be improved. However, after deleting the 15 items based on the item analysis and reevaluating it to SPSS, the new Cronbach's alpha of the 30-item test resulted to a higher index equal to 0.779 or approximately equal to 0.80.

## RECOMMENDATIONS

To verify the increased reliability of the revised version of the Kinematics test (30-item):

1. It is suggested that this will be administered again to Grade 12 Level SHS students under the STEM track. Likewise, it is recommended that to establish a higher reliability index; increasing further the number of respondents and tapping more students from private schools would gain better analysis and understanding.
2. As this concept test in Physics has gone through development and validation processes, and with results showing acceptable standards of indices and coefficients; it is therefore suggested to encourage Physics teachers in the Philippines to utilize this as an assessment tool in a form of diagnostic, formative, and summative assessments (Morales, 2012). This could be a potential questionnaire to measure the conceptual understanding in Kinematics of their SHS students since the standard of the content of this test was consistent on DEPED's K to12 MELC.
3. Likewise, this tool could lessen the burden of other science teachers to come up with a teacher-made test, especially for non-Physics majors teaching the subject. Furthermore, given that distance learning is inevitable in today's educational setting, this Kinematics test can provide options for teachers to administer it in either a paper-and-pencil approach (asynchronous learning) or an online approach (synchronous learning).
4. It is also strongly recommended that similar efforts may be done by other Physics teachers to develop more conceptual tests in General Physics and take advantage of utilizing online tests as distance learning is at its peak during this COVID-19 pandemic.

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