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Readability Formula for Instructional Materials in Science

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Abstract

The study developed and validated a readability formula using measurable variables of readability for physics instructional materials. In developing the formula, .30 reading passages of no less than 100 words each were selected from 18 different books used in Philippine schools. These books were used in the elementary, secondary and collegiate levels. The passages were assigned a readability level by teachers engaged in education for at least 9 years. The readability level scale was from 4 to 16, representing the primary grades (Level 4) up to advanced or graduate level (Level 16). Twelve (12) variables were measured based on the textual and graphical characteristics of the passages. Measurable readability variables used were: Presence/absence of mathematical equation (MEQ), percentage of mathematical words (PMW), percentage of words associated to physics (PWAP), and average sentence length (ASL); Percentage of derived concept words (PDCW), percentage. of words specific (PWSP), average word length (AWL), and presence/absence of graphics element (GRA); and Percentage of PEP (people, events, places) words (PPEP.W), and percentage of PEP sentences (PPEPS). Multiple regression analysis using readability level as criterion resulted in three equally plausible readability formulas. Comparative analysis of the three formulas' proportion of explained variance, residuals, scatterplots and outliners led to the selection of the best model. This was called the 1B Formula and is stated as (PDS = 5.5516 + 0.0949 ASL + 0.0951 PMW +0.0506PWSP) where (ROS = Reading Difficulty Score), ASL (Average Sentence Length), PMW (Proportion of Mathematical Words), and PWSP (Proportion of Words Specific to Physics). The JB Formula was validated against (a) other formulas, (b) reader judgment, and (c) reading comprehension scores. The developed formula was found valid as indicated by its significant relationship with the Flesch and the communication index formulas, and reading comprehension scores.

Keywords: readability, Instructional materials, physics textbook passages

Introduction

Published curriculum materials for elementary and secondary students started to increase in recent years. Textbooks, workbooks and reference materials in different subject areas including the sciences have been written in various series by several groups of authors.

This development indicates our growing independence from foreign books. It also marks a shift to curriculum materials developed by and for Filipinos. As this trend continues, it is relevant to develop appropriate instruments to determine the suitability of these materials to the intended audience. For example, which material matches what type of pupils, classes or grade level? How can a teacher or a school administrator be guided in choosing books for school use? What hints can one consider to rewrite books for better readability? These questions can be clarified when one has an instrument to measure the readability of instructional materials.

Some local researches were done in this area. The researchers used readability formulas developed by foreign authors to determine the readability levels of textbooks and modules used in schools. They also classified books according to appropriate grade or year levels. The Flesch formula was used by Espafiero (1976), Lagarde (1984), Young (1991) and Cafiares (1992). The Fry, procedure was applied by Perez (1982), Talisayon (1983) and Young (1991). The Dale-Chall method was used by Espartero (1976) and Talisayon (1983).

The above formulas used were all developed using popular English language (Canares, 1992) and popular reading materials as samples. Thus, a formula developed and validated for technical materials and content areas like physics may prove more appropriate for science materials. Also, adjustments for readability levels have to be done for Filipinos since the above formulas used readability levels based on English as a first language. Readability level standards that consider English as a second language may be more helpful for local purposes.

In addition, these readability tests were limited to the use of a word list Dale-Chall and variables such as word length and sentence length (Flesch, 1948) and Fry (1968, 1977) as indicators of readability. Some scholars claim that qualitative variables such as syntax, complexity of ideas, cohesiveness of discussion, reinforcement through restatement and repetition, writing style, and student interest and motivation are neglected (McConell, 1982).

A local instrument to estimate readability developed by Talisayon (1983)1 Called the feedback-based communication index, it departs from the use of a word list or an outright formula. It requires readers to mark unclear elements of a reading material. The incidence of unclear elements in a material establishes the communication index.

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Estimating readability by this method relies on whether the readers I indeed mark unclear elements and do it consistently and accurately. Forgetting to mark unclear elements leads to an overestimate of readability. Marking elements which are clear as unclear, on the other hand, underestimates readability. The method also requires a number of readers to establish a valid measure.

The present study is an attempt to develop an instrument to estimate the readability of physics instructional materials based on Filipino reader standards and on a content, area using technical English, especially physics. For this purpose, a combination of Filipino- and foreign-authored materials were used as samples. The Filipino grade and year level system were also used for reckoning readability levels. Since the respondent-judges were Filipinos, the judged readability levels were most likely leveled on English as a second language.

This study aimed to develop and validate a readability formula for physics instructional materials. It sought to determine measurable variables which significantly contribute to the prediction of the readability of physics instructional materials.

Materials and Methods

The formula was developed using the quantitative associational method. This method uses the stepwise multiple regression procedure. The judged readability levels of sample passages were the criterion variable.

A sample of 30 passages with no less than 100 words each were carefully chosen from books used in elementary, secondary and college levels in Philippine schools.

The passages were taken from 17 books and one lecture manual for a total of 18 sources. Of these, 14 were Filipino-authored and 4 were foreign authored. Four of these sources were used in elementary, six in high school and eight in college.

Each of the elementary books were used by Grade Il, Grade Ill, Grade IV and Grade V pupils. Five of the high school books were used by seniors and one by freshmen. Of the eight college level books, five were used by nonscience majors, two were used by science majors and one by engineering and science students.

Grade Level	Readability Level
Primary Grades, Elementary	4
Intermediate Grades, Elementary	6
First and Second Year, High School	8
Third and Fourth Year, High School	10
First and Second Year, College	12
Third and Fourth Year, College	14
Advanced/Graduate Level	16

If the passage was easily understood by primary grade pupils, the readability level of the material was 4. If the passage was easily understood by intermediate grade pupils, the readability level was 6. If the material was best suited for first- and second-year high school students, the readability level was 8; and so on. The readability levels correspond to the grade and year levels in the Philippine educational system. The lowest level (Level 4) corresponds to the primary grades while junior to senior high school level corresponds to Level 10. Level 16 which corresponds to advanced or graduate level was included to allow a wider range for judges.

Of the 21 judged readability level entries, the three highest and three lowest values were excluded to reduce bias and variability. Thus, only 15 entries were used to compute the mean readability level for each passage. This mean was considered the readability level for that •passage and was used as the criterion variable.

To boost the validity of the judges', responses, the purpose of the study was verbally explained to them. The scale for judging was likewise discussed and verbal queries were entertained and answered.

The readability of the judges' responses was also determined to ascertain the stability of the judged readability measures. First, the readability index using the Cronbach alpha was computed for all the judges taken individually. Second, it was computed for the judges grouped according to the levels they taught at (elementary, secondary and college). Finally, it was computed with judges grouped into their fields of teaching (English or Science). The Cronbach alpha magnitudes for all measures were consistently high indicating that the _judges' responses to the judged readability level have high stability which showed that judged readability levels are a valid measure of readability level.

After identifying the factors of readability, the -readability formula was developed. The first step was to run a multiple linear regression model using all independent variables as predictors with readability level as criterion.

Factor analysis was used for data reduction with the intention of identifying a lesser number of variables.

Results and Discussion

Development of the formula

The panel was composed of 18 science and 3 English teachers for a total of 21. Eleven (11) taught at the collegiate level, seven (7) at the secondary level and three (3) at the elementary level. They had a mean age of 40 years. the youngest being 29 and the oldest 53. They taught or were involved in education for an average of 18 years. The youngest taught for nine (9) years while the oldest taught for 29 years, Of the 21 judges, thirteen (13) had a master's degree while four (4) had doctorate degrees. Only four (4) had a bachelor's degree and each earned academic units leading towards a graduate degree.

Eleven of the judges had written instructional materials in the form of laboratory and/or lecture manuals used mostly in their own institutions. Four have published textbooks, all in the secondary level. The sample passages were shown to the panel of judges who were asked to accord each passage its most suitable readability level.

The full model. The full model which included all the ten independent variables as predictors is shown in Table 1. The model accounted for 85.03% of the total variance and the adjusted percentage of variance explained was 77.16%. The latter was a preferred measure of goodness of fit because it was not subject to the inflationary bias of unadjusted R^2 (Norusis, 1988).

Table 1. Multiple regression model using 10 independent variables as predictors of readability

Variables in the equation					
Variable	**B**	**SE B**	**Beta**	**T**	**Sig T**
PPEPS	0.0217	0.0205	0.2208	1.0610	0.3019
GRA	0.1915	0.4767	0.0427	0.4020	0.6924
PWAP	0.0122	0.0801	0.0422	0.1500	0.8821
MEQ	-0.2463	0.6248	-0.0531	-0.3940	0.6978
PDCW	-0.0398	0.0447	-0.1065	-0.8890	0.3852
AWL	-1.2220	1.3622	-0.1152	-0.8970	0.3809
PWSP	0.0946	0.0493	0.2851	1.9170	0.0704
ASL	0.1003	0.0261	0.6203	3.8410	0.0011
PPEPW	-0.1659	0.1602	-0.2154	-1.0360	0.3133
PMW	0.0814	0.0986	0.2684	0.8260	0.4190
Constant	6.8470	2.1556		3.1760	0.0050
Multiple R	0.9221				
R Square	0.8503				
Adjusted R Square	0.7716				
Standard Error	1.0858				

This model, however, does not lend itself to easy administration if it were to be accepted as the readability formula. It would be too cumbersome for one to plug in values of the ten predictor variables and to undergo the tedious process of measuring each of them. Hence, the next better choice was to consider the model which included only the surrogate variables.

Choosing surrogate variables. Factor analysis was used for data reduction with the intention of identifying a lesser number of variables which significantly approximate the model when all variables are considered. Factor analysis came up with three factors of readability, thus indicating three surrogate variables.

The full model shown in Table 1 included the beta weights of each predictor surrogate variable. The variables with relatively large contributions were: average sentence length (ASL), percentage of mathematical words (PMW), percentage of words specific to physics (PWSP), percentage of PEP (People, events, places) sentences (PPEPS), and percentage of PEP words (PPEW), all with standardized beta weights exceeding 0.200Ö. Both ASL and PMW belonged to a factor, PWSP belonged to another factor, and PPEPS and PPEPW to a third factor. ASL and PWSP had the highest significance. ASL contributed more to the regression model than did PMW, and PPEPS contributed better to the regression model than PPEPW as indicated by their beta weights. Thus, the logical choice for surrogate variables were: ASL, PWSP and PPEPS

Readability formula using the surrogate variables. When a multiple regression model (Table 2) was run using the surrogate variables, the resulting equation accounted for 76.52% of the total variance. The adjusted proportion of variance explained was 73.18% which Was not at all bad when compared to the 85.03% variance accounted for by the full-scale model (Table l).

The beta weights indicated the greatest contribution by average sentence length (ASL) at 0.6920 followed by percentage of words specific to physics (PWSP) at 0.2862. The contribution of percentage of PEP sentences (PPEPS) was negligible and insignificant.

Backward regression analysis further simplified the model (lower ha of Table 2) because PPEPS did not significantly contribute to the three-variable model. It was removed following a backward step. The resulting model included only ASL and PWSP which accounted for practically the same amount of variance (76.47% compared to the previous 76.52%). The adjusted amount of variance accounted for improved from 73.81 % in the former model to 74.73% in the latter in spite of the removal of one predictor variable (PPEPS). This model is considered the first plausible formula. Using the computed beta coefficients, it is written as:

$$RLP = 5.3355 + 0.1118\ ASL + 0.0926\ PWSP$$

This formula is named Readability Level using Physics words, RLP for short.

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Table 2. Multiple regression model using surrogate variables as predictors of readability

Using all surrogate variables in the equation					
Variable	B	SE B	Beta	T	Sig T
PPEPS	0.0022	0.0099	0.0225	0.2230	0.8249
ASL	0.1119	0.0183	0.6920	6.1180	0.0000
PWSP	0.0949	0.0389	0.2862	2.4380	0.0219
Constant	5.2494	0.6319		8.3080	0.0000
Multiple R 0.8747 R Square 0.7652 Adjusted R Square 0.7381 Standard Error 1.1626					
Using significant variables in the equation					
Variable	B	SE B	Beta	T	Sig T
ASL	0.1118	0.0180	0.6912	6.2240	0.0000
PWSP	0.0926	0.0368	0.2791	2.5130	0.0182
Constant	5.3355	0.4915		10.8480	0.0000
Multiple R 0.8745 R Square 0.7647 Adjusted R Square 0.7473 Standard Error 1.1420					

factor the variables were classified with. The results are shown in Table 3.

The significant predictors that came out were average sentence length (ASL) and percentage of mathematical words (PMW). The equation was able to account for 80.81% of the total variance. This was about 2 percentage points higher than that of the previous equation. The adjusted R2 of 79.39% was also substantially higher than that of the previous equation which had 74.73%.

Table 3. Final result of stepwise multiple regression using all independent variables as predictors of readability

Variable	B	SE B	Beta	T	Sig
ASL	0.1027	0.0163	0.6350	6.2830	0.0000
PMW	0.1140	0.0306	0.3761	3.7220	0.0009
Constant	5.7805	0.4194		13.7820	0.0000
Multiple R 0.8990 R Square 0.8081 Adjusted R Square 0.7939 Standard Error 1.0313					

This equation also had a more balanced distribution of standardized beta weights: ASL with 0.6350 and PMW with 0.3761. This meant that PMW contributed better in the regression model than did PWSP in the previous equation. The residual sum of squares for this model also decreased which meant that this model better fitted the data.

Using the computed beta coefficients, this equation is written as;

$$RLM\ 5.7805 + 0.1027ASL + 0.1140\ PMW$$

This second formula is named Readability Level using Mathematical words, RLM for short.

Compromise readability formula. The improvement of the regression model with PMW in the equation, instead of PWSP, hinted that both variables contributed well to the prediction of readability along with ASL.

A backward regression analysis of all variables supported this. When most of the variables were eliminated in the backward regression procedure, the last three left in the equation were: ASL, PMW and PWSP, in that order.

The equation which included the three predictor variables accounted for 82.18% of the total variance, 2 percentage points improvement from that where only ASL and PMW were in the equation and 6 percentage points improvement than when only ASL and PWSP were in the equation. The adjusted R2, however, did not improve as much with a negligible difference of 0.74%.

The standard beta weights also showed that each variable substantially contributed to the regression model. ASL had a beta weight of 0.5869 and PMW had 0.3136. PWSP had a beta weight of 0.1524 which was relatively substantial despite having a non-significant t-value.

Using the computed coefficients, this third formula can now be written

$$RLMP = 5.5516 + 0.0949ASL + 0.0951PMW + 0.0506PWSP$$

This equation is named Readability Level using Mathematical and Physics words, RLMP for short.

The JB Readability Formula

Choosing the best readability formula was not easy. Ultimately, the bases for the choice did not entirely rest ort statistical formalism. The plausibility and perceived sensitivity of the formula to measure readability factors inherent in content area texts like physics were considered.

While readability researchers generally recommend the sufficiency of two predictor variables in a readability equation, the present work opted for the inclusion of three. These variables were measures of sentence length and vocabulary (mathematical words and words specific to physics). This was not only due to the variables' significant contribution to prediction. It was also based on the pretext that concept formation for abstract technical concepts, like those that were embraced by the vocabulary variables

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in the equation, is long and tedious. Thus, including three variables can help focus on the special features of science instructional materials which are characterized by the incidence of technical vocabulary.

The best single predictor variable, average sentence length (ASL), commonly appears in numerous readability formulas. This variable invariably relates positively with readability. This is because long sentences usually carry

more ideas or words and are likely to be more complex in their sentence structure.

Average words length (AWL) which prominently figured in other readability formulas like Flesch and Fry did not come out significant in the present work. Instead, other variables, proportion of mathematical words (PMW) and proportion of words specific to physics (PWSP), came out as better predictors of readability. These variables were not found in other formulas. The entry of these variables in the present formula could make it a legitimate measure of readability for a content area. like physics. Being a specialized field, physics is fraught with distinct words like those characterized in the formula. Both groups of words require previous exposure for an accurate understanding.

Mathematical words have a wide range of idea complexity, from a simple and common concept like addition, circle or line to more sophisticated and -complex process words such as integral or exponential. Words specific to physics carry technical meanings. These. are usually abstract and subtle and requires time for concept formation.

This can also be true to other content areas that require extensive use of mathematics as a tool for developing its internal concepts. Physics as a special subject area progressively introduces mathematics along with the development of ideas. Physics is rigorously associated with mathematics which is extensively used as a tool in developing physics ideas and concepts. Most physics concepts are, in fact, mathematical in nature.

Validity of JB Formula

Among the formulas, the Flesch and Fry as a pair measured readability very similarly. The results also indicate that the communication index formula, the JB formula as well as the Flesch formula measure the same thing. Between the Flesch formula and the JB formula, the significant relationship can be attributed to a common variable, average sentence length (ASL).

The significant relationship between the communication index and the JB formula could be indicative of the latter's sensitivity to identify words and sentence factors which agree with what readers consider as unclear. These are technical vocabulary represented by PWSP, quantitative relations represented by PMW and sentence factor represented by average sentence length (ASL).

Previous results by Talisayon (1983) showed a different result where the communication index had little or practically no correlation with the Flesch and Fry formulas. The study explained that factors like reader characteristics gleaned through reader feedback could play a significant role in estimating readability beyond sentences and words, which can be especially true for content materials like physics.

The significant relationship of the JB formula with scores in a reading comprehension test can be explained by the common notion that easier reading materials are easier to understand which, in turn, translated to higher reading comprehension. Difficult reading materials, on the other hand, are harder to understand and impedes reading comprehension.

The above significant relationship shows the ability of the formula to classify passages according to difficulty. This result also demonstrates the capability of the developed formula (JB Formula) as a valid model for measuring readability.

Limitations of the Formula

The developed readability formula, the JB formula, was formulated based on the average reader's perceived readability level. The resulting readability levels in which materials may be classified by the formula is based on a scale where the average reader is the presumed audience. Hence, the formula may not necessarily appeal to the specialist's or expert's demands. This means that the expert would likely find a. reading passage full of mathematical words and equations as well as words specific to physics more readable because this is the language he has been accustomed to. Not so. for the average reader.

Second, the formula's intercept has a magnitude of 5.5516. This value limits the formula's sensitivity to readability levels below this mark. It is, therefore, unable to classify materials to the various elementary grade levels though it is capable of classifying some materials suitable to elementary grade pupils as a whole. The formula, however, appears to be capable of classifying advanced level texts, as the variables in the predictive equation are open to measures beyond those that were encountered in this study. For this reason, future readability researchers should explore whether the developed formula is indeed capable to do this and with what level of accuracy.

The fact that the predictor variables in the formula included only sentence and vocabulary measures may be considered as a limitation to the JB formula. The formula does not include measures of readability variables as writing style, organization, syntax and the tike. One can, however, consider the results of the validating procedure involving the feedback-based communication index which showed a high and significant correlation with the current formula.

Finally, one who expects the JB formula to predict absolute readability levels is in for a disappointment. The formula can only calculate readability estimates and may, in some cases, be far off from the true readability level. It should be noted that

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even readability levels are, in themselves, plain ordinal classifications.

Procedure in Using the JB Formula

1. Randomly select passages of at least 100 words. The passages should preferably be a complete paragraph or paragraphs depicting a complete idea. If one desires to determine the readability of an entire book, take at least one or two passages from each chapter. If one desires to determine the readability of a chapter, take at least one passage for every 10 pages.

2. Count the number of syllables in the passage. A syllable is defined as a phonetic syllable. Generally, there are as many syllables as vowel sounds. For example, stirred is one syllable and wanted is two syllables. Numerals, initialization and equations are given one syllable for each symbol. Thus, 1992 is four syllables, DLSU is four syllables, F = ma is four syllables and % is one syllable.

3. Count the number of sentences in the passage. Determine the average sentence length (ASL): ASL (no. of syllables)/ (no. of. Sentences)

4. Count the number words. Word is defined as a group of symbols with a space on either side. Thus, Juan, DLSU, 1992 and % are each one word. An equation is also considered a word and so is a term taken as an independent entity in a passage.

5. Count the number of words specific to physics (WSP). WSP are words marked by specific scientific (physics) interpretation. For example, work is a word specific to physics when used in a technical sense, but is not when used as an ordinary layman term. Wave function, when used as the mathematical quantity that describes a wave, is a phrase specific to physics. This term is counted as two words. Wave, taken by itself as a verb, is not a word specific to physics. Function, taken by itself to mean "role", is not a word specific to physics. Solve percentage of words specific to physics (PSWP) using:

   PWSP 100 (no. of WSP) / (no. of words)

6. Count the number of mathematical words. This is defined as any word that implies any mathematical operation, relationship or description. These include such words as addition, square root, proportional to, ratio, vector, circle, line, etc. a mathematical equation is considered as a syllable. Any symbol or quantity used in the equation which is mentioned as a separate entity in the text is considered as a word. Then compute the percentage of mathematical words (PMW):

   PMW 100 (no. of MW) / (no. of words)

7. Compute the Reading Difficulty Score:

   PDS = 5.5516 + 0.0949ASL + 0.0951PMW + 0.0506PWSP

8. Classify the passage/chapter/book using the following scale:

Grade Level	**Readability Level**
Elementary grades	Less than 6.50
First and Second Year,	High School 6.51 8.50
Third and Fourth Year,	High Schools 51 - 10.50
First and Second Year, College	10.51 - 12.50
Third Year, College and beyond	Beyond 12.50

Summary and Conclusions

Multiple regression analysis resulted in three equally plausible readability formulas. The first equation is based on surrogate variables of the three factors, the second is based on a stepwise regression analysis of all the variables and the third is a compromise between the two formulas. These are, respectively:

a) RLP: Reading Difficulty Score = 5.3355 + 0:1118 ASL + 0.0926 PWSP
b) RLM: Reading Difficulty Score = 5.7805 + 0.1027 ASL + 0.1140 PMW
c) RLMP or JB Formula: Reading Difficulty Score 5.5516 + 0.0949 ASL + 0.0951 PMW + 0.0506 PWSP

Various statistical measures used to select the best model showed that the third equation, RLMP or JB Formula, best fitted the data, has the widest range of prediction and the least residual. It was subsequently selected as the developed readability formula and renamed as the JB Formula.

Validation of the JB Formula yielded the following results: the JB formula had significant relationships with the Flesch formula, the communication index formula and reading comprehension scores.

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