AC 2010-1808: STEPWISE METHOD FOR DEAF AND HARD-OF-HEARING STEM STUDENTS IN SOLVING WORD PROBLEMS

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StepWise Method for Deaf and Hard-of-Hearing STEM Students in Solving Word Problems

Abstract

At National Technical Institute for the Deaf (NTID), a large percentage of the deaf / hard of hearing (d/hh) students enrolled in college level studies are challenged by their English and mathematical skills.[1] Because of these two critical skills areas, they struggle to master the interpretation of a word problem or written instructional manuals to a problem in order to derive a correct solution.

The StepWise procedural method was developed as a general step-by-step guideline for students to follow in solving a scientific, technological, engineering, or mathematical problem or the instructions of a word problem. The goal was to help d/hh STEM students focus on their English, mathematical and critical thinking skills while they sort through word problems. Based on several observations, some d/hh students who benefit from this method appear to have increased comprehension of the steps necessary to solve a word problem. If the resulting answer does not match the expected answer, StepWise allows students to redo the process.

This StepWise method was developed and implemented during the winter of 2009 when the students struggled in an engineering course with physics and math emphases. This method will be tested in other engineering and information technology courses. In some programming courses, this method is available to students who develop software and web applications. Other applications are under investigation.

Results for students who utilized the StepWise method will be presented and discussed. While the preliminary findings look promising, more work needs to be addressed. The goal of this paper is to share the preliminary findings and to collect feedback from the instructors at the conference.

Background

At NTID, a large percentage of the deaf / hard of hearing (d/hh) students enrolled in college level studies are challenged by their insufficiently developed English and mathematical skills. Because of a weakness in these two critical skills areas, they struggle to understand word problems and instruction manuals, which make it very difficult for them to find correct solutions.

It has been well documented that the majority of the deaf population has some degree of reading and writing challenges. The root of the problem is a lack of communication, especially during the early years. In our society, hearing people acquire their first language from what is spoken around them, chiefly from their parents and from other children. English as a spoken language is very rich, and with our technologies, people gather information through various audio mediums. Even considering syntax, spoken language usually has its own set of grammatical patterns that may be quite different from written language. Being deaf, especially at birth, affords a person very limited ways to acquire the language through hearing and speaking.

Educators have struggled to find new ways to teach deaf students reading and writing. There is extensive research addressing these challenges. In a nutshell, the sooner those deaf children develop personal communication with family and community, the better the opportunity for the children to acquire the language with reading and writing skills. "Communication is the tie that binds children to parents and to society and that provides for social and academic education. There is no aspect of educating deaf learners-from infancy to adulthood-that does not depend on or benefit from clear and accessible communication."[2]

The most common approach is to provide deaf children an early intervention with listening devices such as cochlear implants and to start speech training at a very early age. Another method that has been proven to be successful is to teach deaf children sign language when they have normal vision. The challenge is for parents and family to learn sign language. It is not possible to learn sign language in a short period of time. The family could start learning as soon as they find out that the baby is deaf or hard of hearing but it will require effort. There is nothing new about these approaches and unfortunately, they have not always proven to be very successful. Even today, a large percentage of the deaf community has reading comprehension and writing deficits and this has not changed much over the past 30 years.[3]

When deaf or hard of hearing students arrive at college, they have high expectations of themselves for completing bachelor's and graduate degrees.[4] The research led by Cuculick and Kelly has shown through statistical analysis that only about 17% of incoming deaf students at NTID, 2001 and 2002 had the requisite reading and language skills to enter a baccalaureate program in their first year. Also, with the same data, it indicated that at NTID it takes longer for the deaf students to complete Associate of Occupational Studies (AOS), Associated of Applied Science (AAS), or Bachelor of Science (BS) degrees.

Because of challenges with reading comprehension and writing skills, deaf people face other challenges in learning mathematics word problem solving. Many NTID STEM students have to start with entry-level mathematics as a pre-requisite before they can begin their major in technical or engineering programs. The findings from one source of educational research show that regardless of instructional settings, deaf students are not being sufficiently engaged in a cognitively challenging word problem situation.[5]

A Structured Approach

The StepWise procedural method was developed as a general step-by-step guideline for students to follow in solving a scientific, technological, engineering, or mathematical word based problem. The goal was to help d/hh STEM students use their English, mathematical and critical thinking skills while they sort through word problems. Based on numerous observations some d/hh students who benefit from this method can comprehend and do what is necessary to solve a word problem. If the resulting answer does not match the expected answer, the StepWise method allows students to correct their mistakes and redo the process until an acceptable answer is achieved.

After studying incorrect student answers to multiple word problems, several patterns emerged. Students struggled with selecting the correct formula to use and also in applying them after selection. Specific mistakes included:

- o Selecting wrong formula
- o Using mixed units, i.e.:
  - Seconds/minutes/hours
  - English/metric
  - Inches/feet/miles/kilometers
- o Using conversion factors 'upside down' (60 sec/min vs. min/60 sec)
- o Using wrong data type when programming, i.e.:
  - Integer/real/text string
  - Constants/variables
- o Unable to solve if several steps are required (two unknowns)
- o Algebraic mistakes
- o Inability to estimate if answer is reasonable
- o Basic magnitude errors
- o Incorrect units errors (i.e., ft^2 for volume, ft/min^2 for speed, etc.)

In order to assist students in avoiding these mistakes, a structured, step-by-step procedure was created for approaching and solving word problems. With this ordered process we seek to:

- o Help students in selecting the correct formula to use
- o Provide ways to select the best sequence order for solving multi-answer problems
- o Provide specific steps to follow
- o Remind students to unify units
- o Improve estimation skills and reasonableness checking

With these goals in mind, the StepWise method was developed. The StepWise approach will now be shown and a specific example will be demonstrated.

StepWise Method

1. List the desired goal for the problem (the 'unknown' or what is being asked for) including units. If there is more than one question, list all of the unknowns.
2. List all known and unknown values (numeric value)
3. Look at possible formulae for solving problem
4. Pick a formula that has one goal symbol (unknown) while all other symbols are known
5. If units do not match (both feet and inches OR English and metric OR minutes and seconds, etc.) convert values so that all are the same and match the goal
6. Simplify by eliminating any known zero values and, using algebra, rearrange formula (symbols only) so that the single unknown is isolated on the left side of equation
7. Insert known values for symbols *including units*
8. Solve using algebra, carefully preserving all units
9. Check result by substituting the result into the original formula
10. If the answer is wrong or not reasonable, or units in the answer do not match expected values, redo steps 4-9

Repeat steps 4-9 for next part of the question (if needed)

A specific illustration follows: A car is traveling at 60 mph. The brakes are applied uniformly and the car comes to a stop in 15 seconds.

A) What is the acceleration rate in feet/sec^2?

B) How many feet did it take to stop?

Step	Example
1) List the desired goal for the problem (the 'unknown' or what is being asked for) including units; If there are more than one question, list all of the unknowns	A) Acceleration (a) = ? ft/sec^2 B) Stopping distance (s) = ? ft
2) List all Known and Unknown values	*Known* Time t = 15 sec Initial Velocity v_0= 60 mph Final Velocity v = 0 mph *Unknown* Distance s = ? ft Acceleration a = ? ft/sec^2
3) Look at possible formulae for solving problem	$s = v_0 t + \frac{1}{2} at^2$ $v = v_0 + at$ $v^2 = v_0^2 + 2as$ (from Newton's laws of uniformly accelerated motion)
4) Pick a formula that has one goal symbol (unknown) and all other symbols known	$s = v_0 t + \frac{1}{2} at^2$ two unknowns (skip) $v^2 = v_0^2 + 2as$ two unknowns (skip) $v = v_0 + at$ only one unknown (OK)
5) If units do not match (both feet and inches OR English and metric OR minutes and seconds, etc.) convert values so that all are the same and match the goal units	60 mph (does not match feet or seconds) 60 miles/hr x 5280 ft/mile x 1 hr/ 3600 sec v_0 = 88 ft/sec
6) Simplify by eliminating any known zero values and, using algebra, simplify and rearrange formula (symbols only) so that unknown is isolated on the left side of equation	$v = v_0 + at$ (v = 0 so substitute) $0 = v_0 + at$ $at = - v_0$ $a = (-v_0)/t$ (unknown isolated on left)
7) Insert known values for symbols INCLUDING UNITS	a = (-88ft/sec)/15sec
8) Solve using algebra, carefully preserving all units	a = (-88ft/sec)/15sec a = -5.87 ft/sec^2 NOTE: a is negative because deceleration instead of acceleration
9) Check result by substituting the result into the original formula	$v = v_0 + at$ 0 = 88ft/sec + -5.87 ft/sec^2 * 15 sec 0 = 88ft/sec - 88 ft/sec 0 = 0 checks (Ok)
10) If the check fails or the answer is not reasonable or units in the answer do not match expected values, redo step 4-9	Checking units a = ? ft/sec^2 a = -5.87 ft/sec^2 (Ok)

Answer to part A) Acceleration = -5.87 ft/sec^2

Repeat steps 4-9 for part B) of the question.

Step	Example
4b) Pick a formula that has the goal symbol (unknown) and all other symbols known	$s = v_0t + \frac{1}{2}at^2$ only one unknown (OK) $v = v_0 + at$ all known now so ignore $v^2 = v_0^2 + 2as$ only one unknown (OK) Either 1st or 3rd will work. I choose 3rd
5b) If units do not match (both feet and inches OR English and metric OR minutes and seconds, etc.) convert values so that all are the same and match the goal units	From previous step 5 $v_0 = 60$ mph $= 88$ ft/sec
6b) Simplify by eliminating any known zero values and, using algebra, rearrange formula (symbols only) so that unknown is isolated on the left side of equation	$v^2 = v_0^2 + 2as$ $0 = v_0^2 + 2as$ $2as = -v_0^2$ $s = (-v_0^2)/2a$
7b) Insert known values for symbols INCLUDING UNITS	$s = (-v_0^2)/2a$ $s = (-88 \text{ ft/sec})^2/(2 * -5.87 \text{ ft/sec}^2)$
8b) Solve using algebra, carefully preserving all units	$s = (-7744\text{ft}^2/\text{sec}^2)/(-11.7 \text{ ft/sec}^2)$ $s = 660$ ft
9b) Check result by substituting the result into the original formula	$v^2 = v_0^2 + 2as$ $0 = (88\text{ft/sec})^2 + 2*(-5.87\text{ft/sec}^2)*660$ ft $0 = (7744\text{ft}^2/\text{sec}^2) - (7744\text{ft}^2/\text{sec}^2)$ $0 = 0$ checks (Ok)
10b) If the answer is not reasonable or units in the answer do not match expected values, redo step 4-9	$s = ?$ ft $s = 660$ ft (Ok)

Answer to part B) Stopping distance = 660 ft

For any word problem, students will need to have memorized, be given, or know how to find all of the formulae needed to solve the problem. Just listing the known and unknown values (step 2) can help students get a better "big picture" view of the problem. Step 4 is something many students struggle with on their own. By comparing the list of known and unknown values with the potential formulae, and looking for a formula with only one unknown, the selection process becomes clear. Unifying units in step 5 can be supported by in-class and homework activities specifically focused on conversions from metric to/from English, and in making sure all units of a specific dimension are the same. For the previous example, speed was given in miles per hour but the desired answer for acceleration was in feet per second[2] so both distance (miles to feet) and time (hours to seconds) conversions were needed before solving the problem. For step 8 it is best to emphasize the importance of including units when applying algebra because arriving at an answer with incorrect units is usually an indication that either a wrong conversion factor was used or an error in algebra has occurred. Students often ignore units and just use numbers thus masking common mistakes. Another step often omitted is simply substituting the answer back into the original formula to see if the equation is true.

Findings

Before developing the StepWise process, the authors used examples and illustrations from textbooks and supplementary materials such as Schaum's Outline Series: Theory and Problems of Engineering Mechanics including fully solved problems. Students continued to struggle with word problems. After development of worksheets outlining the StepWise method, the authors made comparisons in two different courses: Digital Logic, and Industrial Electronics, students using the StepWise worksheets scored 14% higher than those without on quiz word questions. The results look promising. One challenge encountered in this study was locating enough d/hh students to form two groups to make meaningful comparisons. A more longitudinal study will improve the accuracy and usefulness of the results. In the spring quarter, the evaluation will be applied in several different courses such as System Troubleshooting, Programming, PC Hardware / Software, Computer Concepts and Mechanical Devices and Systems courses. The goal of this paper is to share the methodology and to collect feedback from instructors at the conference.

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