ENHANCING STUDENT LEARNING IN SOLVING WORD PROBLEMS
IN THERMODYNAMICS BASED ON
NEWMAN’S ERROR ANALYSIS

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ABSTRACT

In this study, Newman’s Error Analysis procedure was used to identify the errors of the students in solving mathematical word problems in Thermodynamics. From these errors, a study guide was designed to enhance the students’ learning in the course. A pre-test and post-test research design was adopted. Eight students enrolled in a degree course in Thermodynamics participated. The pre-test (diagnostic test) helped in identifying the root cause of students' poor performance in solving mathematical word problems. A post-test analysis determined that the intervention (a developed study guide) had a significant effect on performance. The findings of the study confirmed that effective and efficient Thermodynamics pedagogy requires the utilization of a programmed instruction (e.g. a developed study guide) in addition to textbook-based lectures. Exercises used in the study guide were based on Newman’s Error Analysis Pattern. Further, the results showed that the construction of a study guide is the foremost consideration.

The development and utilization of a high-quality study guide poses a number of challenges for instructors however, these efforts are worthwhile, given the beneficial effects for the learning of the students.

Keywords: Newman’s Error Analysis (NEA), Thermodynamics pedagogy, solving word-problems, developed study guide, mathematical errors.
Justification and Design of the Study

Thermodynamics is one of the fundamental courses in the engineering curricula. It is defined as the branch of physics that deals with the relationships between heat and other forms of energy. In particular, it describes how thermal energy is converted to and from other forms of energy and how it affects matter (Lucas, 2015). Engineering and scientific disciplines such as Material Science, Chemical Engineering and Petroleum Engineering requires a good understanding of Thermodynamics.

Smith (2004) claims that the complexity of Thermodynamics concepts results in learners having negative feelings toward the subject. Students think that failure to understand the concepts for the first time, will result in failure to understand the succeeding lessons. Thus, students see themselves as failures right from the beginning. Students’ perception towards the subject adversely affect engineering education in general, given that many students are not motivated to learn the subject.

Mathematical word problem solving is a central skill in subjects such as thermodynamics and engineering (Cummins, 1991 in Seifi et al., 2012). Normally, real-word problems that call for mathematical solutions are not presented as equations ready to be solved but instead as word or pictorial illustrations that need to be symbolically rendered, operated and solved. Verschafel et al. (2000, in Seifi et al., 2012) describe word problems as verbal descriptions of problem situations in which one or more questions are raised, the answers to which can be obtained by using of mathematical operations to numerical data available in problem content. Word problems provide one avenue for the development of understanding and, at the same time, provide the opportunity to enhance computational skills with application to actual or simulated problems (Ballew & Cunningham, 1982). Mathematics word problems in Thermodynamics mostly deal with associating real-world situations to engineering concepts. Indeed, working on those problems helps students to use their thermodynamics knowledge in addressing their day-to-day practical problems as well aside from given them the enough computational and analytical skills (De Corte et al., 1989 in Seifi et al., 2012).
However, students can experience difficulties in grasping the concept and maths in general (Klymchuk, 2010; Medallon et al, 2012; Morgan, 1990; Mullen, 2015), which places them at some risk in their learning. Seifi et al. (2012) studied tutors’ perceptions of the problems students encounter in word problems. The study showed that representation and understanding the problems are some of the pressing concerns. Tutors also reported students’ inability to come up with a plan to solve the problem, inadequate vocabulary knowledge and computation as prime reasons.

Ballew and Cunningham (1982) reported that students generally acknowledge that word problems are difficult to solve. When the researcher solicited experiences on the difficulties in solving word problems of some students who had already done with their Thermodynamics at Southern Institute of Technology, Invercargill, New Zealand, the common responses are: difficulty in analysing the problem, too many formulae to memorise and difficulty in identifying which formula is to be used, and translation of the word problem to mathematical expression. These difficulties experienced by the students eventually led them to errors in solving word problems.

Given the importance and function of word problems in engineering education, it is problematic that learners may not succeed at mathematical subjects, particularly Thermodynamics that uses word problems.

The present study was guided by the notion that topic practicality and simplicity may help realise the goal of eliminating students’ fear towards Thermodynamics. To this end, it was thought that working closely with students to try and identify errors they might be making in computation might provide a means to rectifying problems and improving confidence.

To identify student errors in mathematical word problems, Newman’s Error Analysis procedure was used. Newman’s Error Analysis was developed in 1977 by the Australian educator, Anne Newman. Since then it has been applied to mathematics pedagogy worldwide (Clements & Ellerton, 1996). Applying the technique to Grade 3 and Grade 5 Filipino learners, Jimenez (1992) conducted a cross-lingual study of children’s processing of mathematical word problems. In a more recent study set in...
Australia, White (2010) employed Newman’s method as a diagnostic tool linking numeracy and literacy and as a remediation and general teaching strategy for primary and secondary schools. Indeed, the foregoing studies have consistently demonstrated the flexibility and robustness of Newman’s Error Analysis. The approach seeks to identify the errors that students are making in solving mathematical word problems. These are:

- **Reading Errors (R).** These errors are committed when the student could not read a key word or symbol that prevented him/her from proceeding further.
- **Comprehension Errors (C).** In these types of error, the student can accurately read all the words in the question but lack the comprehension on the sentence level.
- **Transformation Errors (T).** Here the student cannot identify the operation, or series of operations.
- **Process Skills Errors (P).** This type of error is committed when a student cannot identify the appropriate operation, or series of operations, but do not know the specific measures to perfectly apply these operations.
- **Encoding Errors (E).** In this type of error, student worked out the solution to a problem, but could not present the solution in an acceptable written form.

The process consists of asking the student the following questions in order to identify errors they might be making:

- **R:** Read the question.
- **C:** What is the question asking you to do?
- **T:** What method you are going to use to find the answer?
- **P:** Go through the steps you did and tell about your thinking.
- **E:** State the answer to the question.

Engaging students to be involved in reflecting on how they are learning is consistent with a constructivist approach. According to Khalid and Azeem (2012), constructivism is a learning framework that assumes learning as an active, contextualised, or constructive process. It was thought that engaging students in the learning process might help them overcome negative responses to learning thermodynamics.
The Value of Well-Designed Instructional Materials

Learning is not a unitary skill but a complex process. There are several factors that affect learning. Aside from the teacher, one of the things that greatly affects the teaching and learning process is the instructional material. Hence, it is a challenge on the part of the teacher to select appropriate material that will be reflective and responsive of the students’ diverse background. Given the important role the instructional material plays in learning, a thorough analysis of what particular material is needed for engineering education is required. According to Smith and Ragan (1999), there are three activities in instructional design. These are: (1) Perform the instructional analysis; (2) Develop an instructional strategy; and (3) Develop and conduct evaluation.

Anderson et. al. (2011) noted that both the hierarchy of errors identified by Newman and the revised Bloom’s Taxonomy are related given the similarity on their nature and structure. The revised Bloom’s Taxonomy by Anderson et al (2011), include the following cognitive domains: remembering, understanding, applying, analysing, evaluating, and creating. The same authors illustrated how the cognitive domains in Bloom’s Taxonomy are associated with Newman’s Error Analysis. Figure 1 in the succeeding page shows how the domains in Bloom’s Taxonomy are related with Newman’s Error Analysis.

While the different forms of thinking advanced by Anderson et al. (2001) follow a hierarchical structure like that of Newman’s, they differ on the presentation of ‘applying’ and ‘analysing’. Despite that slight difference, Newman’s Error Analysis Procedure can still be categorized as cognitive skill acquisition.

It is of significant scholarly interest to explore students’ reasons for committing mistakes and for constantly committing the same mistakes. Error analysis is an important step to determine sources of error and eventually come up with strategies how to address them given that mistakes may become deep-rooted.
**NEWMAN’S ERROR ANALYSIS**

**READING.**
Can the student read the question?

**COMPREHENSION.**
Can the student recognize the meaning of the question?

**TRANFORMATION.**
Can the student opt for the suitable mathematical operations or procedures?

**PROCESS SKILLS.**
Can the student carry out the mathematical calculation perfectly?

**ENCODING.**
Can the student represent the answer correctly?

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**ANDERSON’S REVISED BLOOM’S TAXONOMY**

**REMEMBERING.**
Recalling and identifying information.

**UNDERSTANDING.**
Explaining ideas concepts.

**APPLYING.** Implementing the information.

**ANALYSING.**
Organizing information to explore understanding and relationships.

**EVALUATING.**
Justifying a decision.

**CREATING.**
Generating new ideas.

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**Figure 1.** Relationship between Newman’s Error Analysis and Anderson’s Revised Bloom’s Taxonomy

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**Aims of the Study**

This study involved, firstly, working with students to identify errors they might be making in solving mathematical word problems. Secondly, instructional materials were designed on the basis of these errors. Thirdly, the materials were tested for their effectiveness.
The study sought to answer the following research questions:

1) How may student pre-test and post-test scores in solving mathematical word problems in Thermodynamics be described?

2) Does the intervention of a specifically designed study guide in teaching mathematical word problems significantly affect the students’ performance in solving mathematical word problems in Thermodynamics?

Hypothesis: The intervention of a specifically designed study guide in the traditional procedure of teaching mathematical word problems will significantly improve student performance in solving mathematical word problems in Thermodynamics.

Methodology

Research Design

A pre-test and post-test design was used to gather data. The pre-test helped identify the root cause of students’ poor performance in solving mathematical word problems in Thermodynamics using the procedure of Newman’s Error Analysis, described above. From the results of the post-test, statistical analysis determined if the intervention (developed study guide) had a significant effect. Figure 2 presents the schematic diagram of the research design.
Sample

A group of eight Year students enrolled in an undergraduate thermodynamics course were pre-tested and post-tested. Participants are all males with ages ranging from 18 to 29. Three of them are from New Zealand and the remaining are from Indonesia, Sri Lanka, South Africa, and India.

Data Gathering Tools and Procedure

A pre-test on mathematical word problems in Thermodynamics was given to students as the pre-test in the earlier part of the semester (2nd Semester, 2018).
When the pre-test was given to the subjects, lectures were already completed and the students answered the test based on their knowledge of Energy, Thermal Expansion, Closed System, Open System, Gases, and Water and Steam.

The test consisted of two mathematical word problems questions from each of the above topics. The instrument is presented as Appendix B. Five of these items involved one unknown (items number 1, 2, 3, 4 and 5) while the other five items involved more than one unknown (items numbers 6, 7, 8, 9 and 10). This was for the purpose of having variation in difficulty. Furthermore, four of these items (items 1, 2, 3, 4) were considered easy; four are considered average (items number 5, 6, 7, and 8); two are difficult (9 and 10). This would ensure even distribution of the level of difficulty.

From their solution and answers to this test, the errors by students in solving mathematical word problems in Thermodynamics were identified using the Newman’s Error Analysis procedure. The results of the Newman’s error analysis in addition to the researchers’ lengthy experience of teaching Thermodynamics were used to develop the study guide. The study guide was given to each student. A post-test was given after the lecture on solving mathematical word problems in Thermodynamics (Learning Outcomes 1, 2, and 3) employing the traditional method for the students and the study guide as a supplemental instructional material. This new result of scores were analysed, interpreted and compared to the students’ scores in their pre-test to determine the effectiveness of the study guide.

Design of the Study Guide

The study guide was developed through the help of the researcher’s colleague, a senior engineering tutor, an engineering technician and a registered moderator. He handles courses on Advanced Thermodynamics, Mechanics of Machines, Fluid Mechanics and Manufacturing Process. The researcher and colleague met for a number of times to discuss the final design of the study guide. The study guide was then piloted with non-study participants to determine and address what would be the possible problems to be encountered by the actual participants. Non-participants’ comments were also incorporated in the final version of the study guide.
Statistical Treatment of Data

The data gathered were recorded, categorised, and subjected to descriptive and inferential statistical analyses. A Paired-sample t-test was used to determine the difference in the performance of the students in their scores in the pre-test and post-test. All computations were done using SPSS version 13.0 and the test of significance was set at 0.05.

RESULTS AND DISCUSSION

Students’ Pre-test Performance in solving Thermodynamics word problems

Students’ pre-test scores from the test on solving thermodynamics word problems are presented in Table 1. Results show that of the eight student participants, only one obtained a score interpreted as ‘average’ score and the rest have scores interpreted as ‘low’.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Pre-Test Score</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student 1</td>
<td>31</td>
<td>Low</td>
</tr>
<tr>
<td>Student 2</td>
<td>28</td>
<td>Low</td>
</tr>
<tr>
<td>Student 3</td>
<td>35</td>
<td>Low</td>
</tr>
<tr>
<td>Student 4</td>
<td>22</td>
<td>Low</td>
</tr>
<tr>
<td>Student 5</td>
<td>52</td>
<td>Average</td>
</tr>
<tr>
<td>Student 6</td>
<td>27</td>
<td>Low</td>
</tr>
<tr>
<td>Student 7</td>
<td>25</td>
<td>Low</td>
</tr>
<tr>
<td>Student 8</td>
<td>22</td>
<td>Low</td>
</tr>
</tbody>
</table>

Legend:

80.1 – 100 Very High
60.1 – 80.00 High
40.1 – 60.0 Average
20.1 – 40.0 Low
0 – 20.0 Very Low

Table 1. Pre-test scores in thermodynamics word problems
These results confirm the concerns described previously about the ability of students to solve word problems in Thermodynamics.

**Errors committed by students in solving Thermodynamics word problems**

Table 2 presents the average number of errors committed by the respondents in solving mathematical word problems in Thermodynamics during the pre-test. The number of errors on each stage of Newman’s error analysis are shown.

**Table 2. Pre-test errors committed by students in solving mathematical word problems in Thermodynamics**

<table>
<thead>
<tr>
<th>Participant</th>
<th>Reading</th>
<th>Comprehension</th>
<th>Transformation</th>
<th>Process Skill</th>
<th>Encoding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student 1</td>
<td>5</td>
<td>3</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Student 2</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Student 3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Student 4</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>Student 5</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Student 6</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Student 7</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Student 8</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>31</td>
<td>38</td>
<td>54</td>
<td>62</td>
</tr>
<tr>
<td>Mean Score</td>
<td>3.75</td>
<td>3.875</td>
<td>4.75</td>
<td>6.75</td>
<td>7.75</td>
</tr>
</tbody>
</table>

The mean errors indicates the average number (out of 10) the subjects committed. An unanswered item or no solution is accounted to reading error as this can be due to unfamiliarity of the word used in the problem. Overall, the subjects committed the most number of errors (the first time) under Encoding. This is shown by the mean error of 7.75 points. They committed an average of 3.75 out of ten under Reading, 3.875 under the level of Comprehension, 4.75 under Transformation and 6.75 under Process Skill. Since the Newman’s procedure is hierarchical, the subjects are expected to commit
higher average number of errors under the dimension of Process Skills and Encoding levels.

Consistent with the definition of the different errors (RCTPE) stated by Newman (1977), those difficulties that resulted into errors are in Transformation. Further, this is supported by Hefferman and Koedinger (1998). They showed that many students could “compute” tasks well, whereas they had great difficulties with “symbolisation” tasks. They said that many students could comprehend the words in the problem, yet still could not write the expressions correctly.

**Causes of Errors in Solving Word Problems in Thermodynamics**

The Reading and Comprehension errors, the lack of vocabulary on the terminologies used in the problem and lack of information about the subject matter, were seen as the sources of errors in this level. Because of these errors, some students did not even attempt of solving the word problem. (Refer to Figure 3a, 3b, and 3c).

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**Question 4 (5 marks)**

The energy content of black coal (by combustion) is about 30 MJ/kg. How much black coal would need to be burnt to release the same amount of energy as the conversion of a 1 kg mass of this coal into energy? The speed of light is $3 \times 10^8$ m/s.

(R) GIVEN AND/OR DIAGRAM:

(C) REQUIRED:

---

**Figure 3a.** Sample of unanswered worksheet
Question 6 (10 marks)
The bomb calorimeter experiment, the can is filled with 2 kg of water. One gram of substance of known energy content 28.5 MJ/kg is burnt and the observed temperature rise is 2.75°C. (a) Determine the heat capacity of the metal parts of the calorimeter. The specific heat capacity of water over the temperature range is 4.187 KJ/kg.K. (b) The same bomb calorimeter is tested with a fuel of unknown energy content, and the following observations are recorded: mass of fuel burnt = 1.25 g; mass of water in the calorimeter = 2.75 kg; water temperature before firing = 18.3°C; water temperature after firing = 21.8°C. Determine the energy content of the fuel.

a)

(R) GIVEN AND/OR DIAGRAM:

(C) REQUIRED:

Figure 3b. Sample of unanswered worksheet

Question 8 (10 marks)
A coal fired steam generator under steady-flow conditions uses coal, with non-combustible content 5%, at a rate of 1.8 t/h. The air-fuel ratio (by mass) is 18:1. The exhaust gas enters a stack of diameter 1.8m at which point the gas has a specific volume of 3.6 m³/kg. Assuming the exhaust gas is free of fly-ash. Determine: (a) the volume-flow rate and mass flow rate of exhaust gas. (b) the velocity of gas entering the stack.

(R) GIVEN AND/OR DIAGRAM:

(C) REQUIRED:

a)

b)
In the Transformation level where the students committed the most number of errors the first time, the causes of these errors were as follows: translation difficulties due to insufficient knowledge, wrong interpretation and incorrect use of operation.

In Figure 4, the student was able to identify the given and understood what is asked in the problem but failed in formulating the proper equations because of lack of knowledge about some derivation concepts.

The correct equations should have been:

*Considering Pressure is 96 KPa then in substituting in the formula:*

\[ PV = mRT, \text{ pressure should be expressed in Pa or N/m}^2. \]

*Therefore, Pressure} = 96 \times 10^3 \text{ Pa or N/m}^2.\]

![Figure 4. Transformation error due to insufficient knowledge.](image)

In Figure 5, aside from the students did not understand what is required in the problem due to insufficient knowledge, another factor of error here is wrong interpretation. The
students wrongly assumed that the volume of tank will decrease when the temperature of the tank decrease from 20°C to 15°C.

![Diagram](image)

**Figure 5.** Transformation error due to wrong interpretation.

Another form of error in translating words into thermodynamic equations was being unable to use the operations correctly. In Figure 6, it can be seen that the statement “15 kg steel component at 300°C is cooled” which means the temperature of the steel will decrease from 300°C and therefore the correct equation for change in temperature should have been (300°C - T₂). Instead the students wrongly treated the change in temperature as (T₂-300°C).
Enhancing Student Learning in Solving Word Problems in Thermodynamics based on Newman’s Error Analysis

Figure 6. Transformation error due to incorrect use of operation

In the process skills errors, though the students know how to carry out the solution, some were mistaken because of carelessness.

In Figure 7, it has to be observed that the student carried out the solution in solving for Work done by $1 \times 10^3 \times 7 (P_2V_2) - 1 \times 10^3 \times 4 (P_1V_1)$ incorrectly due to carelessness.

Figure 7. Process skill error due to carelessness

Encoding errors, were the result of not following instructions.
Enhancing Student Learning in Solving Word Problems in Thermodynamics based on Newman’s Error Analysis

Figure 8 shows that the student was able to proceed correctly until the process skill level but did not write the final answer as instructed.

![Figure 8](image)

**Figure 8.** Encoding error due to not following instructions

The researcher was able to use these results and the causes of errors by the student in dealing with word problems in Thermodynamics as the basis in developing the study guide. The developed study guide is presented as Appendix A.

**Design of the developed Study Guide**

The study guide was developed based on Smith and Ragan’s (1999) three major activities mentioned in their book on instructional design.

The result of the pre-test was used to analyse student performance with mathematical word problems. To come up with the required format and content for the study guide, Newman’s Error Analysis Procedure served as the strategy. In the study guide, different types of worded problems in Thermodynamics were presented. These are: Applications of Thermodynamic Principals to Practical Applications and Heat Transfers. The study guide was designed as a series of solved problems or worked-out examples. It consists of the problem, solution steps (i.e. Given, Required, Working Equations, Solution and the Final Answer) and the complete solution to the problem in obtaining the final answer.
A number of studies according to Sweller, van Merrienboer, Paas (1998 in Schworm & Renkl, 2002) have demonstrated how example-based learning compared to the standard procedure of working on just one example and then solving problems can be more effective for skill acquisition.

Common problems presented in Thermodynamic textbooks as well as those used in the past examinations were used as worked-out examples in the study guide so if would be easier for students to work on those problems given their familiarity with them. This is in relation to what Sweller and Cooper (1985) state that, aside from the fact that subsequent problems similar to initial ones is less time consuming, they too are easier and faster to solve. Furthermore, a direct proportional relationship was observed that is: decrease in solving time also result in decreased on errors committed.

While studies confirm that learning from worked-out examples is necessary for cognitive skills development, Atkinson et al. (2000) mentioned that the use of worked-out examples does not ensure effective learning. One of the elements crucial in learning from worked out examples is its construction. The study guide appears to be similar to any other existing reviewer with worked-out examples, the only difference is the construction of study guide being based on Newman’s Error Analysis Procedure. The results revealed that the majority of students can only carry out effectively the Reading level and Comprehension levels. Hence, the study guide gave more attention having the third highest average, which is Transformation. In the Transformation level, the student should identify the operation to be applied in solving the given problems. According to Hart (1996), many students find it hard to convert a word problem into the necessary mathematical form. They cannot create mental representation associating the text of the word problem to appropriate mathematical expressions. Since this considers mathematical word problem, it is tantamount to saying that student should know how to transform English sentences to mathematical expression.

It should be noted that in the developed study guide, a detailed and more comprehensive explanation is undertaken at the Transformation level. In this level, each premise in the given problem is carefully translated into mathematical equation
so to get the necessary working equations. This is followed by the Process skills and Encoding levels, respectively.

**Pre-test and Post-test Performance in solving Thermodynamics word problems**

Different test was used during the pre-test and post-test. However, the effects of pre-test which gives the participants the chance to practice, was not statistically measured.

<table>
<thead>
<tr>
<th>Paired Differences</th>
<th>95% Confidence Interval of the Difference</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Std. Error</td>
<td>Mean</td>
<td>Lower</td>
</tr>
<tr>
<td>Pre-test</td>
<td>-44.875</td>
<td>15.995</td>
<td>5.655</td>
<td>-58.247</td>
</tr>
<tr>
<td>Post-test</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*p value significant at 0.05*

**Table 3. Difference on students’ performance in pre-test and post-test**

The p-value obtained is .000 which is less than 0.05. This suggests that there is a significant difference on students’ pre-test and post-test scores. Comparing the two sets of scores in Table 3, it could be observed that in the post-test, an overwhelming majority of the students (7 out of 8) have scores ranging from 20 to 40, which is interpreted as low and only one obtained score, which is interpreted as average. Meanwhile, the post-test scores range from very high to average only, and no low score was recorded. Hence, the null hypothesis was rejected.

Students’ post-test scores in solving thermodynamics word problems are presented in Table 4. Results show that students’ performance based on their scores improved significantly, as shown by the paired T-test in Table 5. In the post-test, two students obtained scores which are interpreted as very high, three students got scores considered as high, and there were also three students who received scores, which have verbal interpretation of average.
Enhancing Student Learning in Solving Word Problems in Thermodynamics based on Newman’s Error Analysis

<table>
<thead>
<tr>
<th>Participant</th>
<th>Pre-test Score</th>
<th>Interpretation</th>
<th>Post-test Score</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student 1</td>
<td>31</td>
<td>Low</td>
<td>93</td>
<td>Very High</td>
</tr>
<tr>
<td>Student 2</td>
<td>28</td>
<td>Low</td>
<td>69</td>
<td>High</td>
</tr>
<tr>
<td>Student 3</td>
<td>35</td>
<td>Low</td>
<td>69</td>
<td>High</td>
</tr>
<tr>
<td>Student 4</td>
<td>22</td>
<td>Low</td>
<td>80</td>
<td>High</td>
</tr>
<tr>
<td>Student 5</td>
<td>52</td>
<td>Average</td>
<td>98</td>
<td>Very High</td>
</tr>
<tr>
<td>Student 6</td>
<td>27</td>
<td>Low</td>
<td>57</td>
<td>Average</td>
</tr>
<tr>
<td>Student 7</td>
<td>25</td>
<td>Low</td>
<td>41</td>
<td>Average</td>
</tr>
<tr>
<td>Student 8</td>
<td>22</td>
<td>Low</td>
<td>44</td>
<td>Average</td>
</tr>
</tbody>
</table>

Legend:

- 80.1 – 100       Very High
- 60.1 – 80.00     High
- 40.1 – 60.0      Average
- 20.1 – 40.0      Low
- 0 - 20.0         Very Low

**Table 4. Pre-test and Post-test Performance in word problems**

Post-test errors committed by students in word problems

Detailed presentation of the students’ post-test performance in solving thermodynamics word problems is presented in Table 4. It can be seen that the number of errors on each stage in Newman’s Error Analysis decreased. In the pre-test, the mean score for encoding was 7.75, while in the post-test it become 3.375. It can also be noted that the post-test mean score is the same for the process skill and encoding. On the other stages, decreased on the average number of errors can also be observed from pre-test to post-test.
Enhancing Student Learning in Solving Word Problems in Thermodynamics based on Newman’s Error Analysis

<table>
<thead>
<tr>
<th>Participant</th>
<th>Reading</th>
<th>Comprehension</th>
<th>Transformation</th>
<th>Process Skill</th>
<th>Encoding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student 1</td>
<td>0</td>
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<tr>
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<tr>
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<tr>
<td>Student 6</td>
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</tr>
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<td>1.375</td>
<td>2.125</td>
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</table>

Table 5. Post-test errors committed by students in word problems

Effect of newly-developed study guide

Based on the result from the paired-sample t-test, it can be seen that the study guide was an effective tool in improving students’ performance in solving world problems in Thermodynamics. The result conforms to the findings of previous studies (e.g. Sweller, van Merrienboer, & Paas, 1998 in Schworm & Renkl, 2002) that worked-out examples or example-based learning with increasing level of difficulty, which in the present study are included in the newly-developed study guide, is of major importance for the acquisition of cognitive skills as well as skills acquisition than the standard procedure of studying just one example and then working on the given problems. Meanwhile, the present finding does not corroborate that of Atkinson et.al. (2000) stating that use of worked-out examples do not guarantee effective learning.

CONCLUSION

Given the limited sample and in the absence of control group tested, findings presented in the study may not be generalized. Though traditional teaching methods
have already established its importance in teaching and learning, still there are number of studies that show that educational innovations are also carving niches especially in providing a meaningful, context-rich, and learner-centred experiences.

New Zealand’s educational system implemented the Outcomes-Based Education (OBE), a teaching-learning approach aligned to constructivism which focuses on learner-centred education. This conveys that it is high time that our educators may consider a paradigm shift from the traditional method of teaching to constructivist approach. One of the essential components in developing a constructivist learning environment is to provide the proper instructional material such as a study guide.

The results of the study suggest that study guide may be a useful supplementary material in teaching Thermodynamics. When a study guide is used along with the textbook based lectures, a lot of benefits on the part of students can be derived. Based on the results of the study, it can be concluded that providing students with worked-out examples based on Newman’s Error Analysis can be effective in improving both the instructor’s approach in teaching problem solving competencies and students’ understanding of the entire stages as well.

To cope with modern students’ learning needs, a good and pragmatic instructor must listen to students’ voices by redefining his teaching strategies that is, a shift from being subject-centred to learner-centred teaching. Engineering educators must be creative in tailoring the instructional needs of the students by coming up with a variety of classroom activities that are based on the students’ learning styles, background and interest. Engineering tutors must think hard and try their best to design appropriate instructional materials and be good at employing every means in teaching and helping the learners masters the different processes in Newman’s error analysis in problem solving ranging from reading, comprehension, transformation, process skills and encoding.

Future research should include participants’ profile variables such as age, gender, learning styles and ability to solve word problems and their relationship to the effectiveness of the use of study guide. The use and effectiveness of a study guide in
other subjects should also be tested and explored in future studies. Finally, future studies should also address some of the limitations in the study, which includes the small sample size. As such, larger representation of students across gender, nationality, age, and geographical locations should also be considered. Qualitative data should also be obtained in the future since it offers the benefits of perceiving the richness of peoples’ perspectives and lived experiences in the data. Further, since there is no control group in the study, future research should adopt experimental design with a control group that can be a valuable asset in identifying the cause and effect. Finally, future research could continuously provide deeper insight into the learners’ best learning strategies and effective instructional methodologies. For instance, future undertakings could monitor and present the progressive improvement in students’ grades as well as the knowledge they gained through the help of a study guide over a semester.

REFERENCES:


Biography of Anne Newman as a teacher. Retrieved from:


http://www.niu.edu/facdev/programs/handouts/constructivism.pdf [May 4, 2013]


