The Use Of Automatic Feedback System With Multiple Attempts In Answering Multiple-Response Testing To Improve The Performance Of Students In Thermodynamics Course

Raymund T. Masangya

Technological University of the Philippines, Physics Department.

Abstract

Feedback system is a vital process in improving the understanding and analytical skills of the students. This study examines the effectiveness of using a multiple-response testing with multiple attempts and automatic feedback system in improving the performance of students in a thermodynamics course. This study followed the descriptive mixed methods research design in order to determine the effectiveness of a multiple response testing with multiple attempts and automatic feedback on students' understanding of thermodynamic concepts and word problems. A heterogeneous class of College students in Technology programs were participated in this study. This study used paired t-test and Hakes factor in order to analyze the quantitative data gathered from this study. Thematic analysis is used to code the main themes from the qualitative data. The results showed that there is a significant difference in the pretest and posttest scores after the strategy was employed in the curriculum. In addition to the quantitative results, there is a high gain of scores from pretest to posttest. The findings suggest that incorporating a multiple-attempt and feedback system into testing can improve in conceptual understanding, visualization of the problem and procedures in solving the word problems in thermodynamics, which has implications for the design and implementation of assessments in Science, Technology, Engineering and Mathematics education in the Philippines.

Keywords: Automatic Feedback system, Multiple Attempts, Multiple Response Testing, Hakes Factor, Thematic Analysis.

INTRODUCTION

A. Background of the Project

There is a significant gap between the level of science education in the Philippines and that of other countries

throughout the world, particularly at the level of basic school. The findings of the Second International Science Study (SISS) and the Third International Mathematics and Science Study (TIMSS) placed the Philippines in a less advantageous position than the other nations that took part in the studies (Philippine Department of Education, Culture, and Sports et al. 2000). The Philippines had a ranking that was very close to the very bottom of the list of seventeen (17) countries that participated in this comprehensive evaluation of educational accomplishment that was carried out by the SISS. The results of the TIMSS in 1995, 1999, and 2003 were very similar to one another. The result of this has an effect on the college students that has a weak foundation in science subjects that can affect their performance in tertiary level.

According to the result of the study of Vallespin et al. (2019), that advanced concepts of Thermodynamics and Kinetics were the most difficult topics perceived by the students. Thermodynamics contains a number of concepts that need to be internalized by the learners as well as the mentors, particularly in light of the fact that problem solving in these subjects requires a significant amount of mathematical ability (Vallespin et al., 2019).

Examinations consisting of multiple-choice questions are beneficial when high class sizes, the desire to test frequently, and the goal to send graded exams to students as fast as possible are all present. Exams with multiple choice questions, on the other hand, have a number of drawbacks when it comes to determining whether or not a student has mastered the content of a given course. One of these drawbacks is that students only get one chance to respond to each.

According to Mendoza and Lapinid (2022), students' overall performance on online quizzes significantly improved when they were given three opportunities to complete them and an automatic feedback system. This finding was reinforced by the students' reflective journal entries, which indicated positive views regarding the use of the feedback system, such as assisting the students in becoming independent learners, managing their time wisely among tasks, and understanding the concepts.

The ability to solve problems using thermodynamic concepts is a must for all students who choose to pursue studies in the engineering and technology programs. Students need to work on developing their analytic abilities over the course of their mathematics education in order to become proficient in Physics and steer clear of common misunderstandings in the process of solving thermodynamics problems. According to Digambar et al., 2013, When traditional teaching methods are used, students have significant

challenges learning heat and thermodynamics in particular, as well as physics in general. Another study of Baser (2006) states that the effectiveness of conceptual change oriented instruction and traditional scientific instruction, as well as the impact of logical reasoning skills to seventh grade students' grasp of heat and temperature concepts. There are some studies that also focused in Thermodynamics and they used different methods like cooperative learning, concise data processing assessment, and probing for the improving of the performance of the students in the said field (Christensen et al., 2009; Coca, D. M., 2012; Tanahoung et al., 2010). Some studies also find out misconceptions of the students in this field in order for them to improve and give feedback to these (Engelhardt P. & Beichner R. 2003; Gönen, S. & Kocakaya, S. 2010; Harrison et al. 1999; and Kesidou, S. & Duit. R., 1993).

Education is one of the most important aspects of the 2030 Agenda for Sustainable Development. Not only is it designated as its own goal (Sustainable Development Goal 4), but it is also included as a target in several of the other Sustainable Development Goals (SDGs), including those dealing with health, economic growth and employment, environmentally responsible consumption and production, and climate change (WorldWideMedia Consulting, 2015). They state that their member institutions must " Ensure equitable quality education and lifelong learning for ALL by 2030".

B. Justification of the Project

This study will be found out how automatic feedback system helps in improving the performance of students in multiple-choice testing in Thermodynamics course. The improvement of performance in the said course may help the students to motivate in studying these topics and help promote the full human potential of the students.

Results from studies in other countries show positive outcomes of immediate feedback groups were having a significantly higher than those without feedback (Fullmer and Rollings, 1976). Recent studies also show that feedback system in multiple choice testing improves performance of students in online quizzes significantly (Mendoza and Lapinid, 2022; Jang & Marshall, 2018; Merrel et al., 2015). This is the reason why we need to conduct this study improving the curriculum of the Thermodynamics course in our institution and in order for us to be at par with the international standards based on the Sustainable Development Goal (SDG) 4 of UNESCO in the year 2030.

C. Objectives of the Project

The aim of this study is to assess the effect of automatic feedback system with multiple attempts in multiple choice testing of the existing Thermodynamics course in Technological University of the Philippines. The following are the specific objectives of this study:

(1) Determine the effect of automatic feedback system with multiple attempts in multiple response testing in the performance of students in Thermodynamics course in the university.

(2) Determine the effect of automatic feedback system with multiple attempts in multiple response testing in the attitude and motivation of students in Thermodynamics course in the university.

D. Conceptual Paradigm

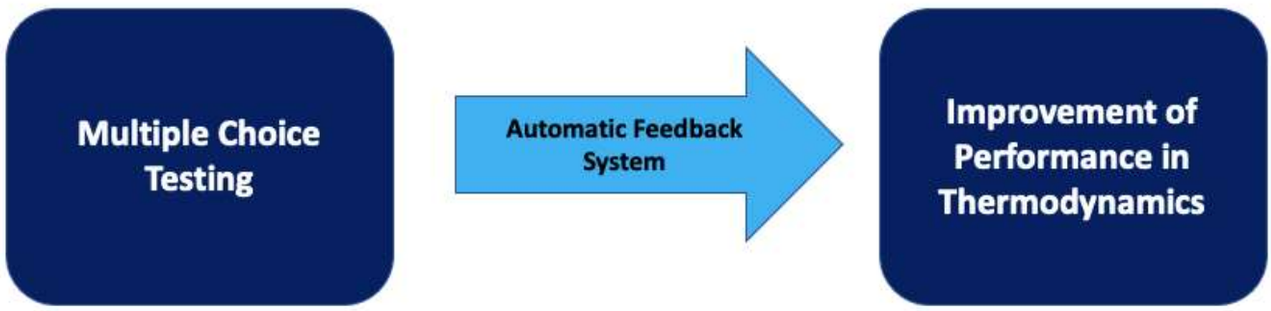

Fig. 1. Conceptual Paradigm of the Study

The conceptual paradigm of this study is to use multiple choice testing in assessing the understanding of the students in thermodynamic concepts and their problem-solving skills. The students will answer a formative assessment with three repeated responses in order for them to know the automatic feedback in their incorrect answers. This study envisions to have an improvement in the performance in Thermodynamics both in academic and motivation of the students in the said course.

METHODOLOGY

A. Research Design

This study is an exploratory action research that is focused on the determining the effect of feedback system in multiple-choice testing in Thermodynamics course in one of state universities in the Philippines. A mixed method research design is selected as it is deemed suitable in explaining, interpreting or contextualizing quantitative findings (Creswell, 2003). Mixed method design used in this study is the concurrent triangulation design. It is characterized by the collection of both quantitative and qualitative data. The quantitative data in

this study will come from the results of pre-test and post-test from students who are taking Thermodynamics course. On the other hand, the qualitative data will be gathered from the survey questionnaire answered by the students for motivation and attitude towards the applied strategy. Although priority is given to the quantitative results, qualitative findings will be used to corroborate the results.

B. Research Setting

This study is characterized as mixed method research based on quantitative and qualitative data collected from students who are taking Thermodynamics course of the Technological University of the Philippines and all of them were included in the College of Industrial Technology. The quantitative data will originate from a pre-test and post-test of college students who are taking Thermodynamics course. Students will be informed about the research and their participation in the survey must be voluntarily. This will be in line with the ethical principles of the university. The qualitative data will be collected from the survey questionnaire answered by the students who are taking Thermodynamics course.

C. Research Instrument

For this study, the researchers will use a mixed-method approach that includes multiple-test questions for pretest and post-test and survey questionnaire to gather both qualitative and quantitative data toward the effectivity of automatic feedback system with multiple attempts in multiple-choice testing and motivation, respectively. The survey questionnaire will be a 5-point Likert scale with items designed to gain insights about the student's motivation and attitude about the feedback system across the different components of the questionnaire. The said questionnaire, which will be made by the researcher, will be validated by experts to be assured of its alignment to the purpose of the study.

D. Procedure

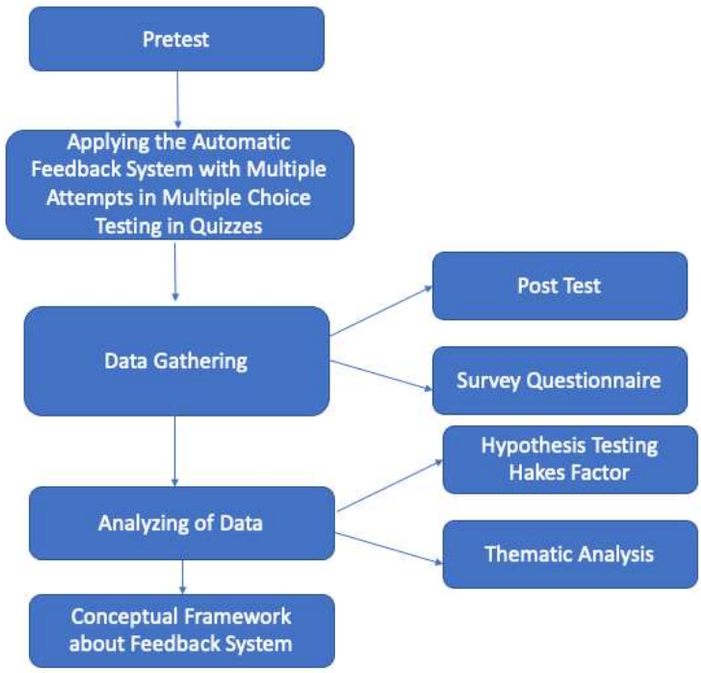

Figure 2. Procedure of this Study

A letter requesting for a permit to conduct a survey and semi-structured interviews will be drafted by the researchers. The pretest is given at the start of the course. The feedback system will be applied in every multiple-choice testing in quizzes. At the end of the course the researcher will administer the posttest and survey questionnaire. The necessary signatures of the institutional administration will be secured before the survey is administered to the students. The survey will be administered online and will be coursed through the students in the Thermodynamics course. The respondents are going to be given an orientation on their role in the research process and will be assured of the data privacy and confidentiality.

E. Data Analysis

The quantitative data will be collected from the pretest and posttest of the students score. Mean scores and standard deviations (SD) will be calculated for the pretest and posttest of the scores of the students. Further analysis was conducted through the use of a paired t-test in order to determine whether there was any significance in the difference between the pretest and posttest of scores of students in multiple choice testing. This statistical tool is used also by Yusop et al., 2015 and Chao, 2017. The null and alternative hypotheses of this study are:

H_0: There is no significant difference in the pretest and posttest of the student score in the multiple-choice testing after the automatic feedback with multiple attempts has been made.

H_1: There is a significant difference in the pretest and posttest of the student score in the multiple-choice testing after the automatic feedback with multiple attempts has been made.

The result of the pre and post tests were analyzed more rigorously using the Hake factor test (normalized gain). It was used to assess the effectiveness of various interventions aimed at improving conceptual understanding in learning thermodynamics. This was used by Necor (2018), to know the gain of the students in chemistry concepts specifically in periodicity of the element. Table 1 shows descriptive equivalents and verbal descriptions for Hake Factor Test findings.

Table 1. Descriptive Equivalents for the Hake Factor Test Results

Formula	Scale Range	Verbal Description
$\mathrm{h} = \frac{\text{post test} - \text{pre test}}{1 - \text{pretest}}$	0.71-1.00	High Gain
	0.31-0.70	Medium Gain
	0.10-0.30	Low Gain

The qualitative data, on the other hand, will be gathered from the survey questionnaire conducted for the students to know the motivation and attitudes towards the automatic feedback system with multiple attempts in taking multiple-choice testing. The survey questionnaire transcripts will be transcribed then coded. The themes will then be identified from the codes to support the quantitative data on the overall perception of the students on how feedback system will help them to learn the concepts of Thermodynamics topics. This method is consistent to Braun and Clarke (2006), that this method provides a technique to qualitative data analysis that is both accessible and conceptually versatile.

RESULTS AND DISCUSSIONS

The presentation and analysis of the results was done considering if the multiple attempts with automatic feedback system can enhance learning specifically for Thermodynamics course. The results and discussions were presented the quantitative and qualitative findings of this research.

A. Quantitative Results of Feedback System in Multiple Response Testing

The multiple response test that was used in this study is composed of 50 items multiple choice with four options. Based on the results in Table 2, the highest mean is the posttest of Section E, while the lowest mean is the pretest of Section C. The standard deviation shows that pretest (SD = 9.28) has more dispersed distribution compared to the distribution of posttest (SD = 8.38). To determine if it is statistically significant, a paired t-test was performed based on the pretest/posttest mean

scores. It revealed that there is a significant difference between the mean scores of pretest and posttest for 177 respondents who took the pretest and posttest of the examination (t statistics = 37. 31, t critical = 1.97, $p < 0.05$). This is consistent to the results of Mendoza & Lapinid (2022), Dobson (2008), Johnson & Kiviniemi (2009) that feedback system can have a significant difference in pretest and posttest through the use of feedback system and multiple attempts to multiple response testing. Hence, based on the hypothesis testing that we must reject the null hypothesis and there is a significant difference between pretest and posttest scores of students after we implement the feedback system in the course.

Table 2: Results of Students in Pretest and Posttest in Thermodynamics course (significance at 5% level*)

		Pretest		Posttest			
	n	Mean	SD	Mean	SD	T Stat	T Critical (two tail)
Section A	33*	20.93	7.06	39.84	6.56	15.06	2.03
Section B	36*	20.33	8.99	38.41	8.38	12.83	2.03
Section C	48*	15.23	4.57	42.22	7.06	23.75	2.01
Section D	12*	18.5	9.28	46.08	2.64	11.13	2.20
Section E	48*	19.83	5.43	46.60	3.33	32.09	2.01

The Hake Factor Test result in Table 3 shows that Sections C, D and E have a verbal description of high gain followed by Sections A and B, with a medium gain of description. These proved that all the sections gained from the application of multiple attempts with feedback system in Thermodynamics. This result is consistent to Voerman et al. (2012) and Hill et al. (2015) that feedback system has a significant effect in improving their mean scores in the academic field.

Table 3: Descriptive Equivalents for the Hake Factor Test Results in the pretest/posttest

Section	Mean	Verbal Description
Section A	0.66	Medium Gain
Section B	0.62	Medium Gain
Section C	0.78	High Gain
Section D	0.87	High Gain
Section E	0.89	High Gain

B. Results of Feedback System with Multiple Attempts in Answering Multiple Response Testing using the Survey Questionnaire

The effect of the automatic feedback system in motivation and attitudes toward this course is important as well and needs to consider as an improvement in teaching modality. In order for us to investigate the cause of application of feedback system to the said variables, we asked 170 respondents who answered this surveyed questionnaire. All of them answered the survey questionnaire voluntarily and agreed in terms of conditions at the end of the form. The first question that arises in the survey questionnaire is that if feedback system can help them to learn the concepts in Thermodynamics. Most of the of the respondents answered that they strongly agree (n = 119) that feedback system can help them learn Thermodynamics concepts as shown in Figure 2. According to Cavalcanti et al.(2021), that based on their analysis there is an increase in student performance in activities that is shown to be associated with the use of automatic feedback in 65.07 percent of their studies.

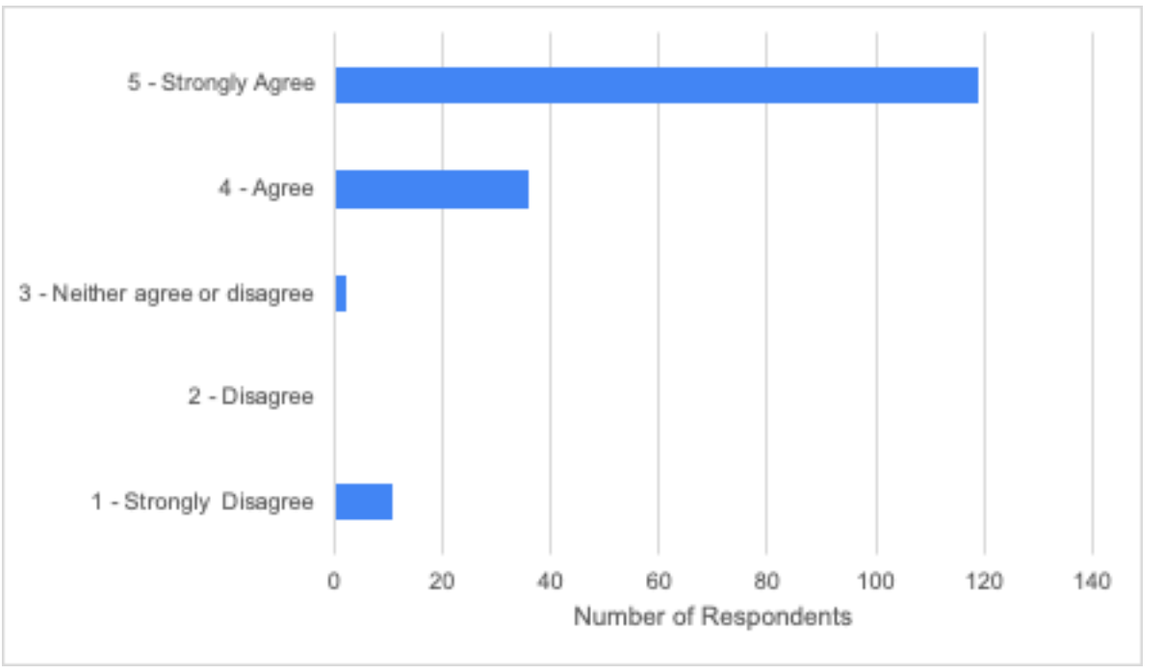

Figure 2: Result in the question: “Do you think that feedback system can help you to learn the concepts in Thermodynamics?”

The main reason how feedback system helps the students to understand the question and answer it correctly is through the application of appropriate formula to be used in solving the problem (n = 80) in this course as shown in Figure 3. Most of them agree that feedback can help to grasps concepts that can help them to solve the given problem or question (n = 53). The least response is that they were not agree that clues (feedback system) are useful to come up with the correct answer in the given problem (n = 3).

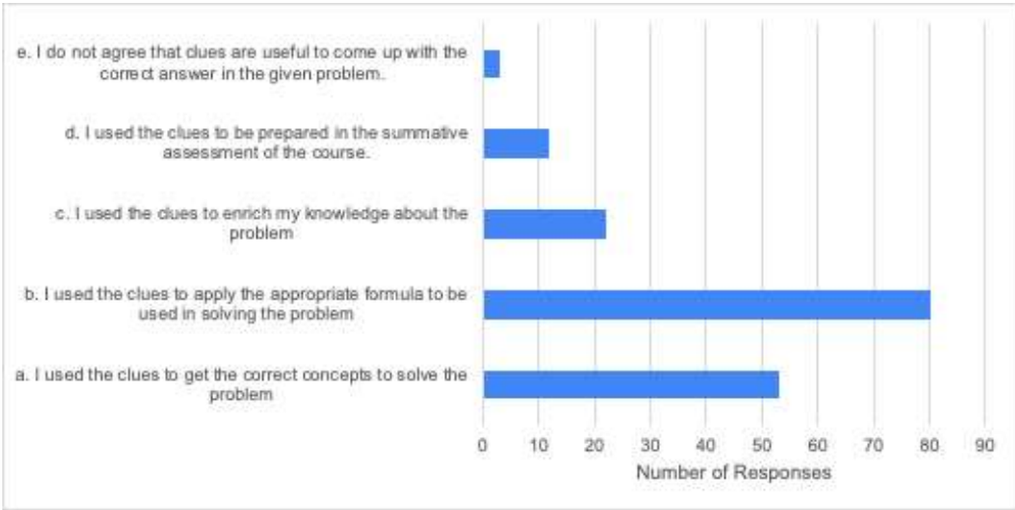

Figure 3: Result in the question: "How does the feedback system helps you to understand the question and answer it correctly?"

The first open ended question in this study is their explanation on their answer on the previous question. The students explain their answer about the previous question on how they select their response and we come up with three themes based on their answers. The three themes that were coded are (1) understanding the concepts, (2) visualize the problem and (3) implementing the procedure to solve the problem. The major themes that arise from this question is most of the respondents uses the feedback as their guide in order for them to solve the given problem. The following are the codes, frequencies of each code and the sample response from the respondents. Based on this thematic coding, the feedback mechanism can help students in conceptual understanding of the theories, visualization of the problem and application of formula to solve the given problem.

Code	**Frequency**	**Sample Response**
Code 1: Understanding the concepts	n = 46	• "Clues help me to understand how to answer the questions given." (Student No. 4) • "For me, it's important to use a clues to get the correct concepts to solve the problem. Therefore, students can understand well the theory." (Student No. 25) • "When giving clues, I remember the concepts because the concept is the main foundation of every problem. With that, it is easy for me to remember the formula and apply it in solving the problem." (Student No. 36)
Code 2: Visualize the Problem	n = 2	• "It helps me to visualize the formula and the process must be used to solve the problem." (Student No. 84) • "I used the clues for helping me for visualize the problem if I don't know how to start in beginning." (Student No. 8)

Code 3: Implementing the procedure to solve the problem	n = 97	• "I strongly agree that the clues are very helpful in answering and solving the given activities. When there are clues given in the activities, I used them as a base on how to solve the problem given." (Student No. 49) • "With the help of the clues that given I can come up with the correct solution in the problem." (Student No. 54) • "The clues help me a lot in answering the activity because sometimes I don't know what to do on the problems but when I see the clues I know what will I going to do, The clues serves as my guide to answer the problems" (Student No. 75)

Table 4: Summary of the Thematic Coding of the First Open Ended Question.

The respondents were evaluated the feedback system that was employed in this study. Forty Nine percent (n = 83) of the respondents rated the feedback system as excellent as shown in Figure 4. Hence, in their perspective that the feedback in this study truly helps them to learn the concepts and improve their analytical skills. The second open-ended question is why feedback system can help them to learn the course effectively and we come up with the three themes based on their answers. The coded are (1) the application of the course to the industry, (2) improving their knowledge and understanding in Thermodynamics, and (3) to improve the areas of weaknesses in the said course. The following are some answers of the respondents based on the themes stated in this section:

"Because we can apply my learning to industry."
-Student No. 2

"it is important for the student to have a feedback system for the responses and know the learning course for the students"
-Student No. 98

"Feedback is one of the most effective teaching and learning strategies and has an immediate impact on learning progress to us as a student."
-Student No. 97

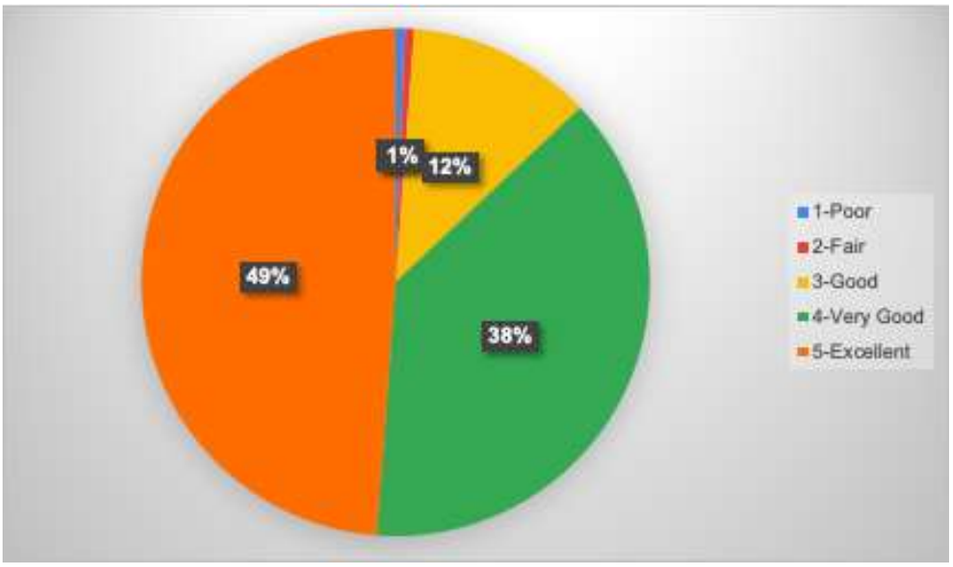

Figure 4: Student's Rating on the Feedback System Employed in this Study

The respondents were asked if there must be an improvement in the in the feedback system applied in their course. Based on Figure 5, most of the students are satisfied already in the feedback system employed in this course (n = 86). However, we need also to know the suggestions and comments of other students in improving the feedback system in this study (n = 84). The following are the sample answers of the students for their comments and suggestions in the feedback system employed in this study:

"The feedback system in this course is good, but I think there are improvements that can be done and to be polished so that it can be more enjoyable, yet effective."
-Student No. 28

"It should add a question to determine the level of difficulty of a subject that should be answered by the students by knowing their capabilities or weaknesses when it comes to this matter."
-Student No. 86

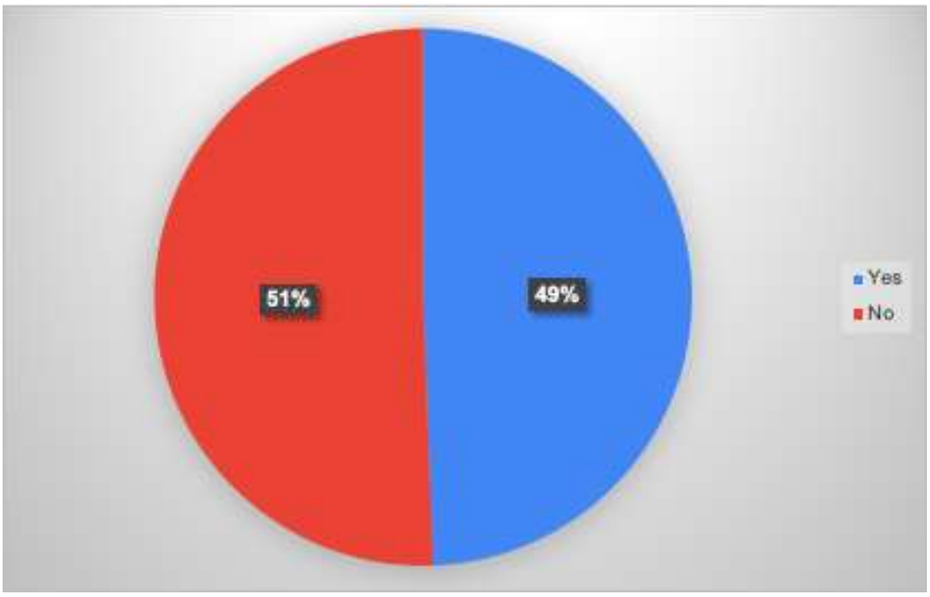

Figure 5: Result in Survey if there is a need to enrich the feedback system in this course.

For multiple attempts, this study asked the students on how many repeated responses they suggest in answering the formative assessments to get the feedback in their incorrect answers. Based on Figure Most of them suggest that there must be two repeated responses (n = 94) to grasps and improve their learning in the said course. The students also do not agree that the more repeated response they perform in formative assessment the better they will grasp the concepts and solve the problems on their own (n = 21). These findings will be investigated in the future studies of some researchers.

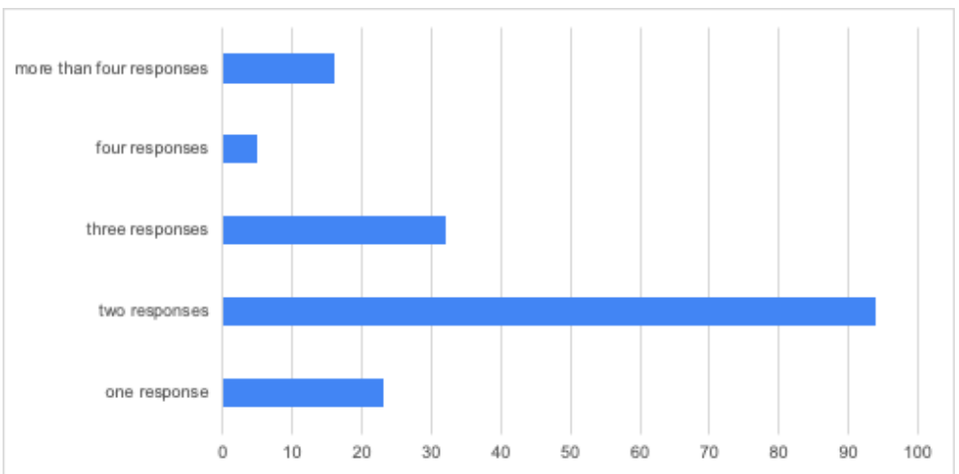

Figure 6: Suggestion of Students for Multiple Attempts in Formative Assessment

CONCLUSION

The effect of feedback system in multiple response testing in the performance of students in Thermodynamics course has significant effect on the improvement of learning with multiple attempts in formative assessment. This finding is consistent with the findings of Mendoza and Lapinid (2022), Dobson (2008), and Johnson and Kiviniemi (2009), which indicate that

the use of feedback systems and repeated attempts to multiple answer testing can produce significant differences between the pre-test and post-test scores. Hence, based on the results of the hypothesis testing, we must conclude that the null hypothesis must be rejected and that there is a substantial difference between the pre-test and post-test scores of students after the introduction of the feedback system into the curriculum. This is supported through the use of Hake's Factor wherein there is a high gain of scores from pretest to posttest of the course (Overall Average of Gains = 0.76). This study corroborates the findings of Voerman et al. (2012) and Hill et al. (2015), which found that the use of a feedback system had a significant impact on the students' ability to improve their mean scores in the academic field.

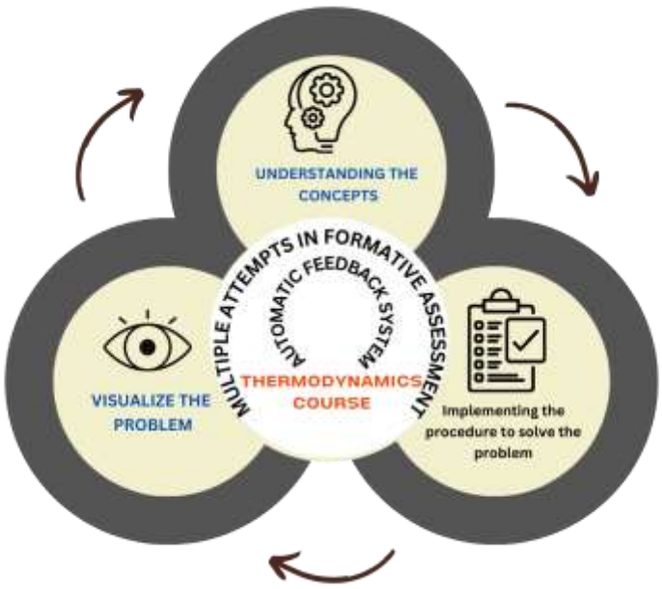

Figure 7: Theoretical Framework of this Study Derive from the results in Thematic Analysis

Based on the results of survey questionnaire in this study the theoretical framework of employing a feedback system with repeated attempts sounds like a potential strategy to improving conceptual knowledge, visualizing difficulties, and developing processes to solve them. Several efforts at feedback might give students with a more iterative and interactive approach to learning. This allows individuals to put their knowledge to the test in a low-stakes situation, which can boost confidence and uncover areas that require more attention. Rather than merely being informed the correct answer, students can learn from their mistakes by receiving feedback on their attempts. A feedback system with several attempts can be very helpful in a Thermodynamics course, which can be complex and demanding. Students must understand abstract principles and apply them to real-world issues in thermodynamics, which can be challenging without a solid foundation of knowledge and problem-solving skills. Students can gain a better understanding of the concepts involved and learn to picture difficulties in a more intuitive way

by breaking problems down into smaller, manageable portions and providing feedback on each effort. This can assist them in identifying patterns and correlations between various concepts, which can lead to improved problem-solving abilities. Furthermore, by repeating the technique for solving the problem, students can reinforce their knowledge and skills, so solidifying their mastery of the content. This is especially useful when dealing with more difficult challenges that necessitate a deeper comprehension of the concepts at hand. Overall, the given theoretical framework for employing a feedback system with repeated attempts in a Thermodynamics course is a promising method to improving conceptual comprehension, visualizing issues, and implementing solutions. This can help students build the information and skills they need to succeed in the course and beyond by providing them with a more iterative and participatory approach to learning.

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Appendix A

t-Test: Paired Two Sample for Means for all the Scores of the Participants

	Variable 1	Variable 2
Mean	18.80225989	42.45762712
Variance	49.11408577	48.76097843
Observations	177	177
Pearson Correlation	0.273427462	
Hypothesized Mean Difference	0	

df	176
	-
t Stat	37.31988325
P(T<=t) one-tail	7.92278E-86
t Critical one-tail	1.653557435
P(T<=t) two-tail	1.58456E-85
t Critical two-tail	1.973534388