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Excellence
Community
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EDITORIAL POLICY

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EDITOR'S NOTE

With the advent of the internet and the availability of state of the art technologies, we see the transformation of people and society at a rapid pace. Change is inevitable as we observe the acceleration of progress and development. We also note the emergence of researchers and inventors displaying their latest work to cater to the needs of the time. We have finally arrived at the Fourth Industrial Revolution (FIRe). According to Klaus Schwab, "The Fourth Industrial Revolution will affect the very essence of our human experience." The challenge is for us to be aware of the change so that we can benefit from it and ensure its positive impact on the environment and society in general. In its effort to contribute to humanity, Cor Jesu College encouraged its personnel to indulge into research and innovation.

In this volume, we present the inventions and research outputs of Cor Jesu College personnel. First, Engr. Wayne Manabat, Mr. Jonathan Lanterna, and Dr. Alex D. Niez displayed their innovation project for a student driver-friendly and safer driving vehicle. This project is an enhancement of the two-wheel student-driving vehicle of the school. Engr. Jamie Eduardo Rosal presented his invention of a structural health-monitoring device, which can measure the vibration of the beams in the building to determine their strength and to help engineers improve the safety and structural integrity. Engr. Juvy Amor Galindo and Engr. Jamie Eduardo Rosal developed a laboratory trainer board using the Arduino microcontroller kit. The faculty of the College of Engineering already used this device to help students in their programming subjects. Students made use of this device before finalizing their projects.

The other two articles were products of semi-experimental researches of two of the school's Mathematicians. In the pursuit of quality instruction, Mr. Jun Mark Panlaan and Mr. Christian Camańan tried separate teaching strategies in teaching Mathematics. On the one hand, Mr. Panlaan used the Gradual Release of Responsibility Approach. He found it effective in teaching Geometry 7. On the other hand, Mr. Camańan employed Concrete-Representation-Abstract Approach. He also found it effective in teaching first-year college students taking General Education 4 subject.

The five articles published in this volume are the school's humble contribution to the scientific community. Despite experiencing four major earthquakes during the last quarter of 2019, Cor Jesu College is happy and proud to share the research outputs and inventions of its faculty. The buildings might have collapsed, but the spirit of Cor Jesians and their resolve to pursue excellence, community, apostleship through research, and innovation will continue to rise.

Ametur Cor Jesu! Ametur Cor Mariae!

AUTO-SHIFT APPLICATION PILOT (ASaP) CONTROL SYSTEM: AN INNOVATION PROJECT FOR A STUDENT DRIVER FRIENDLY AND SAFER DRIVING VEHICLE

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ABSTRACT

The facilitation of effective driving lessons is the preoccupation of every Technical Vocational Education (TVE) institution offering a driving competency program. It is observed that with one steering wheel driving unit, the driving lessons are delayed since both student driver and driving instructor will take turns positioning in the same steering wheel during demonstration and application of driving competencies. Likewise, the safety of both student driver and driving instructor is at stake since the driver instructor's control of the student driver's manipulation of the steering wheel and pedals is done only through verbal instruction. This development study aimed to innovate an Auto-Shift Application Pilot (ASaP) control system for a driver student-friendly and a safer driving vehicle. ASaP controls the functioning of the two sets of steering wheels and two sets of pedals, respectively, for the student driver and driving instructor to facilitate teaching-learning of car driving competencies. Using quantitative and qualitative descriptive design, test and evaluation of the functionality and aesthetic design of ASaP control system were conducted to 5 driver instructors and 15 student driver respondents. Results showed that ASaP control system is functional in its set-up and needs enhancement in its aesthetic design. It is recommended that this ASaP control system be installed in a manually transmitted school driving vehicle for a student driver-friendly and safer school driving lessons.

Key Words: ASaP Control System, Invention, Innovation, Technical Vocational, Cor Jesu College, Digos City, Philippines.

INTRODUCTION

To have a car driving knowledge and skill is very important. It facilitates time management in reaching destinations, accomplishing works, and attending appointments. It makes it easy for one to have personal control and autonomy over his/her specified reasons for driving, especially when the situation calls for it as the only option for independent mobility. Also, it is one of the requirements for most jobs in the country.

Yet, the acquisition of car driving knowledge and skills must be indicated by an approved professional driver's license, which shows the actual driving capacity and passing the driver's national qualification competency. This then implies that before anyone can drive, he/she must have to undergo training either formally in a technical vocational school (TECHVOC) or informally in one's observations and experiences.

In the case of Cor Jesu College, all college students are enrolled in the driving program and formally attending driving lessons as part of their curriculum. In other words, it is compulsory and one of the requirements for graduation prescribed by the institution. Consequently, since students are flocking to enroll in the driving program, the observation of the schedule for quality driving instruction and quality driving skill development is a challenge.

Meanwhile, in support of ascertaining one's worth of possessing a car driver's license, the Department of Transportation and Communication (DOTC), through Memorandum No. 2011-25, required that before any driver for public utility vehicle (PUV) can drive, he/she must undergo training in the Technical Education and Skills Development Authority (TESDA) schools or any accredited institution to get a certification of training and TESDA assessment (Ramirez, 2015). This provision implies that a driving program with TESDA standard, aside from ensuring safety of the public, is needed to cater to a big number of enrollments in the said driving program.

Moreover, to maintain TESDA standard in a driving program means conservatively utilizing the appropriate time scheduled for quality driving instruction and quality driving skill development. More often than not, however, the standard is sacrificed because of the accepted means and methods for the driving program. One of the factors observed in this case is the available driving unit of Cor Jesu College, which has only one steering wheel and one set of pedals for the trainee. However, the school also come up with a driving unit with two (2) sets of fixed parallel steering-wheel and two (2) sets of fixed parallel pedals for driver instructor and student driver respectively. With one steering-wheel car driving unit, the driving lessons and skill development are delayed for two reasons: 1) There is a fear of getting an accident on the part of the student driver due to the possibility of not driving appropriately; and 2) Both driver instructor and student driver still need to take turns in positioning in the same steering-wheel and pedals in demonstrating (driver instructor's function) and applying driving competencies (student driver's assimilation). Also, with two (2) sets of fixed parallel steering-wheel and two (2) sets of fixed parallel pedals, taking turns in positioning and manipulating in the same steering-wheel in demonstrating and applying driving competencies may be addressed. Still, the fear of getting an accident on the part of the student driver due to the possibility of misdriving or distraction remains. This observed factor then suggests a modification of the means and methods to be employed in a driving program. Thus, the Auto-Shift Application Pilot (ASaP) control system is introduced. This innovation project addresses the obstruction of facilitating quality driving instruction and quality driving skill development for student drivers. It also anticipates prevention of getting an accident while learning how to drive.

Theoretical Framework

The ASaP control system was anchored on Alexander & Pulat's ergonomic principle of "fitting the task to the man," which objective is the enhancement of employee's comfort and well being along with the concern of human and organization performance (Morgan, 2003). In other words, it is about fitting the work to the man instead of fitting the man to work for human safety and productivity (Animashaun & Odeku, 2014; Pheasant & Haslegrave, 2018). Similarly, the ASaP control system is an electro-mechanical device that can be used to transform a car driving unit as student driver-friendly, and safer driving vehicle since the design of its steering wheel and pedals are conforming to the student driver's capacity and confidence in practicing and learning in driving. The driving unit, as well as the driving learning task, fits in the student driver's capabilities and limitations (Liu, 2007; Mallon, 2010) as a beginner.

Conceptual and Technical Description

The Auto-Shift Application Pilot (ASaP) Control System is an electro-mechanical system recommended for the double steering wheel and the double set of pedals driving unit with manual transmission. It is composed of electronic, electrical solenoid switch and disengaging mechanical gear. It will be installed on the student driver's steering wheel shafting, as well as in the pedals. In the operation of the ASaP control system, the driving instructor's steering wheel and pedals will serve as a capacitive sensing input device that will electrically activate or deactivate the ASaP control box. At the moment that the car driving unit is near to get an accident due to the student driver's misdriving or distraction the driver instructor will immediately hold his steering wheel and step on the pedals, and automatically disable the steering wheel and pedals of the student driver. Likewise, when the car driving unit goes back to its normal situation, and the student driver recovers from distraction and fear, the driving instructor will press the auto-engage button switch to give the student driver access of his steering wheel and pedals and start driving practice again. And at the moment that the two steering wheels are synchronized, the driving instructor will release his steering wheel and pedals to give the student driver full control of the driving vehicle for his/her driving lessons (see Figure1).

Figure 1: Technical Design

Cor Jesu College TechVoc Education Institute, Digos City, Philippines, like other driving institutions all over the world, has devised a driving unit with two (2) sets of fixed parallel steering-wheel and two (2) sets of the fixed parallel pedal. However, the problem of uncontrollable dangerous direction or crash may be run after by a distracted student driver since both sets of steering-wheels and pedals are fixed, and their flexibility is dependent only on the listening ear of the student driver from the instruction of the instructor. It is in this context that the present research and development on Auto-Shift Pilot (ASaP) control system is seen as an appropriate innovation. It is a system that can be used in transforming the already existing driving unit with a manual transmission, devised with two (2) sets of fixed parallel steering-wheel and two (2) sets of fixed parallel pedals into a student driver-friendly driving vehicle and a safer driving unit.

Objectives of ASaP Control System

The purpose of this research and development of ASaP control system is to innovate a student driver-friendly and safer driving vehicle. Specifically, it will address the following problems: 1) the taking of turns by both driver instructor and student driver in positioning and manipulating in the same steering-wheel and pedals of a driving unit during the demonstration and application of driving competencies, 2) the student driver's fear of getting accident due to the possibility of misdriving a driving vehicle with two (2) sets of fixed parallel steering-wheel and pedals, 3) the possibility of reducing the risk of getting an accident while on car driving training, 4) easy acquisition of driving competencies or development of driving skills, and 5) the presentability and acceptability of the aesthetic design of the innovation project.

Significance of ASaP Control System

The output of this research and development project would be significant to the following, namely: 1) student drivers, with this innovation project they would be able to acquire the confidence of becoming professional drivers as they can acquire the driving competencies easily; 2) driving instructors, through the innovation project they would be able to facilitate driving instructions with ease since they are confident about the safety of their student drivers during training; 3) driving school, with the innovation project they would be able to train many student drivers and increase their revenue because of the facilitative design of the project. Likewise, in the wider context, through the innovation project the; 4) Land Transport Office, would become confident about the appropriateness of issuing professional driver's license to the applicants from the said driving schools; and 5) the interested public, the project would become their benchmark for their own research and development project in the future.

DEVELOPMENT OF THE ASAP CONTROL SYSTEM

This chapter covers the working components, supplies and materials, construction procedures, tools and equipment used, and production cost of the present research and development project.

ASaP Working Components.

The following are the component parts of the ASaP Control system: (1) ASaP

Main Control, (2) ASaP SPWheTr-TS, (3) ASaP-PTr-FS, (4) ASaP Power Relay, (5) ASaP SWheTe-Act, (6) ASaP PTe-Act, and (7) Other Sub Components.

1. ASaP Main Control. It is composed of electronic components, pilot light indicators, switches, and 12 volts source. Its function is to control the operation of all of its input and output auto-switches and devices and can be monitored through its signal LED indicators (see figure 2).

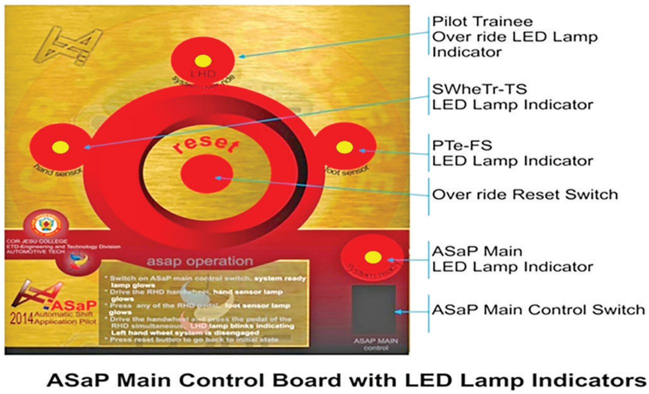

Figure 2. Steering wheel trainer touch sensor

2. **ASaP SWheTr-TS.** It is a Steering wheel trainer touch sensor input device. It is composed of NE555 IC, capacitor, resistor, power relay, and sensing pad. Here, the sensing pad is installed on the trainer's steering wheel to activate the *ASaP SWheTr-TS* when touched by the bare human hand. This activation then causes the release of capacitance discharge, agitates electrons within the sensing pad to flow electronic current to *SWheTr-TS* electronic system, activatesNE555 IC to allow generated voltage to trigger its power relay which is then ready to energize ASaP Power Relays soon as the ASaP PTr-FS is switched on. This *ASaP power* relay is dependent on the simultaneous activation of the control relay of the two ASaP sensors (see figure 3).

Figure 3. ASaP SWheTr-TS

3. **ASaP-PTr-FS.** It is a pedal trainer-foot switch sensor input device. It is a mechanical footswitch device, which is dependent on the pressure of the trainer's foot to control the relay switch operation (see figure 4).

Figure 4. Pedal Trainer Foot Switch

4. **ASaP Power Relay.** It is an electro-magnetic switch that needs electric power to close its switch contact. This device is controlled simultaneously with SWheTr-TS and PTr-FS sensor to control ASaP SWheTe and ASaP PTe-Act actuators. (see figure 5).

Figure 5. Electro-magnetic Switch

5. **ASaP SWheTe-Act.** It is a steering wheel trainee actuator, which is an electrical power-operated output device. It is composed of the enclosure, solenoid switch 1, and mechanical powered coupling. Solenoid actuates its coupler to override the control of the trainee's steering wheel and transfer the control to the instructor's steering wheel. (see figure 6).

Figure 6. ASaP SWheTe-Act

6. **ASaP PTe-Act.** It is a pedal trainee actuator, which is an electrical power-operated output device. It is composed of the enclosure, solenoid switch 2, and mechanical paralleled powered latch (MPL). Solenoid 2 actuates MPL to override trainee's pedals control and transfer the control to the trainer's pedals (see Figure 7).

Figure 7. ASaP PTe-Act - Pedal Trainee Actuator

Other Sub Components

These are the necessary connecting components that can make the major components synchronized and functional. These include: 1) Solenoid Switch 1, 2) Movable Steering Coupler, 3) Solenoid Switch 2, and 4) Movable Pedal Latch.

1. Solenoid Switch 1 is a combination of a coiled cylinder and movable shafting (actuator rod/switch). It is also called as an electro-magnetic jack, that once energize, its rod moves inward with tremendous electrical power, pulling the *MSC-Movable Steering Coupler* to disengage the steering wheel of the trainee (see Figure 8).

Figure 8. Solenoid Switch

2. Movable Steering Coupler. It is the state of the art solid metal tapered slotted rotatable coupling. Its function is to connect/disconnect the steering rod and steering wheel (see Figure 9).

Figure 9. Movable Steering Coupler

3. Solenoid Switch 2. It is a combination of a coiled cylinder and a paralleled movable shafting (actuator rod/switch). It is also called an electromagnetic-jack that once energized its rod moves inward/outward with tremendous electrical power, pulling the *Movable PedalLatch-MPL* to disable the trainer's pedal (see Figure 10).

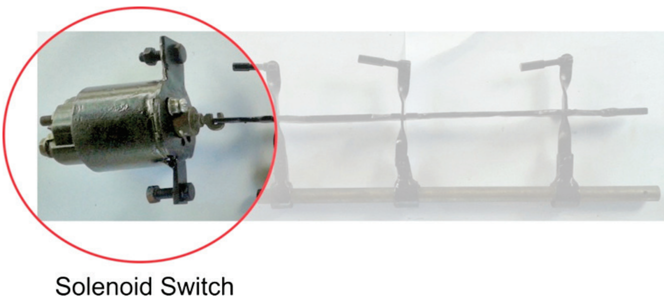

Figure 10. Solenoid Switch 2

4. Movable Pedal Latch. It is an inventive latch system, which is composed of powerful mechanical pushed-spring and tapered pins that are in engaged position so that once the solenoid actuates; latch will be pulled and trainee's pedal will be disengaged (see Figure 11).

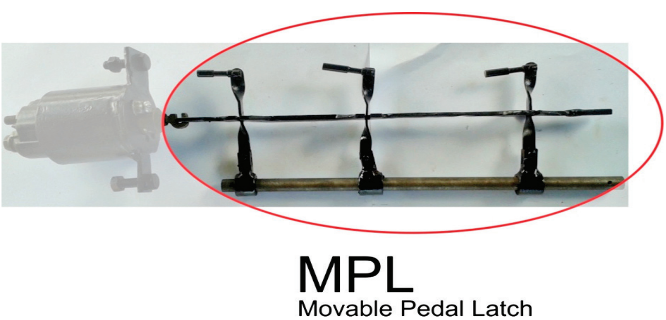

Figure 11. Movable Pedal Latch

Supplies and Materials

Table 1 shows the list of supplies and materials needed for the construction of the innovation project.

Table 1
List of Supplies, Materials and Cost for the ASAP

Description	quantity	Unit	Unit cost php	Total cost php
Steel plate 8ft x4ft	½	sheet	1,500.00	750.00
Round bars 3/16" diameter	2	length	140.00	280.00
Angle bars 1"x1"	2	length	380.00	760.00
Steering wheel	2	pc	800.00	1,600.00
Rack and pinion steering gear box	1	pc	1,200.00	1,200.00
Front suspension assembly multicab	1	pc	5,000.00	5,000.00
Square tube 2"x3"x6ft	½	length	470.00	235.00
Welding rod	50	pc	15.00	750.00
Automotive wires #16	10	meter	22.00	220.00
Brake light switch	3	pc	160.00	480.00
Brake master assembly	1	pc	280.00	280.00
Chain	2	length	40.00	80.00
Sprocket	2	pc	35.00	70.00
TOTAL - 11,705.00				

As displayed in Table 1, the innovation project only costs PhP11,705.00. Among the materials needed, only the steering wheel, rack and pinion steering gearbox, and front suspension assembly multicab materials have a thousand amounts. While the first two materials cost PhP2,800.00, the latter costs PhP5,000.00. This means that the innovation project is very much affordable.

List of Tools and Equipment

Table 2 shows the list of tools and equipment and their functions, to be used for the construction of the innovation project.

Table 2
List of Tools and Equipment and their Functions

Name of Tools and Equipment	Functions
Hacksaw	For the cutting of metals
Flat File	Metal sharp ages remover
Long Nose Pliers	For holding objects during fabrications
Pull-Push Rule	Measuring the dimensions of the project
Ruler	Measuring the distances between equipment and devices

Micrometer Caliper	Measuring small dimensions of the workpiece
Hummer	For pounding
Adjustable Wrench	For tightening and loosening nuts
Drill Press	For drilling holes
Electric Hand Drill	For drilling holes
Lathe Machine	For facing and threading
Welding Machine	For solidification of metals

As shown in Table 2, tools and equipment needed for the construction of the innovation project are very basic since they are the required instruments for an ordinary automotive shop. This implies that the innovation project can easily be done, and the researcher would be hustle free.

Construction Procedures

The procedure in constructing the research project is displayed by the figure. This includes the preparation of two (2) assemblies of the steering wheel, fabrication of pedals, preparation of two (2) assemblies of pedals, construction and preparation of the chassis, the physical set-up of ASaP Control System, and the final output of the innovation project.

Figure 17. Preparation of 2 Assemblies of Steering Wheel

Figure 18. Fabrication and Preparation of Pedals

Figure 19. Preparation of 2 Assemblies of Pedals

Figure 20. Construction and Preparation of the Chassis

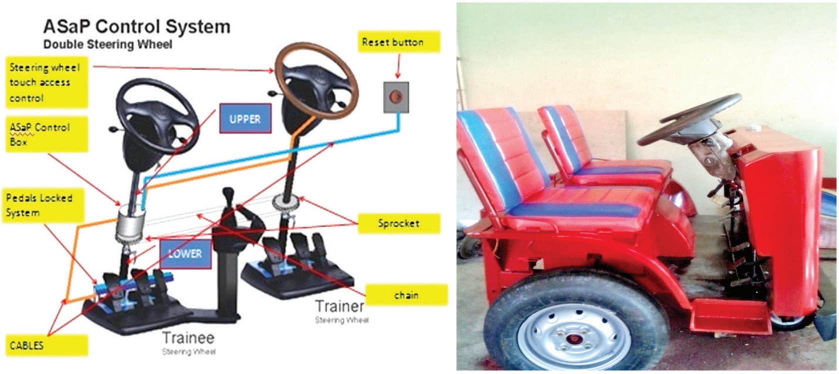

Figure 21. The Physical Set-up of ASAP Control System Project

Figure 22. The Functional ASAP Control System Invention

The figures showed above tell the doability of the innovation project. This implies that when ingenuity is coupled with diligence and industry, any innovation projects can easily be constructed.

TEST AND EVALUATION OF THE FUNCTIONALITY AND AESTHETIC DESIGN OF ASAP CONTROL SYSTEM

This section presents the purpose of test and evaluation, the method of test and evaluation, respondents/participants, research instrument, data gathering procedure, and the results of the tested and evaluated ASaP Control System.

Purpose of the Test and Evaluation of ASaP Control System

The purpose of this test and evaluation was to determine the desired functionality and aesthetic design of ASaP Control System. Specifically, it sought answers to the following questions: 1) Does the taking of turns by both driver instructor and student driver in positioning and manipulating in the same steering-wheel and pedal of a car-driving unit during the demonstration and application of driving competencies can be addressed? 2) Does the student driver's fear of getting an accident due to the possibility of misdriving a car-driving unit with two (2) sets of fixed parallel steering-wheel and pedal can be eliminated? 3) Does the risk of getting an accident while on car driving training can be reduced? 4) Does the acquisition of driving competencies or development of driving skills can be easily facilitated? And 5) Is the ASaP Control System competitive in its aesthetic design?

The Method of Test and Evaluation

As an innovation project, ASaP Control System employed a developmental research design, which involves situations in which the product-development process is analyzed and described, and the final product is evaluated (Richey; 1994; Richey, Klein, & Nelson, 2004). This research design systematically tests and evaluates the functionality and the aesthetic design of the innovation project that must meet the criteria of internal consistency and effectiveness through the facilitation of descriptive research design as its technique and tool.

For the purpose of testing and evaluating the functionality of the present innovation project, this developmental research employed a descriptive research design, which can be both quantitative and qualitative in nature (AECT, 2001). The descriptive research design involves the collection of quantitative information that can be expressed in numerical form and the gathering of qualitative information that can be grouped into themes or patterns (AECT, 2001). Also, while a quantitative descriptive research design requires numerical data, the descriptive qualitative design requires textual data (AECT, 2001; Williams, 2007). Moreover, while the former design answers questions in the laboratory or through written surveys, the latter answers questions in the real world and natural setting (Bossman & Rallis, 2017).

Respondents/Participants of the Developmental Study

The respondents/participants of the study were the five (5) invited driver instructors from the driving schools of Digos City and fifteen (15) student drivers of Cor Jesu College-Technical Vocational Education Institute (CJC-TVEI). They were chosen as respondents/participants of the study using purposive and convenient sampling techniques. Purposive sampling technique was used to get participants who can appropriately give information (Creswell, 2009) on the observable facts of the innovation project. In the same manner, a convenient sampling technique was also employed since the study considered the present CJC-TVEI driving students who can easily be gathered (Creswell, 2007) for quantitative and qualitative evaluations of the present innovation.

Research Instrument

The instrument used in the testing and evaluation of the functionality and the aesthetic design of ASaP Control System was a prepared questionnaire with quantitative survey questions and a space for the participants' qualitative data of evaluation. For the quantitative interpretation of the data in testing and evaluating the functionality of the innovation project, the following rating scale was used:

Range	Description	Descriptive Interpretation
4.20 – 5.00	Strongly Agree	Highly Functional
3.40 – 4.19	Agree	Functional
2.60 – 3.39	Undecided	Moderately Functional
1.80 – 2.59	Disagree	Slightly Functional
1.00 – 1.79	Strongly Disagree	Not Functional

In the same manner, the following rating scale was used for the quantitative interpretation of the data in testing and evaluating the aesthetic design of the innovation project.

Range	Description	Descriptive Interpretation
4.20 – 5.00	Strongly Agree	Highly Competitive
3.40 – 4.19	Agree	Competitive
2.60 – 3.39	Undecided	Moderately Competitive
1.80 – 2.59	Disagree	Slightly Competitive
1.00 – 1.79	Strongly Disagree	Not Competitive

Likewise, for the qualitative interpretation of the data in testing and evaluating the functionality and the aesthetic design of the ASaP Control System, the following method of the suggested by Tudy and Tudy (2018), which was pattered from the method by Colaizzi (1978).

Significant Statements of the Participants	Participant's Code	Formulated Meanings	Recurring Themes

Data Gathering Procedure

The present research and development study had the following procedures and processes: 1) invitation letters were sent to the identified five (5) driver instructors in Digos City to participate in testing and evaluating the ASaP Control System; 2) A letter was also sent to the CJC-TVEI Program Head of the Driving Program requesting him to provide fifteen (15) student drivers as participants of the test and evaluation of the innovation project; 3) the participants were gathered in the area where the researcher oriented them to manipulate the innovation project in order to test and evaluate its functionality and aesthetic design; 4) The questionnaires were distributed to the participants to rate the innovation project as well as to give their comments about the said project, and 5) then the answered questionnaires were retrieved for analysis and interpretation.

Analysis and Interpretation

This section deals with the analysis and interpretation of the data gathered from the developmental study. Analysis and interpretation are presented according to the test and evaluation of the functionality and aesthetic design of the innovation project. This developmental study then used survey questionnaires for quantitative analysis and interpretations and utilizing comments of the respondents below the said questionnaires for qualitative analysis and interpretations. On one hand, the presentation on the functionality of the ASaP Control System covers the three sub-problems of the developmental study, specifically: the taking of turns by both driver instructor and student driver in positioning and manipulating in the same steering-wheel and pedals of a driving unit during the demonstration and application of driving competencies; the student driver's fear of getting accident due to the possibility of misdriving a driving vehicle with two (2) sets of fixed parallel steering-wheel and pedals; the reduction of the risk of getting an accident while on car driving training; and easy acquisition of driving competencies or development of driving skills.

On the other hand, the presentation on the aesthetic design of the ASaP Control System covers the competitive level or the presentability and acceptability of the innovation project. The presentations are systematically arranged in the two headings, namely: the quantitative presentation of the functionality and aesthetic design of the innovation project and the qualitative presentation of the innovation project's functionality and aesthetic design.

The Quantitative Presentation of Functionality and Aesthetic Design. Displayed in Table 3 and 4 are the quantitative data pertaining to the functionality and aesthetic design of the ASaP Control System based on the test and evaluation of the professional driver respondents and student driver respondents.

Table 3 shows the ratings of the five driver instructor respondents on the functionality and aesthetic design of the ASaP Control System. Driver instructor respondents' ratings revealed that the ASaP Control System is highly functional, with a mean score of 4.46 and moderately competitive with a mean score of 3.36.

Table 3: The Quantitative Data on the Functionality and Aesthetic Design of the ASaP Control System According to the Driver Instructor Respondents

Driver Respondent	Rating on Functionality	Descriptive Interpretation	Rating on Aesthetic Design	Descriptive Interpretation
1	4.5	Highly Functional	3.2	Moderately Competitive
2	4.66	Highly Functional	3.6	Competitive
3	4.0	Functional	3.2	Moderately Competitive
4	4.5	Highly Functional	3.6	Competitive
5	4.66	Highly Functional	3.2	Moderately Competitive
Mean	**4.46**	**Highly Functional**	**3.36**	**Moderately Competitive**

Likewise, Table 4 shows the student driver respondents' rating on the functionality and aesthetic design of the ASaP Control System. As displayed, the ASaP Control System got a mean score of 4.43 for its high level of functionality and 3.5 for its level of competitiveness in aesthetic design.

Table 4: The Quantitative Data on the Functionality and Aesthetic Design of the ASaP Control System According to the Student Driver Respondents

Driver Respondent	Rating on Functionality	Descriptive Interpretation	Rating on Aesthetic Design	Descriptive Interpretation
1	4.5	Highly Functional	3.6	Competitive
2	4.6	Highly Functional	3.8	Competitive
3	4.5	Highly Functional	3.6	Competitive
4	4.6	Highly Functional	3.6	Competitive
5	4.0	Functional	3.6	Competitive
6	4.5	Highly Functional	3.2	Moderately Competitive
7	4.6	Highly Functional	3.2	Moderately Competitive
8	4.0	Functional	3.6	Competitive
9	4.5	Highly Functional	3.6	Competitive
10	4.0	Functional	3.6	Competitive
11	4.6	Highly Functional	3.2	Moderately Competitive
12	4.6	Highly Functional	3.6	Competitive
13	4.5	Highly Functional	3.6	Competitive
14	4.5	Highly Functional	3.6	Competitive
15	4.5	Highly Functional	3.6	Competitive
Mean	**4.43**	**Highly Functional**	**3.5**	**Competitive**

Furthermore, it is shown that while both driver instructor and student driver respondents rated the ASaP Control System as highly functional, they differ in their rating on the ASaP Control System's aesthetic design. While the driver instructor respondents rated it as moderately competitive with the mean score of 3.36, the student driver respondents rated it competitive with a mean score of 3.5. However, it is noticeable that their different ratings belong to the scale range that needs improvement. Thus, while the functionality of the ASaP Control System is assured, the enhancement of its aesthetic design is considered.

The Qualitative Presentation of Functionality and Aesthetic Design. Displayed in Table 5 are the thematically analyzed qualitative data pertaining to the functionality and aesthetic design of the ASaP Control System based on the written evaluations of the driving instructor and student driver participants. Results of the thematic analysis revealed three (3) main themes, namely: the functionality of the ASaP Control System, the presentability of the ASaP Control System, and its proper placement.

Functionality of the Project. One of the common responses in both written and verbal responses of the driver instructors and student drivers was on the functionality of the project. First, they said that many students could be accommodated for driving training by this innovative project since both instructors and students do not need to exchange seats. Both steering wheels and pedals are functioning according to their respective purposes. Because of this innovation, the purpose of safety is ensured. The practice of driving is far from an accident, and it can build confidence in the apart of the student driver. In fact, one of the participants said:

> "Kay layo man sa disgrasya ang pagpractice sa pagdrive ma arisgado moeskuela ang estudyante (Driver 1)."
> (Since the driving practice is far from an accident many students would be encouraged to take driving lessons.)

Also, according to the responses, the sensor of the driving instructor's steering wheel and pedals are sensitive that can easily incapacitate the student driver's steering wheel and pedals and making the training of driving far from an accident. It added to the functionality of the project. In short, this innovative project can easily facilitate the acquisition of driving competencies. This was expressed by one participant who shared:

> "Dali rang ma driver and estudyante kon iinstall ang project sa driving unit (Student Driver 5)."
> (It is easy fora student to become a driver when this project is installed in the driving unit).

These participants' evaluations imply that the ASaP Control System can really serve the purpose for which it is being made, which is making a driving vehicle student driver-friendly and safer school driving unit. This result conforms to Alexander & Pulat's ergonomic principle of "fitting the task to the man" instead of fitting the man to work for human safety and productivity (Animashaun & Odeku, 2014); Pheasant & Haslegrave, 2018).

Presentability of the Project. The innovation project needs improvement, especially the arrangement of wirings and some electronic devices inside the prototype, the participants suggested. It was noted that the prototype was assembled but would be later installed in a real vehicle. However, the prototype itself needs improvement in its appearance. Specifically, a student driver suggested:

> "Mayo kon hapsayon ang mga wirings sa sulod sa project (SD9)."
> (It is good to arrange the wirings and some electronic devices of the project properly).

From these evaluations of the participants, it can be deduced that the innovation project needs improvement in its aesthetic design to become more competitive. This result is result is related to the findings of Barata and Nevado (2014), Brondoni (2015) and Whaley (2009) about considering the improvement of project's aesthetic design for competitiveness as very important since the design is linked to the performance of the project and design is connected to highly promising and sustainable innovation.

Proper Placement of the Project. Since it was just a prototype, the participants wanted to have it installed in a real vehicle. They would like to test it and see its real functionality. One student driver commented:

> Nindot kon modagan unta ning gibutangan sa project (SD5)."
> (It is good if the project is installed in a running driving vehicle).

This suggestion implies that the functionality of the innovation project makes it appropriate to be installed in the manually transmitted school driving unit. In other words, it is a confirmation that the innovation project works for its intended purpose (Lemley, 2016). This suggestion of the participants then coincides with the nature of prototyping, which is to demonstrate a system or project to discover issues as well as to plan for the use or implementation of the prototyped project (Prototype, 2012; Udell, 2013).

From these three themes mentioned, it can also be gleaned that the ASaP Control System is useful, practical, and can really serve the purpose for which it is being made. However, its aesthetic design needs improvement, and its installation in the real driving vehicle with manual transmission is advisable.

CONCLUSION AND RECOMMENDATION

The conclusions were formulated from the findings of the developmental study, and the recommendations were made to help improve the ASaP Control System project.

Conclusion

Results of the test and evaluation made by the professional driver and student driver respondents confirmed that ASaP Control System is functional that can address: 1) the taking of turns by both trainee and trainer in positioning and manipulating in the same steering-wheel and pedals of a driving unit during the demonstration and application of driving competencies, 2) the trainee's fear of getting accident due to the possibility of misdriving a driving vehicle with two (2) sets of fixed parallel steering-wheel and pedals, 3) the possibility of reducing the risk of getting an accident while on car driving training, 4) the easy acquisition of driving competencies or development of driving skills. However, while the innovation project is seen useful, practical, and can really serve the purpose for which it is being made, the innovation project is seen as less competitive in its aesthetic design.

Moreover, the results of the test and evaluation made by the professional driver and student driver respondents suggested enhancement of the ASaP Control System for public acceptability. The respondents observed that the innovation project is less presentable to the public when it is displayed.

Lastly, as indicated in the test and evaluation of the ASaP Control System, it is recommended by the professional driver and student driver respondents that this innovation project is installed in a school driving vehicle with manual transmission.

Recommendations

Taking into account of the results of the developmental study, the following recommendations were made: 1) the innovation project's aesthetic design and physical set-up must be improved to make it more presentable and acceptable to the public; 2) the innovation project must be installed in the manually transmitted school driving vehicle for a student-friendly and safer driving unit; and 3) the further explorations on the application and installation of the innovation project in an automatically transmitted school driving vehicle. Also, it is recommended that other innovation projects that observe the ergonomic principle of "fitting the work to the man rather than fitting the man to the work" for human safety and productivity can be developed.

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ACCELERATION DATA LOGGING SYSTEM FOR STRUCTURALHEALTH MONITORING USING TRIAXIAL MEMS ACCELEROMETER

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ABSTRACT

A structural health monitoring system for midrise structures prototype developed for monitoring building vibration and health is presented. An accelerometer sensor connected to a computer was used for collecting and monitoring acceleration data on structural beams of midrise buildings. The prototype provides information and representation of the acceleration vibration of Z Axes on a midrise structure.

Keywords—Rasberry Pi; acceleration data; vibration monitoring

INTRODUCTION

Structures are built to protect people from the negative effects of a natural disaster. It is important that our buildings are healthy and monitored from severe structure loadings such as earthquakes (Roghaei & Zabihollah, 2014), typhoons (Han et al., 2016; As'ad & Sukiman, 2013), and active daily loading and overloading with heavy contents, which can cause substantial economic loss. Moreover, this can bear continuing damage when structural integrity deteriorates gradually over time (Boudiaf, Djebala, Bendjma, Balaska, & Dahane, 2016; Matsubara & Nagamachi, 1997). With the Structural Health Monitoring (SHM), the high repair costs by monitoring and discovering these detrimental circumstances can be reduced. It has developed into a fundamental instrument that enhances safety and maintains significant infrastructures. The need to develop this technology is essential in keeping structures safe and in generating information to improve future structural designs.

In developing this particular technology, there are different methods, calibration, and measurement techniques that were designed and used to collect, calibrate and measure vibrations on structural health. For example, the experimental design was employed to combine the subwoofer method for frequency response and inclination sensing method of calibration to accelerometers, which resulted to huge accuracy levels. Another calibration technique, the two-point calibration method, was used to a number of temperature sensors, which accounted to not more than 10% percent error. It was considered to be with high data integrity, which was utilized for effective checking and experimenting on structural acceleration, vibration, temperature drifts, and surrounding temperature information from a concrete bridge experiment podium. The method of experimentation on sensing distinctiveness of the sensors facilitated on a winning improvement of the sensing (Lacis, 2016). Another experimental method was used to certify the information output of accelerometers. A shaking stimulator attached to a centrifuge was created that provided synchronized harmonic constant linear accelerations. Its calibration method was used to assess the shaking refinement inaccuracy of the accelerometer (Panin et al., 2017). Another technique was used to investigate the causes of three-axis digital accelerometer MPU6050 errors using the Maximum Likelihood Estimation (MLE) method. This method involves the rotating of the accelerometer, which is set up on one hundred hertz (100hz) data rate on the X, Y, and Z axis. After this process, the computation of acceleration data averages for each axis was done. With recurring procedure, the averages were used as input to the MLE algorithm. As a result, the MLE-based algorithm obtained a high precision estimation in acceleration data (McCann & Forde, 2001). In a similar note, another technique in data gathering method, which decreases the variance of parameter estimation of micro electro-mechanical accelerometer sensors, was the use of optimum experimental design via the auto-calibration model (Moore, Glenncross-Grant, Mahini, & Patterson, 2012). Another method of the calibration was experimented to determine the linear velocity and adjust the untreated data of an accelerometer by means of an encoder utilizing a fuzzy inference systems technique (Bluman, 2009). These modern techniques and methods prove the data integrity in calibrating accelerometer, which can promote the improvement of the qualifications of sensor sensing an acceleration monitoring and frequency response of structures.

Despite the existence of the different methods and calibrating techniques, very few ventured into attaching the equipment on mid-rise buildings. Hence, the goal of this project was to develop an acceleration monitoring system that collects vibration data from structures to help engineers improve safety and structure maintainability. Mainly, this project aimed to calibrate the accelerometer to ensure profound data integrity in structural health monitoring using inclination sensing and subwoofer calibration methods and to test the develop system on a midrise structure.

METHOD

A. System Setup

1) Hardware Setup

The Acceleration Data Logging prototype was fabricated using an industrial-grade plastic container housing the onboard computer and the accelerometer sensor. Figure 4 shows the developed prototype of the acceleration data logging system. The organization of the sensor node, which is, enclosed in an industrial-grade plastic which the ADXL 345 accelerometer and Raspberry Pi 3 Model B+ computer, and an external power supply is attached to the sensor node. The software which runs on the Acceleration Data Logging system was incorporated through the Raspberry Pi platform using the Raspbian Jessie operating system running a python script.

2) Software Setup

The built-in open-source Python Idle on the Linux based Raspbian Jessie operating system of the Raspberry Pi (2) platform was used to program the functions of the system. The Python idle used a processing programming language based on python with user-friendly clean syntax and simple user interface. For program testing and troubleshooting, the Raspberry Pi (2) itself can be connected with peripherals to monitor functions of the components of the system. A Python script was used to read accelerometer (1) data and transfers the data on the CSV file on system memory of the Raspberry pi (2). The system block diagram is shown in figure 1.

Fig. 1. System Block Diagram of Acceleration Data Logging System.

3) *ADXL 345 Accelerometer Sensor*

For the ADXL 345 sensor calibration and acceleration measurements, a program was developed to initiate a calibration procedure. Inclination sensing and subwoofer-setup (Bluman, 2009; Concepcion, 2017) technique were function generator that will be its input, and frequency values will be setup. The accelerometer data, after a minute, will be compared to the input frequency from the function generator. The data from the accelerometer and the function generator did not match. The accelerometer was recalibrated until the value coincide. For the acceleration test, the prototype was exposed to a 1 Hz; 2 Hz: 3 Hz; 4 Hz vibration data and was calculated using a Fast Fourier transform algorithm implemented in Numerical Python.

B. *System Operation*

1) *Control Circuitry and Power Supply*

The system's operation was controlled by Raspberry Pi 3 Model B+ Computer through a python script. The Raspberry Pi-powered the accelerometer and read the sensor data through I2C port and stored acceleration values to the system memory. All the electrical components of the hardware operated on the DC power source.

2) *Data Collection and Data Logging*

The whole system operated on a five-stage methodology, as shown in Figure 2. The Acceleration Data Logging system was installed on a structural beam, specifically midpoints and collected acceleration data. These data were converted waveform outputs, parameter values, and categories in two groups which are data on active load and dead load schedules on ten data points per second monitoring for sensitive acceleration vibration detection.

Active load schedule, typically, is where the building is being used and supporting moving loads most of the time from 7 am to 5 pm schedule; dead load schedules typically lies on the 5 pm to 7 am where least-moving loads are experienced. To verify the active loading vibration, a time series representation of the acceleration vibration was used. Spikes in the time series representation were considered as the active loads acting upon the structure, and the constant vibration were dead load movements.

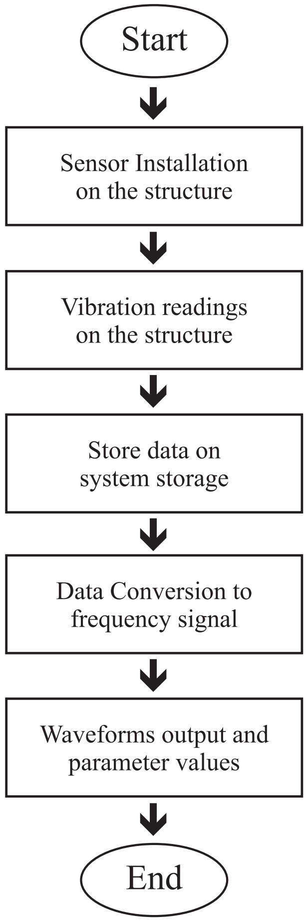

Fig. 2. Acceleration Data Logging methodology.

C. *Deployment Site*

The deployment site was a 25-year old 3-storey midrise building named Polycarp Building in Cor Jesu College, Digos City, Davao del Sur, Philippines. Shear stress and fatigue of beams on the building storey's gradually decreased storey levels go up, which means that lower stories levels with respect to the ground floor experience more fatigue (Loh, Zimmerman, & Lynch, 2007; Panin, et al., 2017). One of the factors of structural fatigue is service life and exposure to other moving loads (McCann & Forde, 2001; Woo, Kim, Kim, & Kim, 2011). This suggests that the beam on the right side of the older Polycarp Building experiences more fatigue and vibrations induced by the moving loads (Hu, Wang, & Ji, 2013; Weeger, Wever, & Simeon, 2014). Figure 3 shows the older Polycarp Building. The Acceleration Data Logging prototype was deployed at the right side second floor beam of the 25-year-old Polycarp Building for seven days and gathered significant data.

Fig. 3. Polycarp building in Cor Jesu College, Digos City, Philippines

D. *Statistical treatments*

Paired T-test statistical (Moore, Glenncross-Grant, Mahini, & Patterson, 2012) treatment was used to compare the vibrations of the old Polycarp Building, the daily acceleration readings of the active loads, and dead load schedules. The T-statistic formula, as defined in equation 1, is explained, where d as the mean of the difference, S^2 as the standard deviation, n as the sample size, t as the T-statistic, and n-1 as the degrees of freedom.

$$t = \frac{d}{\sqrt{S^2/n}} \quad (1)$$

RESULTS AND DISCUSSION

The method described in section II and Figure 1 were successfully implemented to the prototype, as shown in Figure 5. The prototype was deployed for seven days at a period where the site gave good acceleration vibration. The maximum and minimum acceleration data of the Z-axis were recorded, as shown in Tables 1 and 2. It can be observed that the acceleration vibration varies over the whole duration of deployment in terms of daily building usage levels each day, as observed in a time series representation in Figure 5.

Fig. 4. Final prototype. Accelerometer sensor (1), Raspberry Pi 3 (2)

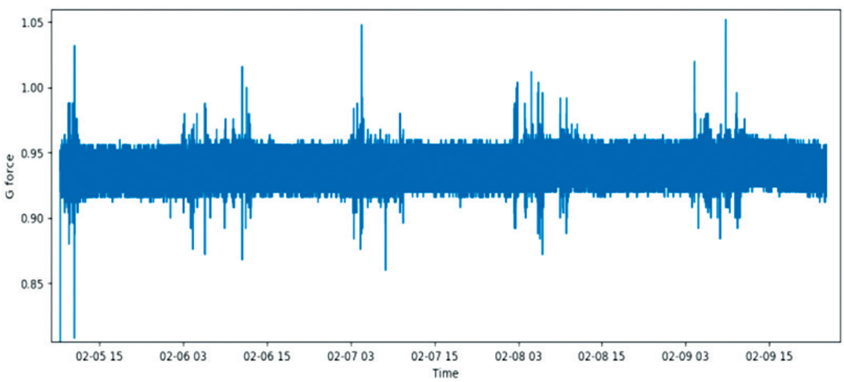

Fig. 5. Time series representation of vibration on the Polycarp building

The time-series representation of the seven-day monitoring of the Polycarp Building using the SHM system with respect to time and g force is shown in Figure 5. The spikes in time series graph indicate active loads moving through in the building, and the constant vibration is the dead loads experienced by the Polycarp Building.

The difference of the maximum and minimum value of the acceleration readings, as shown in Tables 1 and 2, was computed to determine the active load vibration for the Polycarp buildings. It was used T-test statistical treatment to verify the vibration. The null hypothesis was that the active load vibration on Polycarp is equal or no significant difference than the dead load on Polycarp. The alternative hypothesis was that active load vibration on Polycarp is greater than dead load vibration. The null hypothesis H0 and alternative hypothesis Ha are written below, H0 (null hypothesis): if T-statistic<critical value of 1.943, then it is statistically the same.

Ha (alternative hypothesis): if T-statistic> critical value of 1.943, then reject the null hypothesis.

Table 1. Polycarp building difference in Max and Min accelaration readings 7am to 5pm Active load

Day no.	Max acceleration value reading of Z-axis (g)	Min acceleration value reading of Z-axis (g)	Difference in Max and Min acceleration readings of Z-axis(g)
1	1.02982994	0.91782994	0.112
2	1.02182994	0.94782994	0.074
3	1.00382994	0.94382994	0.06
4	1.00982994	0.95782994	0.052
5	1.03982994	0.95582994	0.084
6	0.99982994	0.95582994	0.044
7	0.99382994	0.96782994	0.026

Table 2. Polycarp building difference in Max and Min accelaration readings 5pm to 7am Dead load

Day no.	Max acceleration value reading of Z-axis (g)	Min acceleration value reading of Z-axis (g)	Difference in Max and Min acceleration readings of Z-axis(g)
1	0.99382994	0.96982994	0.024
2	1.00782994	0.94982994	0.058
3	1.03782994	0.95182994	0.086
4	1.01982994	0.94982994	0.07
5	1.02382994	0.95982994	0.064
6	0.99382994	0.96782994	0.026
7	0.99382994	0.96982994	0.024

CONCLUSIONS AND FUTURE WORKS

The study has developed the Acceleration Data Logging system and compared it to the Acceleration vibrations reading of a midrise building named Polycarp. The Polycarp Building has a 0.064571429g acceleration reading on average during an active load, and 0.050285714g acceleration reading on average during dead loads. Statistical treatment using T-test on the difference of the maximum and minimum vibration readings for Polycarp active and dead loads showed a significant difference during the active load. The results revealed the standard deviation of 0.0279 and T-statistic of 2.5406 with 0.05 level of significance. Hence, the null hypothesis was rejected, and alternative hypothesis was accepted. Data suggest that vibration on active was greater than dead loads with a mean difference on the average acceleration readings of 0.014285714g. This implies that the developed monitoring system is working optimally in monitoring vibrations readings. Implementation of the developed system on high-rise buildings and bridges is recommended.

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DEVELOPMENT OF A MICROCONTROLLER LABORATORY TRAINER MODULE FOR ENGINEERING STUDENTS

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ABSTRACT

The knowledge of microcontroller to engineering students is essential since it will help them in the development of their prototypes for their design projects. The idea of this study was to develop a laboratory trainer board using arduino microcontroller kit. The developed laboratory trainer module covers sensors, motor, Bluetooth modules, switches, and display. The laboratory module evaluation was assessed through the finished projects using the trainer module. Students were given a survey questionnaire after performing experiments. Based on the results, the microcontroller trainer module was essential in helping students learn hardware programming and microcontroller interfacing.

Keywords —Engineering, Arduino, sensor, Bluetooth, microcontroller, laboratory trainer module, Philippines

INTRODUCTION

A microcontroller is a small computer on a single integrated circuit, which contains a processor core, memory, and programmable input/output peripherals (Bannatyne & Viot, 1997). A microcontroller is widely used nowadays in almost every application such as printers, remote control, and modern automobile. Because of its usefulness, engineering students find it essential in building design prototypes for their thesis related projects. Microprocessor and Design Projects are important subjects required to complete their course (Hamad, Kassem, Jabr, Bechara, & Khattar, 2006). In these subjects, students are required to learn the concepts of Microprocessor system and its purpose. However, the previous researches use the older version of Programmable Interface Controller (PIC) microcontroller for their laboratory experiments (Hamad et al., 2006), where they need external clock and other components for it to function properly. Hence, previous designs were prone to complications.

In Cor Jesu College, the courses Microprocessor Systems (ECE/CpE 423) and Design Projects (ECE 511/CpE 510) are two of the important subjects required for engineering students to complete their course. In these subjects, students are required to learn and understand the concepts of a microcontroller and their purpose. These students conduct laboratory activity by taking the electronic components, module, and other devices piece by piece during lab activity. These components are prone to damage or loss, disorganization, and non-systematic laboratory activity. With this scenario, the components and microcontroller modules are easily damaged due to electrostatic discharge brought by humans to the components. For this reason, the proponents decided to develop a trainer module that integrates and organizes various microcontrollers, electronic module, and other devices to limit electrostatic discharge. It allows students to earn self-pace the concepts of hardware programming (Hamad et al., 2006).

The main goal of this study was to assist students in prototyping their future projects; enhance user's programming skills in hardware applications, and help the students in understanding the concept presented in the laboratory experiments.

MATERIALS AND METHOD

The design integrated microcontroller and other electronic components in one development trainer module to have an organized laboratory activity not prone to damages of the electronic components and modules.

Arduino development board was chosen by the proponents as the microcontroller to be used in the design because of its flexibility with interactive objects or environments (Wang, Lim, Wang, Leach, & Man, 2014). Arduino Integrated Developments Environment is an open-source (Wang et al., 2014) and is available to many Operating Systems like Windows, Linux, and Mac OS. It can be programmed in C programming language and the Integrated Developments Environment has loads of examples, which can be easily understood, as a start.

1. Hardware Design

The hardware design, as shown in figure 1, illustrates the process and connection of components of the trainer board. The power supply is the device that produces electric power to the trainer board. The microcontroller is a small computer in a single integrated circuit (Bannatyne & Viot, 1997). It is where the program is to be loaded for laboratory exercises. The servo motor and display are components that generate visual or moving output. The tact switch and keypad are components where data can be entered as input to be processed by the microcontroller. The Bluetooth module is a wireless communication (Asadullah & Ullah, 2017) device that enables electronics to connect with arduino microcontroller via Bluetooth connection via Android Phone (Chen, Zhang, & Wang, 2018). The Global System for Mobile communication (GSM) is a module that enables the electronic component to receive/send text messages (Madhura, Poojalakshmi, & Pravin, 2017) or call via Telecommunication Network. GSM module can control different electrical appliances (Teymourzadeh, Ahmed, Chan, & Hoong, 2013) via text messaging.

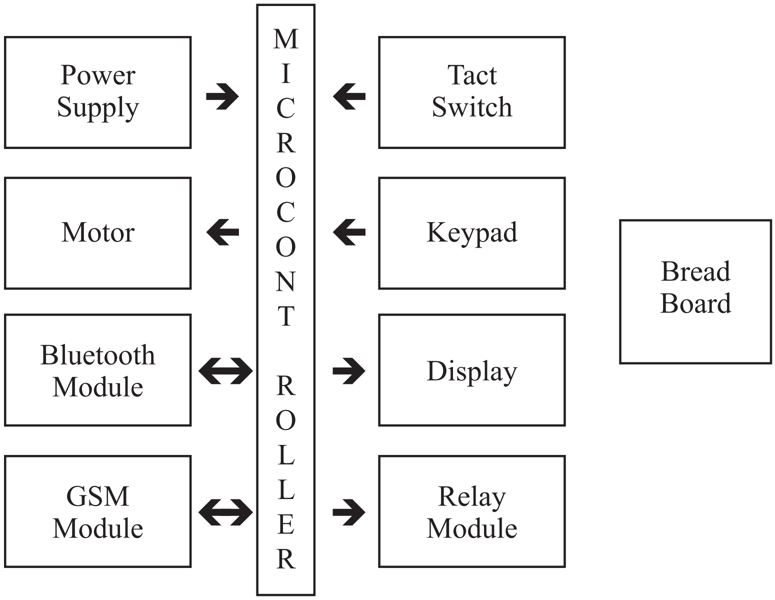

Figure 1. Block Diagram of the Hardware Components

2. System Flowchart

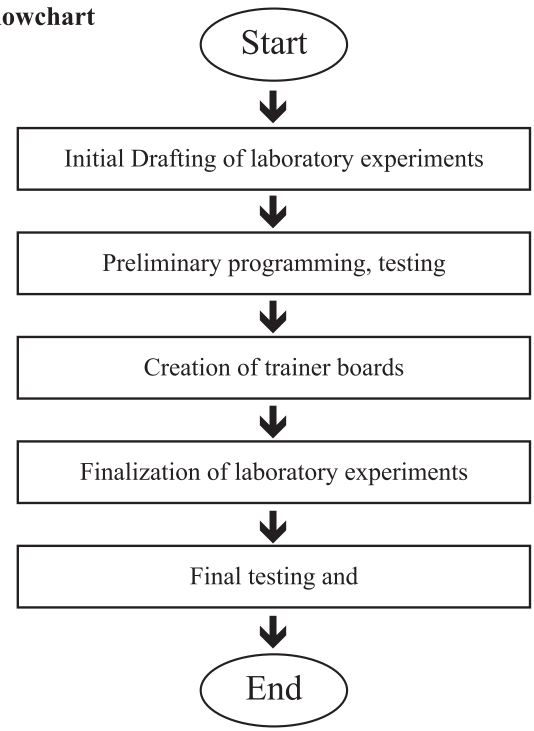

Figure 2: System flowchart of the Design

Figure 2 shows the design and step-by-step process in developing the trainer module. It started with the initial drafting of the laboratory experiments. Objectives were formulated, and exercises were created for each experiment. Initial circuit schematic diagrams to be used were also designed. The next step was the preliminary programming, testing, and debugging. The Arduino program source codes for the exercises in each experiment were created. These exercises were performed and tested by downloading the source code to Arduino and build the corresponding circuit diagram to be used on a breadboard. Necessary adjustments to the program source codes and circuit schematic diagrams were also performed.

The creation of a laboratory trainer module was done. The circuit schematic diagrams for each experiment were designed and tested successfully. The circuit designs were transferred into printed circuit boards. Creating PCB layouts, etching, drilling, soldering, and debugging PCB connectivity were performed in this step. Finally, testing and debugging were performed. All the laboratory experiments were conducted following the laboratory manual draft that was created earlier as a reference. The trainer boards were tested and debugged for problems until all were successfully working. With all those processes, the finalization of the laboratory experiments was done. The initial draft for the laboratory experiments was finalized as a laboratory manual following the format below for each laboratory experiment, like Experiment number and experiment title; Objectives; Equipment and Materials; Discussion; Trainer Board Reference Schematic Diagram; Procedures; and Activities. The final prototype is shown in figure 3.

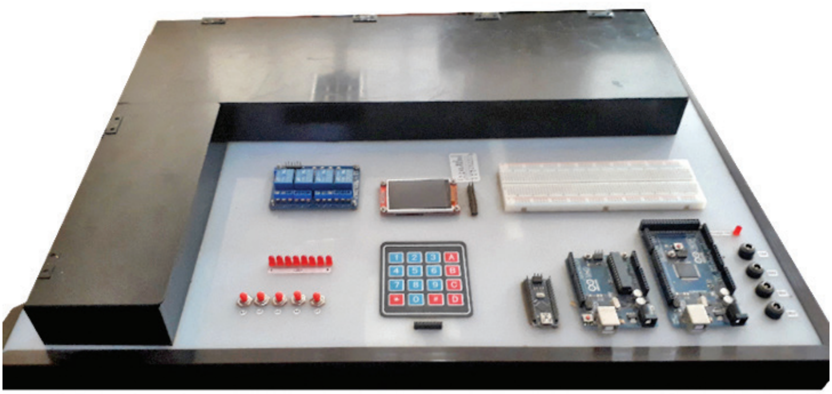

Figure 3. Final Prototype

RESULTS AND DISCUSSION

The finalized laboratory trainer module helps the students in completing the student's final requirement in their major subjects. Figure 4-a shows the finished line follower robot; figure 4-b shows the completed Biometric Attendance System. Figure 4-c shows some of the wireless-controlled designs. All finished projects underwent programming, testing, and debugging using the newly developed microcontroller laboratory trainer board.

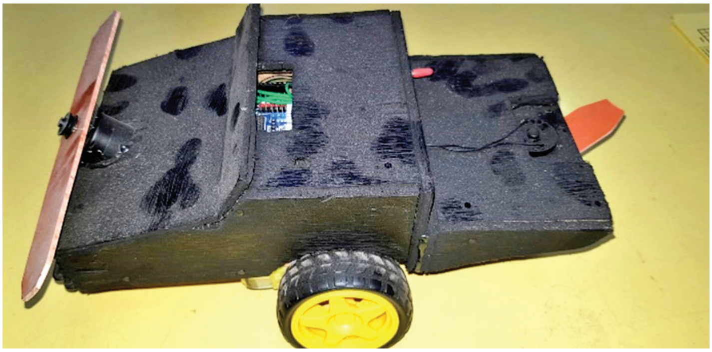

Figure 4-a: Line Follower Robot

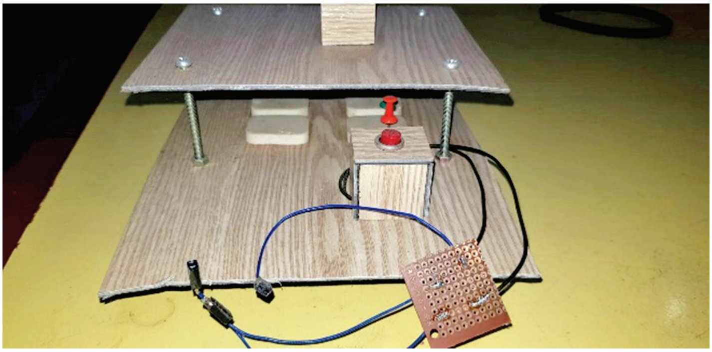

Figure 4-b: Biometrics Attendance System

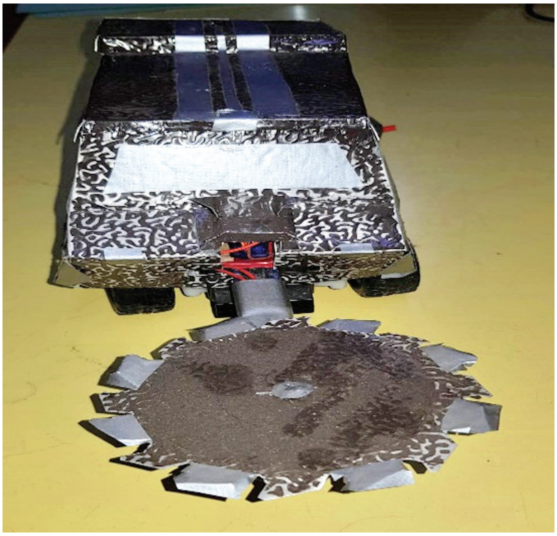

Figure 4-c: Bluetooth-controlled Robot

Finally, the survey questionnaire was distributed to eight pairs of students who have the background on electronics, Circuits, and C++ programming but have little or no background on programming microcontrollers.

Every time a pair finished an experiment, they were required to answer a laboratory assessment form to evaluate their experience in the performed experiment.

The data gathered from the answered laboratory assessment forms were separated into three sections: laboratory experiment section, trainer board section, and the self-assessment section.

Table 1
Laboratory experiment evaluation summary table

Statements	Overall Weighted Mean	Interpretation
1. The discussion is clear in introducing the basic concepts necessary to perform the experiment.	4.9	Very High
2. The schematic diagram is readable and understandable.	4.85	Very High
3. The procedures are clear and easy to follow.	4.95	Very High
4. The activities are easy to perform.	4.85	Very High
5. The objectives of the experiment have been met.	5	Very High

Table 2
Trainer Board evaluation summary table

Statements	Overall Weighted Mean	Interpretation
1. The trainer board is suited to the experiment to be performed.	4.8	Very High
2. The trainer board is helpful in understanding and performing the experiment.	4.85	Very High

Table 3
Self-assessment evaluation summary table

Statements	Overall Weighted Mean	Interpretation
1. I am confident that I could apply the concepts I learned in the experiment using an Arduino board	4.95	Very High
2. I am confident that the knowledge I obtained will be helpful in learning and using other kinds of microcontroller	4.9	Very High

Table 1 shows the evaluation of the laboratory experiment section. The respondents rated very high that the discussion in the experiment was clear, the schematic diagram was readable, the procedures were easy to follow, the activities were easy to perform, and the process of the performed experiment had been met. Table 2 shows the evaluation of the trainer board evaluation section. The two statements both received a very high rating. It means that the respondents agreed that the trainer board was suited to the experiment to be performed and is helpful in understanding and performing the experiment. For the self-evaluation section, as shown in Table 3, the respondents also rated very high. It means that they are confident that they could apply the concepts they learned in the experiment using Arduino board, and the knowledge they obtained is very helpful in learning and using different kinds of a microcontroller.

CONCLUSION AND RECOMMENDATION

The evaluation of the respondents showed that the created laboratory trainer module helped the students in interfacing microcontroller and improved their hardware programming skills. Line follower robots, running message board, and other wireless-controlled design projects were successfully done. Also, based on the results gathered from the survey questionnaire, the interpretation of the results shows that the developed trainer module helped the students in understanding the concepts presented in the laboratory experiments. Similarly, it enhanced their confidence in creating future design projects. Finally, the researchers concluded that the developed microcontroller trainer module is an essential aid in learning the concepts of microcontrollers.

Despite the success of the development of the microcontroller trainer board, it is still considered as a continuing projecy. Thus, some points are considered for future enhancement. Improved components or modules and better design can be applied to make the design best suitable that can be implemented for other applications. For larger applications that need multiple tasking of outputs or design projects that requires larger memory and database, it is highly recommended to include a Raspberry Pi in the laboratory module. It is also recommended to include Pi Camera Module and LCD Monitor for future designs that need digital image processing.

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THE EFFECTIVENESS OF GRADUAL RELEASE OF RESPONSIBILITY APPROACH IN IMPROVING PERFORMANCE OF STUDENTS IN MATHEMATICS

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ABSTRACT

Mathematics is fun but very challenging to teach. Several studies reported different teaching approaches that are considered effective in enhancing students' performance in Mathematics. This quasi-experimental design of the study aims to determine the effects of the Gradual Release of Responsibility (GRR) Approach in improving the performance of students in Mathematics, particularly in lesson Geometry 7. The subjects were grouped into a control group that was exposed to the Traditional Teaching Approach Employed by the School and experimental group, which was exposed to the GRR approach. Data gathered were analyzed using mean, t-test for independent sample, paired sample t-test, and ANCOVA. Results revealed that before the implementation of the approaches, both levels of proficiency of the groups are at the beginning level, which implies that they were struggling in their understanding due to lack of essential knowledge and skill on the topics. The results showed that there is an improvement in the performance of students in Mathematics after being exposed to the GRR approach and traditional teaching approach. The post-test performance of the control group found to be at the developing level of proficiency while the experimental group found to be at the approaching proficient level. Finally, the study indicated that there was a significant difference in the post-test mean scores between the control and experimental groups with pre-test mean scores covariates. The findings revealed that the GRR approach could improve the Mathematics performance of students. Based on the result of this study, the Gradual Release of Responsibility Approach is recommended to be used as an approach in teaching Mathematics.

Keywords: Mathematics, performance in Mathematics, gradual release of responsibility, quasi-experimental design, Philippines

INTRODUCTION

The continued concern of teachers on students' performance in Mathematics calls for the implementation of an innovative teaching approach that is best suited to the students. In fact, according to the International Mathematics Union (2010), one of the crucial issues in educational development is the need to strengthen Mathematics development. Unfortunately, many students continue to show incapability of performing basic Mathematics skills like solving and analyzing (Alzhanova-Ericsson, Bergman & Dinnétz, 2017). Thus, the poor performance of students in Mathematics remains to be a widespread problem today.

The low performance of students in Mathematics is also a problem for many countries like Finland, Germany, Kuwait, Netherlands, and Saudi Arabia (TIMSS, 2015). Even one of the leading countries, which is the United States of America, is experiencing a low performance in Mathematics. The report of the Programme for International Student Assessment (PISA) revealed that among the 35 members of the Organization for Economic Cooperation and Development (OECD), the US ranked 30th in Mathematics. The data provided by the reports of TIMSS (2015) and PISA (2015) concluded that there is a poor status of students' performance in Mathematics internationally.

Some of the Association of Southeast-East Asian Nation countries are also experiencing a low performance in Mathematics. For example, the PISA 2013 results for Indonesian students showed that they got the second-lowest in the OECD league table, worse than the last PISA in 2009 when Indonesia ranked 57th (PISA, 2013). Furthermore, low performance in Mathematics is also a problem in Thailand (Armstrong & Laksana, 2016; Mala, 2016) and Malaysia (World Bank, 2018; PISA, 2012).

Hence, low performance in Mathematics is also a continuous problem in some ASEAN countries. In the Philippines, low performance in Mathematics is also a concern. For instance, in the report of the 2016-2017 Global Competitiveness Report of the World Economic Forum (WEF, 2017), the Philippines was ranked 79th out of 138 countries in the quality of Mathematics education. Consequently, these records showed that the Philippines has poor performance in Mathematics.

Locally, the result of the Mathematics K to 12 Diagnostics Test conducted by the Center for Educational Measurement, Inc. in 2018 in one of the private schools in Davao del Sur showed that only about 12% of the students got above the middle 80%, which implies that there are only a few students who are above in the average range of scaled scores. Thus, these data manifested the low performance of students in Mathematics.

Many reasons lead students to perform poorly in Mathematics. However, many of the researchers claimed that it is due to teachers' poor teaching methods and qualifications (Harris & Bourne, 2017; Tshabalala & Ncube, 2016; Ali & Jameel, 2016). Moreover, Sullivian (2011) stressed that the teacher must give attention to the learning process in order for the students to perform in Mathematics.

One of the teaching approaches that can address this concern is the Gradual Release of Responsibility (GRR). In fact, many studies showed the effects of GRR in teaching English subject (Read, Landon-Hays & Martin-Rivas, 2014; Fullerton, Andrews & Robson, 2015; Stahl & Garc, 2015, Lin & Cheng, 2010) and Science and Technology Subject (Loewenstein, 2016; Whittaker, 2016; Gillies, Nichols & Burgh, 2011; Hackling, Peers & Prain, 2007). However, only a few studies were conducted for Mathematics subject, such as the studies conducted by Reyes (2019) and Saligumba and Tan (2018). The limited studies on the Gradual Release of Responsibility Approach and the possibility that it can be an effective teaching approach to improve students' performance in Mathematics are what prompted the researcher to conduct this study. Thus, the researcher conducted this study to determine if the Gradual Release of Responsibility was also an effective approach to improving the performance of students in Mathematics.

Review Related Literature

In this section, different pieces of literature and studies associated with the study were reviewed, particularly the performance of students in Mathematics and the Gradual Release of Responsibility (GRR) approach.

Performance of Students in Mathematics

Mathematics is one of the most important core subjects in a school curriculum. Achievement in this subject is important, and it is recognized as vital to the nation's success (Bell, 2011). Early Mathematics higher performance is an important predictor of later academic achievement and a variety of measures of adult health and economic well-being (Geary, Hoard, Nugent & Bailey, 2013; Gerardi, Goette & Meier, 2013; Jordan, Glutting & Ramineni, 2010). However, students' performance in Mathematics has been so low in the past decades (Schimdt, 2012).

One of the leading countries, the USA, is experiencing poor performance in Mathematics. Poor international mathematics achievement of American students has been documented as early as the 1960s (Mayfield & Glenn, 2018). In addition, only 40 percent of grade 4 students in 2015 scored at or above proficient on the NAEP Mathematics Assessment (National Center for Education Statistics, 2015). Significantly, Provasnik et al. (2016) showed that other countries outperformed U.S. students on the mathematics assessment by margins that reached statistical significance. Furthermore, the report of International Results in Mathematics said that Finland, Germany, Kuwait, Netherlands, and Saudi Arabia got a lower average in Mathematics performance compared to other countries (TIMSS, 2015). Thus, poor performance in Mathematics is rampant worldwide.

Low performance in Mathematics is also a problem of some countries of the Association of Southeast-East Asian Nations, like Indonesia (PISA, 2013). A similar concern was found out in Thailand. Over the past decades, Thailand had faced alarming rates of underachievement in Mathematics among students of all ages (Shaikh, 2013). On the contrary, neighboring countries like Singapore, Hong Kong, Chinese Taipei, and Japan are leading in Mathematics achievement (TIMSS, 2015). Thus, achievement in Mathematics shows a relevant effect on a certain nation.

In the Philippines, low performance in Mathematics is also a problem. For instance, in the report of the 2016-2017 Global Competitiveness Report of World Economic Forum (WEF, 2017), the Philippines got ranked 79th out of 138 countries in the quality of Mathematics and Science education. This problem is already occurring even a decade and a half ago. For example, Trends in International Mathematics and Science Study (2003) noted that the Philippines ranked 34th out of 38 countries. Additionally, the Philippine educational system underperformed among peers in other Asian countries (Cordero, 2018). Consequently, these records showed that the Philippines had a poor mathematical performance. The Department of Education (DepEd) mandated that Mathematics as a school subject must be learned comprehensively and with much seriousness (DepEd, 2013). In fact, as part of the government effort to respond to the perceived needs of the education sector, the DepEd had pushed for the implementation of the K to 12 Program (Capate & Lapinid, 2015). However, low performance in Mathematics still prevails.

Research on different types of feedback suggests that process-oriented, descriptive, and specific feedback has more positive effects (Fluckiger et al., 2010; Harks et al. 2014, Davis & Carson, 2005). Recently, several empirical researches based on large scale surveys such as TIMSS or PISA had extensively investigated the relationships between teacher characteristics and students' performance in Mathematics. For example, Kim and Ham (2014) investigated the effects of school-level variables on Korean students' non-cognitive outcomes in Mathematics using the PISA 2012 data. They found that as process variables in the classical process–product model, teacher characteristics such as student-oriented teacher behaviors and disciplinary climate of math classroom had positive effects on students' self-efficacy in Mathematics, which in turn, served as a major non-cognitive factor that drives students to higher math performance.

Lack of experience and qualification as Mathematics teachers are also the reason that leads the students to perform poorly in Mathematics (Harris & Bourne, 2017; Tshabalala & Ncube, 2016; Ali & Jameel, 2016). Furthermore, they also lack the relevant experience with classroom assessment practices as they have never previously taught or received training in the field (Campbell & Evans, 2010). This lack of experience, knowledge, and skills poses a problem to the system as these teachers are not adequately prepared to meet the diverse learning needs of students in the classroom (Akos, Cockman & Strickland, 2007). Although these teachers have undergone short term placements in secondary schools as part of their training, they are not adequately prepared to meet the learning needs of the diverse student population. This type of recruitment arrangement is one of the major contributing factors to poor standards in classroom assessment practices in Britain (Department of Education, 2012).

Flores (2016) discussed that the teacher's ability to engage in quality instruction has the greatest impact on student learning and become competent in Mathematics. Teachers must use explicit instruction (Preston, 2016; Archer & Hughes, 2011) and cooperative learning (Gupta & Pasreja, 2018; Turgut & Turgut, 2018; Ling, Ghazali & Raman, 2016). Therefore, a Mathematics teacher must consider this reason and improve their teaching performance and develop an effective teaching approach.

To ensure the students' mastery in certain Mathematical skills and perform accordingly, it is also important to let the students perform independently with the aid of teacher's feedback and let them start to become independent to improve learning (Hockings, Thomas, Ottaway & Jones, 2017; Knight, 2012). Furthermore, as discussed in the findings of McVee, Shanahan, Pearson, and Rinker (2015), if the teacher knows how to guide and learn how to release responsibility to the students, they will reflect more on their own apply the authentic task in Mathematics with full of understanding and essential skills.

Gradual Release of Responsibility (GRR)

Teachers tend to find an effective approach in teaching that suits to the students of today. As observed, students this day are in need to develop their social-conventional knowledge. Focusing on this matter, it ensembles to Pearson and

Gallagar's (1983) Gradual Release of Responsibility model of instruction. This approach has "I do—We do—You do" format in teaching (Fisher & Frey, 2008). Later, it was developed by Fisher and Frey (2013), who devised the phases into four components. Explicitly, focused instruction, guided instruction, collaborative learning, and independent learning. Thus, if teachers focus on this approach, it will be a practical approach in today's students.

Twenty-first-century learners are in need of concrete instruction and modeling before leaving them some responsibilities. This is undeviating to the first phase of the gradual release of responsibility approach, which is the focused instruction. According to Fish and Frey (2013), this phase ensures that students understand the relevance of the lesson. This phase shows the teacher as a model in the learning process (Collet, 2015). Additionally, teachers who are careful in sequencing and connecting the lessons and approaches through focused instruction (Smith & Stein, 2011; Smith, Bill & Hughes, 2008) leads to good quality education of the students (Vic Zbar, 2014; Zakaria, 2009; Lazarowitz, Hertz, Lazarowitz & Baird, 1994). Generally, it allows students to work on cognitive structures and schemata of the lesson (Piaget, 1952). Moreover, GRR influences punitive knowledge, not only for students but also for teachers (Confrey & Maloney, 2012). Thus, focused instruction leads the way on the totality of GRR and a very important phase in students' learning.

Mastery of the lessons is needed in the learning process. In other words, the teacher must find a way so that the students can develop mastery of the lesson. Mastery in lessons and skills is more developed by scaffolding (Schukajlow, Kolter & Blum, 2015). The gradual release of responsibility's guided instruction is making scaffolding better and producing more independent students (Fish & Frey, 2013; Read, Landon-Hays & Martin-Rivas, 2014). Mastery of learner is more important in the teaching-learning process. Accordingly, to develop mastery in lessons, a gradual release approach must be employed. Through this instruction, the children tend to develop a higher mathematical idea (Daro, Mosher & Corocoran, 2011; Bakker, Smith & Wegerif, 2015).

Students are interacting with one another to build each other's learning. Outward indicators include body language and movement associated with meaningful conversations. This notion is called collaborative learning (Fish & Frey, 2013), the third phase of the gradual release of responsibility. According to O'Brien, Fielding-Wells, Makar, and Hillman (2015), interaction in Mathematics facilitates growth on mindsets. This is providing opportunities for students to engage in discourse about tasks and mathematical ideas (Huffered-Ackles, Fuson & Sherin, 2004), and using formative data to design subsequent mathematical tasks (Joyner & Muri, 2010). Moreover, students who were instructed using cooperative learning achieved significantly higher scores than students who were instructed using lecture-based teaching or traditional teaching (Tan, 2014; Zakaria, Solfitri, Daud, & Abidin, 2013; Shimazoe & Aldrich, 2010). Added by Palincsar and Herremkohl (2002), interacting with peers is learning. GRR with this phase is also proven in writing (Lee, 2013). Therefore, a gradual release approach advocated for the enactment of collaborative learning pedagogies to increase both student achievement and students' understanding of subject concepts.

Ideally, teachers want to create learners who are not dependent on other information and ideas. As such, students need to practice completing independent tasks and learning from those tasks, and this is recognized as the ultimate goal of the gradual release of responsibility (Fisher & Frey, 2013). Releasing responsibility gradually to students increases their ability and boosts their confidence (Donohoo, 2010). Moreover, self-responsible learning enhances students' Mathematics academic performance (Su, 2015).

Gradual Release of Responsibility must be utilized as an approach to teaching Mathematics subject. However, most of the published studies focus on the effect of the gradual release of responsibility approach towards performance in English, since the approach was coined for the development in language and writing (Fisher & Frey, 2011), not in Mathematics. In fact, GRR shows the effectiveness in teaching English subject (Read, Landon-Hays & Martin-Rivas, 2014; Fullerton, Andrews & Robson, 2015; Stahl & Garc, 2015, Lin & Cheng 2010). Additionally, the scaffolding approach base on GRR gives promising progress on young English learners (Fullerton, Andrews & Robson, 2015).

Some studies were conducted on the effect of GRR on Science subjects. For example, Whittaker (2016) found that scientific understanding is more developed through the use of a gradual release of responsibility model of instruction. It is also effective in other fields of Science (Loewenstein, 2016; Whittaker, 2016; Gillies, Nichols & Burgh, 2011; Hackling, Peers & Prain, 2007). Moreover, it creates better teaching practices that integrate phases for better learning in other fields of Science (Loewenstein, 2016; Whittaker, 2016; Gillies, Nichols & Burgh, 2011; Hackling, Peers & Prain, 2007). Therefore, if the GRR approach can have a positive outcome towards the other core subjects, it must also be in Mathematics.

There are only a few published studies about the implementation of the Gradual Release of Responsibility in teaching to improve the performance of students in Mathematics. For example, Saligumba and Tan (2018) state that GRR can improve the performance of students in Mathematics. It is also supported by the findings of Reyes (2019) as he found out that GRR predicts the performance of students in Mathematics. Therefore, if a teacher optimizes the Gradual Release of Responsibility Approach, then a poor performance of students in Mathematics will be lessened.

Based on the above-related literatures and studies, it can be argued that the Gradual Release of Responsibility Approach provides phases that are effective in improving the academic performance of students. Since GRR shows a positive result in other core subject areas, then it can also provide a positive result in Mathematics. The teacher should have a teaching approach that reinforces students in responsible learning because it can lessen the poor performance in Mathematics. Further, the foregoing presentation and discussion of various literatures have helped in bringing into focus the two important variables: Gradual Release of Responsibility (GRR) Approach and performance of students in Mathematics. These served as support to the results and findings of the study.

Theoretical Framework

The theoretical orientation that underpins the notion of this study is Fisher and Frey's (2013) version of the Gradual Release of Responsibility Approach. It is the revised version of Person and Gallagher's (1983) GRR approach. The original approach limits the interactions to adult and child exchanges: "I do it"; "We do it"; "You do it alone." But the new version argues that this three-phase model omits a truly vital component, which is learning through collaboration with their peers. Thus, the "You do it together" phase was added.

The first phase of this approach is the "I do it." In this phase, the teacher first gives the information that allows the students to learn the concept and terms on the given topic. It was based on the concept of cognitive constructivism (Piaget, 1952). The students are expected to understand the lesson through the teacher's discussion. Thus, this phase allows students to work on cognitive structures and schemata of the lesson.

The second phase of this approach is the "We do it". In this phase, the teacher does a certain task with the students. Gradually, he/she will let the students answer or solve the question given through the guided questions and instructions. This was grounded from Wood, Bruner, and Ross' (1976) scaffold instruction. Hence, through this, teachers are slowly making students responsible enough to handle the task.

The students work on attention, retention, reproduction, and motivation through other students in order to perform better. This is the goal of the third phase, which is the "you do it together". It was coined from the notions of Social Learning Theory of Bandura (1965). Consequently, in this phase, the students will understand more in in-depth analysis of the lesson by comparing their ideas and constructing new knowledge that they acquire from their peers.

The proper invigorating of the first three phases is expectedly resulted in to drive of students to learn independently, which is the last phase of this approach, the "You do it alone" phase. Fisher and Frey (2013) argue that learning is most developed if the learners can understand, analyze, and comprehend without the help of others. Therefore, the last phase will illustrate the performance of the learners on the topic.

Objective of the Study

The study aimed to determine the effects of the Gradual Release of Responsibility Approach in improving the Mathematics performance of the Grade 7 students. Specifically, the pre-test mean scores of control and experimental groups, the post-test mean scores of control and experimental groups. It also investigated if there is a significant difference between the pre-test mean scores of control group and experimental group, if there is a significant difference between the pre-test and post-test mean scores of students in the control group, if there is a significant difference between the pre-test and post-test mean scores of students in experimental group, and if there is a significant difference in the post-test mean scores between the control and experimental groups with pre-test means scores as covariates.

Hypothesis

The null hypotheses in this study were tested at 0.05 level of significance.

HO1: There is no significant difference between the pre-test mean scores of control and experimental group.

HO2: There is no significant difference between the pre-test and post-test mean scores of students in the control group.

HO3: There is no significant difference between the pre-test and post-test mean scores of students in the experimental group.

HO4: There is no significant difference in the post-test mean scores between the control and experimental groups with pre-test mean scores covariates.

Method

This study utilized the quasi-experimental design. This research design is appropriate to use when it is not possible to randomly assign participants to control or experimental groups for comparison (Cook, Campbell & Shadish, 2002). In addition, the nonequivalent pretest-posttest control group design was used to contrast the mean scores of the control and experimental groups.

O1	X	O2
- - - - - - - - - - -	- - - - - - - - - - -	- - - - - - - - - - -
O3		O4

Figure 1. *The Nonequivalent Control Group Design*

Where:	*X*	=	*Experimental Treatment*
	O1	=	*Pretest of the Experimental Group*
	O2	=	*Posttest of the Experimental Group*
	O3	=	*Pretest of the Control Group*
	O4	=	*Posttest of the Control Group*
	----------	=	*Non-randomized Selection of the Subjects*

The subjects were the intact groups of Grade 7 students in a naturally accumulated classroom setting. The study was conducted during the third grading period of the school year 2018-2019. In totality, there were 81 Grade 7 students included in the study. Of this number, 41 students were coming from Grade 7-Section E, and the other 40 students were coming from Grade 7-Section F. Both were socialized sections in which students were heterogeneously distributed. In identifying which of the two sections would be assigned as a control and experimental group, the purposive sampling technique was employed. A coin was tossed that resulted in the selection of Section E as the experimental group, while section F was assigned as a control group.

The data-gathering tool used in the study was a set of the teacher-made instrument. It was a 40-item multiple-choice type of summative test, in which seven (7) topics on Geometry were distributed as follows: (1) 5 items for Points, Lines, and Planes; (2) 6 items for Subset of a Line; (3) 5 items for Angles; (4) 6 items for Line and Angle Pairs; (5) 6 items for Polygons; (6) 6 items for Polygons focused on Triangles; and (7) 6 items for Parallel Lines Cut by Transversal Lines. The decision as to the number of items per topic was based on the competencies expected to be acquired by the students as articulated in the K-12 curriculum for Mathematics 7.

In order to establish the content validity of the instrument, expert validators and Mathematics teachers were tapped. Letters with the attached instrument were given to them, and the notes or comments made by the test evaluators were used as the basis for judging which items would be retained, improved, or removed. Results from table 1 reveal that the overall mean score is 4.39 and interpreted as to be very good. This result indicates that the content of the survey questionnaire, when tested in areas of clarity of language, presentation, or organization of topics, the suitability of items, adequacy of purpose, attainment of purpose and objectivity, passed the content validity. In addition, the test instrument was administered to 38 Grade 8 students for pilot testing. The data gathered from the pilot testing were processed and tested using Cronbach's Alpha to establish reliability and internal consistency. Tavakol and Dennick (2011) explained that Chronbach's Alpha estimates the quantity to add validity and accuracy to the interpretation of the research data. Results of the reliability statistics on table 2 show that Cronbach's Alpha was above .60, which is according to Ghazali (2008), is an acceptable value for reliability test (Tavakol & Dennick, 2011). Thus, the survey questionnaire was reliable enough to be administered.

The following are the procedural steps observed in executing this quasi-experimental design study: first, letter seeking permission to conduct the experiment was sent to the office of the Principal for approval. Second, the selection on which of the two sections would be the control or experimental group was determined by the tossing of a coin. After the toss coin, it was determined that Grade 7-F would be the control group, and Grade 7-E will be the experimental group. Third, prior to the start of the actual teaching, a pre-test was administered for both control and experimental groups. Fourth, before the first day of actual teaching, the topics included in the study were presented and referred from the learning competencies in the syllabus. Fifth, after the orientation of classes, the experiment started. Sixth, the researcher used the Gradual Release of Responsibility approach in teaching the experimental group employing the activities developed by the researcher. 7. For the control group, the researcher used the traditional teaching approach employed by the school. This approach is anchored on Social Constructivism theorized and popularized by Lev Vygotsky (1986). Eight, after the delivery of the seven lessons, post-tests were administered to both the control and experimental groups. Ninth, the Pre-test and Post-test results were scored and transmuted (60%) using the Transmutation Table and qualitative description, as shown in table 1 adopted from the Department of Education Grading System pursuant to DepEd Order No. 73 s. 2012. Lastly, data were analyzed using the most appropriate statistical tools.

Table 1. Table for Interpretation of Pre-test and Post-test Scores

Initial Mean Percentage Score	Level of Proficiency	Indicators
35 – 40	Advanced	Student exceeds core requirements in terms of knowledge, skills and core understanding; can transfer them automatically and flexibly through authentic tasks.
32 – 34.9	Proficient	Student develops fundamental knowledge, skills and core understanding; can transfer them independently through authentic tasks.
28-31.9	Approaching Proficiency	Student develops fundamental knowledge, skills and core understanding; with little guidance can transfer understanding through authentic tasks.
24 – 27.9	Developing	Student possesses the minimum knowledge and skills but needs help throughout the performance of authentic tasks.
Below, 23.9	Beginning	Student is struggling with his/her understanding due to lack of essential knowledge and skills.

In identifying the result of the study, the following statistical tools were used: First, mean was used to identify the mean scores of the subjects in the control and experimental groups. Second, the T-test for Independent Samples was utilized to find the significant difference between the pre-test mean scores of students in the control and experimental groups (Heeren & D'Agostino, 1987). Third, the Paired Sample T-test was employed to analyze if there exist significant differences between pre-test and post-test scores in the control and experimental groups (Mee & Chua, 1991). Finally, Analysis of Variance (ANCOVA) was employed to answer used to detect the difference between the means scores of the groups while controlling for scale covariant (Rutherford, 2011). The researcher employed ANCOVA since the homogeneity of the variance of the groups in terms of the level of their Mathematics performance is not determined because of the heterogeneous sectioning of the subjects. Thus, it was used to determine the significant difference between the post-test scores of control and experimental groups while controlling the pre-test scores.

Results

The results presented into six clusters with tales based on the six statements of the problem.

The Pre-Test Mean Scores of Control and Experimental Groups

Table 2 presents the pre-test mean scores of the control and experimental groups on the topics of Grade 7 Geometry: (1) Points, Line and Plane, (2) Subset of the Line, (3) Angles, (4) Line and Angle Pairs, (5) Polygons, (6) Polygons Focused on Triangles and (7) Parallel Lines Cut by Transversal Line.

The pre-test mean scores of the students in the control group, as reflected in Table 2, were between 1.33 and 2.08. The results revealed that of all the topics measured, the students were found to be weakest on the topic Angles with a mean score of 1.33 and described as being at the beginning level. Although, the students got a higher mean score of 2.08 on topic Points, Line, and Plane, still, the level of proficiency was at the beginning level. The overall pre-test means score of the students in the control group is 11.28, which indicates that the students in the control group are said to be at the beginning level of proficiency in all the specified topics on Grade 7 Geometry. Thus, the students in the control group at this level indicate a lack of essential knowledge and skills in the said topics.

Also, as presented in Table 2, the students in the experimental group were able to attain the mean scores between 1.37 and 2.05. The results revealed that of all the topics measured, the students in the experimental group were found to be weakest on the topic Subset of the Line with a mean score of 1.37 and described as being at the beginning level. Though the students got a higher mean score of 2.05 on topic Points, Line and Plane, still, the level of proficiency is at the beginning level. The over-all pre-test means score is 11.20, which indicates that the students in the experimental group are said to be at the beginning level of proficiency in all the specified topics on Grade 7 Geometry. Thus, the students in the experimental group at this level indicate a lack of essential knowledge and skills in the said topics.

Table 2. The Pre-test Mean Scores of Students in the Experimental and Control Group

TOPICS	Control Group		Experimental Group	
	Mean	**Level of Proficiency**	**Mean**	**Level of Proficiency**
Points, Line, and Plane	2.08	Beginning	2.05	Beginning
Subset of the Line	1.63	Beginning	1.37	Beginning
Angles	1.33	Beginning	1.90	Beginning
Line and Angle Pairs	1.68	Beginning	1.54	Beginning
Polygons	1.38	Beginning	1.51	Beginning
Polygons Focused on Triangles	1.53	Beginning	1.44	Beginning
Parallel Line Cut by Transversal Line	1.68	Beginning	1.39	Beginning
All Topics	**11.28**	**Beginning**	**11.20**	**Beginning**

In looking at the pre-test mean scores of both groups, it can be said that the two groups do not differ in their level of performance in all the topics that were measured. Both levels of proficiency of the groups were at the beginning level, which implies that in general, the students were struggling in their understanding due to a lack of essential knowledge and skills on the topics.

The Post-Test Mean Scores of Control and Experimental Groups

Table 3 reveals the post-test mean scores of the control group and experimental group on specified topics of Grade 7 Mathematics on lesson Geometry, namely; (1) Points, Line and Plane, (2) Subset of the Line, (3) Angles, (4) Line and Angle Pairs, (5) Polygons, (6) Polygons Focused on Triangles and (7) Parallel Lines Cut by Transversal Line.

As presented in Table 3, the students belonging to the control group were said to be already in the advanced level of proficiency in terms of the topic Angles with a post-test mean score of 4.23. This indicates that the students at this topic exceed core requirements in terms of knowledge, skills, and core understanding. Moreover, they got a mean score of 3.98 in the topic Point, Line, and Plane, which designated that they are proficient in this topic and can already transfer their fundamental knowledge, skills, and core understanding independently through authentic tasks. For the topics Subset of the Line, Line and Angle Pairs, Polygons, Polygons Focused on Triangles and Parallel Line Cut by Transversal Line, the students are said to be at the developing level of proficiency with 3.80, 3.55, 3.80, 3.78 and 3.83 post-test mean scores respectively which means that the students still possess the minimum knowledge and skills on these topics.

Table 3. The Post-test Mean Scores of Students in the Experimental and Control Group

TOPICS	Control Group		Experimental Group	
	Mean	**Level of Proficiency**	**Mean**	**Level of Proficiency**
Points, Line, and Plane	3.98	Proficient	4.29	Advanced
Subset of the Line	3.80	Developing	4.05	Developing
Angles	4.23	Advanced	4.78	Advanced
Line and Angle Pairs	3.55	Developing	3.88	Developing
Polygons	3.80	Developing	3.80	Developing
Polygons Focused on Triangles	3.78	Developing	3.98	Developing
Parallel Line Cut by Transversal Line	3.83	Developing	4.41	Approaching Proficiency
All Topics	**27.05**	**Developing**	**29.20**	**Approaching Proficiency**

Overall, it can be said that although the control group obtained an overall post-test mean score of 27.05, described as already in the developing level, the said students only possess the minimum knowledge and skills on Grade 7 Geometry and need help and support throughout the performance of authentic tasks.

In looking at the post-test mean scores of the students in the experimental group, they were able to attain mean scores of 4.29 for topic Points, Line and Plane, and 4.78 for topic Angles. These denote that they exceed core requirements in terms of knowledge, skills, and core understanding of these topics. Furthermore, they got a mean score of 4.41 in the topic Parallel Line cut by Transversal Line which indicates that they are already at the level of approaching proficiency in this topic and with a little guidance, they can already transfer their fundamental knowledge, skills, and core understanding independently through authentic tasks. For the topics Subset of the Line, Line and Angle Pairs, Polygons, and Polygons Focused on Triangles, the students are said to be developing the level of proficiency with 4.05, 3.88 3.80 and 3.98 as post-test mean scores respectively. This means that the students still possess the minimum knowledge and skills on these topics.

The results in Table 3 also show that the overall post-test mean score of the students in the experimental groups is 29.20, which is described as already at the approaching proficiency level. Thus, it can be claimed that the students at this level already developed fundamental knowledge, skills, and core understanding and, with little guidance, can already transfer their fundamental knowledge, skills, and core understanding independently through authentic tasks.

Significant Difference between the Pre-test Mean Scores of Control and Experimental Groups

In this study, the researcher tried to determine if there is a significant difference between the pre-test mean scores of students in the control group and the experimental group. In order to answer the research problem, a T-test for Independent Sample was utilized.

As observed in Table 4, the t value for the topic Angles is -2.328 with a “sig” value of .022. This indicates that there is a significant difference between the pre-test scores of control and experimental groups on the said topic with the experimental group (m=1.90) showing a higher level of performance as compared to the control group (m=1.33). Meanwhile, the “sig” values of the topics Point Line and Plane, Subsets of a Line, Line and Angle Pairs, Polygons, Polygons focused on Triangle and Parallel Lines Cut by Transversal Lines are .924, .264, .480, .564, .712 and .154 respectively. These values were all above the 0.05 level of significance set for this study and indicate that the differences in the mean scores between the control group and the experimental group on the said topics were not significant.

Table 4. ***Significant Difference in the Pre-test Scores of the Students in Experimental and Control Groups***

TOPICS	Mean		T	Sig. (2-tailed)	Remarks
	CG	EG			
Point Line and Plane	2.08	2.05	0.096	.924	Not Significant
Subsets of a Line	1.63	1.37	1.125	.264	Not Significant
Angles	1.33	1.90	-2.328	.022	Significant
Line and Angle Pairs	1.68	1.54	.705	.480	Not Significant
Polygons	1.38	1.51	-.580	.564	Not Significant
Polygons focused on Triangle	1.53	1.44	.371	.712	Not Significant
Parallel Lines Cut by Transversal Line	1.68	1.39	1.440	.154	Not Significant
ALL TOPICS	**11.28**	**11.20**	**.107**	**.915**	**Not Significant**

LEGEND: CG = Control Group, : EG = Experimental Group

Table 4 also shows that when an attempt to determine whether there exists an overall difference in the mean scores when all topics are included, the overall significance value of 0.915 is found to be higher than the 0.05 level of significance set for this study. It designates that the study failed to reject the null hypothesis, which is there is no significant difference in the pre-test scores of the students in experimental and control groups. Thus, the difference between the mean scores of the two groups during the pre-test was found to be nearly the same.

Significant Difference Between the Pre-test and Post-test Mean Scores of Students in Control Group

The study also aimed to determine whether the traditional teaching approach employed by the school is effective in improving Mathematics performance. The level of mean scores of Mathematics performance was determined before and after the implementation of the teaching approach. Mean scores were calculated, and a Paired-sample t-test was used in order to establish whether there is a significant difference in the performance of students in Mathematics before and after the teaching approach was employed.

Table 5. Significant Difference between the Pre-test Scores and Post-test of the Students in Control Groups

TOPICS	Mean Scores		T	*d*	Sig. (2-tailed)	Remarks
	Before	After				
Point Line and Plane	2.08	3.98	-10.250	1.62	.000	Significant
Subsets of a Line	1.63	3.80	-9.618	1.52	.000	Significant
Angles	1.33	4.23	-14.363	2.27	.000	Significant
Line and Angle Pairs	1.68	3.55	-8.564	1.28	.000	Significant
Polygons	1.38	3.80	-10.109	1.59	.000	Significant
Polygons focused on Triangle	1.53	3.78	-11.152	1.76	.000	Significant
Parallel Lines Cut by Transversal Line	1.68	3.83	-9.315	1.47	.000	Significant
ALL TOPICS	**11.28**	**27.05**	**-20.921**	**3.31**	**.000**	**Significant**

As observed in Table 5, the performances of students in the specified topics have increased after the implementation of the traditional teaching approach. The most apparent result is the topic Angles, whereby the mean score increased from 1.33 to 4.23 or from the beginning level to advance level. Another interesting result is the topic polygons, whereby the mean score has increased from 1.38 to 3.80. Interestingly, results in Table 5 indicate that the performance of students in the post-test in all topics has significantly increased as manifested by sig. (2-tailed) valued of 0.000, which are all below the 0.5 level of significance. In addition, the effect size (d) of all the topics is above 1.0 with the overall d value of 3.31, which implies that the effect size is large and the results' differences are consequential. Furthermore, the results also indicate that when looking at the overall performance of students involving all topics, the value of the sig. (2-tailed) which is equal to 0.000, with a T-value of -20.921, reveals that there is a significant improvement in their performance in the specified topics.

Significant Difference Between Pre-test scores and Post-test Mean Scores of Students in Experimental Group

Another aim of this study was to determine whether the gradual release of responsibility approach is effective in improving Mathematics performance. The level of mean scores of Mathematics performance was determined before and after the teaching approach. Mean scores were calculated, and a Paired-sample t-test was employed in order to find whether there is a significant difference in the Mathematics performance of students in the treated group before and after the teaching approach was implemented.

Table 6. Significant Difference between the Pre-test Scores and Post-test of the Students in Experimental Groups

TOPICS	Mean Scores		T	*d*	Sig. (2-tailed)	Remarks
	Before	After				
Point Line and Plane	2.05	4.29	-13.768	2.15	.000	Significant
Subsets of a Line	1.37	4.05	-13.702	2.14	.000	Significant
Angles	1.90	4.78	-17.112	2.67	.000	Significant
Line and Angle Pairs	1.54	3.88	-12.535	2.67	.000	Significant
Polygons	1.51	3.80	-10.101	1.95	.000	Significant
Polygons focused on Triangle	1.44	3.98	-13.025	1.58	.000	Significant
Parallel Lines Cut by Transversal Line	1.39	4.41	-15.194	2.38	.000	Significant
ALL TOPICS	**11.20**	**29.20**	**-25.333**	**3.96**	**.000**	**Significant**

As observed in Table 6, the performances of the students in the specified topics had increased after the implementation of the gradual release of responsibility approach. The most outward result is on the topic Parallel Lines Cut by Transversal Lines, whereby the mean score has increased from 1.39 to 4.41 or from the beginning level to approaching proficiency level. Another interesting result is on the topic Polygon Focused on Triangle, whereby the mean score has increased from 1.44 to 3.98. Interestingly, results in table 6 indicate that the performance of students in the post-test in all the topics has significantly increased as manifested by sig. (2-tailed) values of 0.000, which are all below the 0.05 level of significance set for this study. In addition, the effect size (d) of all the topics is above 1.0 with the overall d value of 3.96, which implies that the effect size is large, and the results' differences are consequential as regards to its topics. Furthermore, the results also indicate that when looking at the overall performance of the students involving all topics, the value of the sig. (2-tailed) which is equal to 0.000 with a T-value of -25.333, reveals that there is a significant improvement in their performance in the specified topics.

Significant Difference in the Post-test Scores between the Control and Experimental Groups with Pre-Test Mean Scores as Covariates

This study correspondingly attempted to determine if there is a significant difference between post-test scores of students in the control group and students in the experimental group while controlling the pre-test scores. In order to answer the research problem, ANCOVA was employed.

Source	Post-test Mean Scores		*d*	F-Value	P-value	Remarks
	Control	Experimental				
Group	*27.05*	*29.20*	*0.46*	*5.56*	*0.021*	*Significant*
Pre-Test				*17.20*	*0.000*	

Table 10 shows the analysis of covariance (ANCOVA) of post-test results between treatments. As observed in Table 10, the pre-test with an F-value of 17.20 was used as a covariate to statistically equate dissimilar prognostic variables that may have an effect on the analysis. In addition, the results specify that when looking for the significant difference between the post-test mean scores between the groups with pre-test mean scores as covariates, the F-value between groups is 5.56 with a probability value of 0.021 ($p<0.05$) indicating a significant difference; thus there is a difference in the post-test scores between the control and experimental groups with pre-test mean scores as covariates. This implies that the experimental group with a mean score of 29.20 performed better than the control group with a mean score of 27.05. Moreover, the size effect (d) of 0.46 was identified, which means that the effect size of the two groups is medium and consider approaching consequential. Therefore, the students exposed in the Gradual Release of Responsibility Approach perform better than the students exposed in the Traditional Teaching Approach employed by the School.

Discussion

Teaching Mathematics continues to be a posing challenge for teachers. The results of this study could help them to improve students' performance in Mathematics. Thus, they would have a teaching approach that is essential for teachers and effective for students.

As to Mathematics teaching, results revealed that before the implementation of the approaches, both levels of proficiency of the groups are at the beginning level, which implies that they were struggling in their understanding due to lack of essential knowledge and skill on the topics. But after the implementation of both approaches, the results showed that there is an improvement in the performance of students in Mathematics after being exposed to the GRR approach and traditional teaching approach.

The difference between the mean scores of the two groups during the pre-test was found to be nearly the same. This is nearly similar to the study conducted by Reyes (2019) involving students' pre-test Mathematics performance before using Team-Pair-Solo Approach patterned in Gradual Release of Responsibility Instruction for the experimental group and Traditional Method (Lecture-Discussion) for the control group. Reyes discovered that there is also no significant difference between the pre-test mean scores of the students in control and experimental groups.

The traditional teaching approach employed by the school demonstrates positive outcomes towards students' academic performance in Mathematics. This result confirms what Diab and Abdel (2016) also discovered in their study involving the effectiveness of flipped classroom instruction anchored in Vygotsky's social constructivism theory on students' achievement in Mathematics. Diab and Abdel found that learners' performance in Geometry topics that were taught and exposed to social constructivism significantly increased. Thus, Vygotsky and Cole (2018) argued that this approach should be practiced in students' early learning years.

Students exposed in the Gradual Release of Responsibility Approach perform better than the students exposed in the Traditional Teaching Approach employed by the School. This conformed by Caligumba and Tan (2018) and Reyes (2019), wherein they found out that there is a significant difference between pre-test mean scores of control and experimental group with pre-test mean scores as covariates. Caligumba, Tan, and Reyes found that the students exposed to the approach patterned in the Gradual Release of Responsibility Approach perform better in Mathematics than the students who are not exposed to the said approach. In addition, the results also confirm what Ciubal and Tan (2018) also discovered in their study involving students exposed to Mathematics Communication Strategies (MCS), which was also utilized by the researcher in the phases of Gradual Release of Responsibility Approach. Ciubal and Tan (2018) found out that the students exposed to the said approach are significantly different from those who are non-exposed while controlling their pre-test mean scores. Thus, Fisher and Frey (2013) argued that students perform better in any subject area after being exposed to the Gradual Release of Responsibility approach than other approaches.

Conclusions

In the light of the objectives of the study, the statistical analysis, and findings of the study, the following conclusions were drawn: first, it found out that there is a problem in the performance of the students in Mathematics. The pre-test mean scores of the students were both found to be at the beginning proficiency level. Hence, the level of Mathematics performance of the Grade 7 students before they were exposed to different approaches was concluded as low. Second, after the application of the traditional teaching approach employed by the school, a significant increase in the performance of the students had been found, although it only improved the developing level. Thus, the effects of such an approach had been recognized. Third, after the implementation of the Gradual Release of Responsibility (GRR) Approach, a significant increase in the performance of the students has been found. Specifically, the performance of students has improved from the beginning level to approaching proficiency level. Finally, it was concluded that those students who had been exposed to the Gradual Release of Responsibility Approach performed significantly better than those students in the traditional teaching approach. Therefore, the Gradual Release of Responsibility Approach is more effective than the traditional teaching approach employed by the school in improving the performance of students in Mathematics.

Recommendations

In the light of the findings and conclusions of the study, the following recommendations were offered: Mathematics teacher is encouraged to improve the performance of their students through the use of Gradual Release of Responsibility (GRR) Approach since it is noted in this study that there is a significant increase in the performance of the students after the implementation of the said approach. Also, in teaching Mathematics, the teachers should gradually release the students to learn independently. It would help them to enhance their learning and understanding of the concepts in Mathematics by following the four phases of the GRR approach. Then the school administrators should employ the usage of the Gradual Release of Responsibility Approach as an approach in teaching Mathematics from the elementary level to a higher level of education. They should also develop a program that will facilitate the training of Mathematics teachers in acquiring the skills on how to use the Gradual Release of Responsibility Approach. The program may contain different activities based on the phases of GRR. For example, in phase 1, there will be training for effective, focused discussion; in Phase 2, training for effective guided instructions; in Phase 3, training for effective collaborative learning and in Phase 4, training for effective individual and responsible learning. Also, the findings of the study may serve as a basis in conducting a more profound study, specifically pertaining to the Gradual Release of Responsibility (GRR) approach. Moreover, the findings should be used as one of the references testing the validity of other related findings needed and useful in designing an effective and Mathematics curriculum.

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EMPLOYING CONCRETE-REPRESENTATION-ABSTRACT APPROACH IN ENHANCING MATHEMATICS PERFORMANCE

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ABSTRACT

This quasi-experimental research study aims to determine the effect of two teaching approaches—the concrete-representation-abstract approach and conventional approach—in enhancing the performance of students in Mathematics. Participants were grouped into a control group that was exposed to the conventional approach and experimental group that was exposed to the CRA approach. Pre-test and post-test of the two groups were gathered and analyzed using mean, paired sample t-test, independent sample t-test, and analysis of covariance (ANCOVA). Results revealed that there was no significant difference found between the pre-test mean scores of the experimental group and the control group. A significant difference was established between the pre-test and post-test mean scores of the students in both the control and experimental group. Lastly, there was a significant difference between the post-test mean scores of the control group and the experimental group while controlling the pre-test scores. It was also found out that the CRA approach had a higher mean score than the conventional teaching approach. Thus, the CRA approach found to be better than the conventional in enhancing students' mathematics performance.

Keywords: concrete-representation-abstract approach, traditional lecture approach, mathematics performance, quasi-experimental research, Philippines

INTRODUCTION

The poor performance in Mathematics subject has been a continuing problem that necessitates concrete approach and strategy to address. It is necessary to do because Mathematics achievement can be considered as a measure of success in academic advancement. Despite the importance of mathematics, it was found that many students face difficulties in learning, and teachers suffer in making students understand the subject (Hidayat & Prabawanto, 2018). These low performing students cannot identify and carry out routine and obvious procedures, and they are incapable of employing basic algorithms, formulas, procedures or conventions to solve problems and interpret results literally (Alzhanova-Ericsson, Bergman, and Dinnétz, 2017; Braza & Supapo, 2014; European Commission, 2011, 2013a, 2013c, 2014; OECD, 2014).

The teacher's capacity is one of the important factors that contributes to the quality of education in the classroom. It is for the teachers to modify and adjust their pedagogical skills to accelerate the learning process in the classroom (Behlol, Akbar, & Sehrish, 2018). Proper teaching methods characterize all good teaching, and priority may be given to improve the capacities and professional competencies of the teachers to apply appropriate teaching methods that may enhance the learning of students.

In trying to look at situations around the world, the Program for International Student Assessment (PISA) (2015) reported specifically in mathematics achievement, among the seventy-two (72) participating countries, that only 24 or about only 33% performs above average while the 67% lies below the mean score. No less than 30 of the 56 other countries that participated in the Program for International Student Assessment (PISA) math test had a larger percentage of students who scored at the international equivalent of the advanced level on our National Assessment of Educational Progress (NAEP) tests (Hanushek, Peterson & Woessmann, 2010). Evidently, the poor quality of mathematics education in South Africa can be traced to the low achievement levels reached by the students in standardized tests (Reddy et al., 2012). It was also found out that the African students in the international exams such as Trends in International Mathematics and Science Study (TIMSS) have consistently shown that students were not able to do less than the standardized and curricular expectations for their respective level (Sandefur, 2018).

Neighboring countries in Asia like Singapore, Japan, Chinese Taipei, Vietnam, and Korea are among the Asian countries that have only reached the above-average, respectively (PISA, 2015). In Thailand, the result of the PISA test in 2015 shows Thai students had much lower scores than their neighboring countries (Armstrong & Laksana, 2016). Thai students are underperforming their peers in several Asian countries as their scores were below the international average in Mathematic subjects (Mala, 2016).

In the Philippines, it was found out that its education system underperformed among peers in East Asia and the Pacific (Cordero, 2018). In the World Bank report (2018), it was noted that the Philippines, alongside Indonesia, Malaysia, and Thailand, scored below average in international exams under the Programme for International Student Assessment (PISA). In addition, among the 41 participant countries that participated in the PISA in 2011, Filipinos performed poorly in Mathematics (Nambatac, 2011). Moreover, it is reported that Filipino students have poor performance in Science and Mathematics subjects. In fact, the National Mean Percentage Score in Math in 2012 was only 48.90, which is described as below the national standard, and it is among the lowest in the five subjects in the National Achievement Test (NETRC, 2012).

Locally, the school year 2018-2019 first semester, students who enrolled in General Education 4 (Mathematics in the Modern World) under the College of Education, Arts, and Sciences (CEDAS) have a low result with respect to their academic performance on the said subject. In fact, 59.38% got a grade lower than 80, which is below the cut-off grade of the said program. In addition, there were only 34.37% from the class population who got grades between 80-90, and there were only four (4) students or 6.25% from the population who got a grade higher than 90. Thus, this shows a rising concern in the subject of mathematics to the aforementioned college.

Outside of the pedagogical debates in Mathematics, Martin (2013) pointed out the strategy in teaching Mathematics seems to prepare students as future Mathematicians, although very few of these students will reach the university level. Thus, one instructional approach, Concrete-Representational-Abstract (CRA,) is consistently used for supporting students especially those who have difficulties in mathematics (Flores, Hinton, Stroizer & Terry, 2014; Stroizer, Hinton, Flores, & Terry, 2015; Yakubova, Hughes, & Shinaberry, 2016). Previous studies stressed out also that the CRA approach found to be effective and beneficial to students. It was also found that students who were taught using the CRA learning approach scores higher than conventional or traditional learning (Putri, Misnarti, & Saptini, 2018; Salingay, & Tan, 2018; Hughes E., 2011). In fact, in the study conducted by Salingay & Tan (2018), the students under CRA significantly performed higher than those under the non-CRA. This was supported by the study of Calfoforo (2013) about multiple representation-based instructions, which also found out that the performance of the students exposed to multiple representation-based instructions is significantly higher than the control group.

The fact that there is a continuing problem on the poor performance of students in mathematics and the popularly acclaimed effectiveness of the Singaporean CRA approach in helping students perform better in mathematics is what prompted the researcher to conduct this study (Salingay & Tan, 2018). Specifically, the researcher would like to implement a quasi-experimental research design using the CRA approach to determine whether it is applicable and effective for Filipino students. The limited studies showing how effective the CRA approach in helping Filipino students learn mathematics is another reason that prompted the researcher to conduct this study.

Review of Related Literature

This review provides interrelated literature and studies about the two teaching approaches, namely Concrete-Representation-Abstract and Conventional, which give clarification and elaboration in the discussion of the nature of the study.

Concrete-Representation-Abstract Approach

The concrete-representational-abstract is an approach that combines the behaviorist and constructivist practices (Sealander, Johnson, Lockwood & Medina, 2012). This strategy is especially effective when used to teach individuals across grade levels and in many different topic areas in Mathematics (Hughes, Riccomini & Schneider, 2018). CRA uses demonstration, modeling, and guided practice followed by independent practice and immediate feedback, which are aspects commonly found in direct instruction. CRA also includes discovery-learning strategies involving representation to help students' transition between conceptual knowledge and procedural knowledge (Sealander, Johnson, Lockwood & Medina, 2012).

Recent research highlighting the CRA framework emphasizes the need to teach each phase to mastery (Flores, Hinton, Strozier, & Terry, 2014; Mancl, Miller, & Kennedy, 2012; Strickland & Maccini, 2013). Hence, the CRA sequence is an effective instructional model that increases conceptual, procedural, and declarative knowledge in mathematics (Mancl, Miller, & Kennedy, 2012). Teachers ought to start at the concrete level before moving to the representational level and, finally, the abstract level. The third part of the sequence, abstract thinking, will only be required if the information cannot be readily represented at the concrete or representational level. To achieve this outcome, teachers need to plan carefully and use innovative strategies in class.

The concrete understanding ought to be attempted first by using appropriate concrete objects. This uses well-planned instruction using physical manipulates, which allow students to become active participants in knowledge construction (Ünlü, 2018). When students use manipulatives to explore concepts, they are more engaged and motivated. They can participate in mathematical discourse, share their thinking, and reflect on their learning. This leads to increased achievement and a deeper understanding of the concepts studied (NCTM, 2010). Furthermore, the use of manipulatives increases the number of sensory inputs a student uses while learning the new concept, which improves the chances for a student to remember the procedural steps needed to solve the problem. The concrete phase develops conceptual learning using three-dimensional manipulatives (Witzel, Ferguson, & Mink, 2012). Hence, students will have an easier way of remembering the process of answering Mathematics problems.

On the other hand, representational understanding is achieved by using an appropriate drawing technique and, finally, appropriate strategies are used to assist learners in moving towards the abstract level of understanding of the concepts and symbols for a particular mathematical idea using explicit teaching. Other visual representations can take the form of a graphic organizer. Graphic organizers, in themselves, are search-supported intervention, depict the relationship between facts and concepts, helping a student to organize, and subsequently solve math problems (Strickland & Maccini, 2010; Strickland & Maccini, 2013). Hence, research supports the use of representational over pictorial graphics (van Garderen, Scheuermann, Poch, & Murray, 2018). This implies that the manipulations in the concrete and representational stages allow students to rationalize the conceptual mathematical procedures into logical steps and understandable definitions (Jones & Tiller, 2017). When students encounter a difficult mathematical problem, they are able to construct pictorial representations to assist in finding the solution (Witzel & Kiuhara, 2017). Teachers should use appropriate concrete manipulatives first. It is also important to ensure that learners acquire, retain, and master the mathematics skills at each stage of the instructional sequence (Hughes, Riccomini & Witzel, 2018). With that, students will be able to perform Mathematical procedures correctly.

Finally, the last phase of CRA is solving problems using numbers only, the abstract level. Prior to this level, students developed a conceptual understanding of numbers and operations using manipulatives, then pictures and drawings. Instruction at the abstract level focuses on completing tasks and solving problems using numbers only, developing procedural knowledge and fluency or declarative knowledge (Miller, Stringfellow, Kaffar, Ferreira, & Mancl, 2011). Strickland and Maccini (2013) asserted that generalizing the previously mastered conceptual understanding from the concrete and representational phases and applying that to the abstract phase is the most challenging aspect for students. Often students are supported in the transition between the representational and abstract phases through the application of a cognitive strategy (e.g., mnemonic or cue) that prompts students to remember the steps in the given mathematical process (Mancl, Miller & Kennedy, 2012). Miller, Stringfellow, Kaffar, Ferreira, and Mancl (2011) suggested that transition to the abstract phase is facilitated when students are exposed to Mathematical notation alongside presentations of Mathematics problems in concrete and representational formats.

To sum up, using the CRA instructional sequence will not guarantee accurate and complete mathematical understanding and success in any and every secondary Mathematics concept. However, there is a guarantee that the explicit sequence and multisensory approach of CRA provide flexibility when implemented in any Mathematical concepts. Resource room teachers may choose to introduce math topics and support general education abstract instruction using concrete and pictorial instruction before abstract instruction as a student preparation intervention. This approach was used to connect lessons and stages, which is necessary for learning targeted skills and comprehending associated concepts (Jones & Tiller, 2017; Witzel & Kiuhara, 2017). Using partial components of the Concrete-Representation-Abstract instructional method (i.e., abstract only, representational only, or representational and abstract only) did not demonstrate the significant gains in measures compared when the instruction uses the three methods (i.e., there is the abstract, representation and concrete). Therefore, it is a must that in using the CRA approach, these three methods should be done accordingly for better academic gains (Mancl, Miller, & Kennedy, 2012).

Conventional Teaching Approach

Teaching methods and approaches play a vital role in the teaching and learning process. There had been plenty of methods and approaches used. But, one such is the lecture method. The conventional or traditional teaching method is the oldest teaching method and still the most frequently used method of instruction inside the classroom throughout the world (McKeachie & Svinicki, 2014). The traditional conventional approach of teaching is teacher-centered with minimal or no active participation from the students. It has minimal or no integration of the subject, both horizontal and vertical (Kamran, Rehman, & Iqbal, 2011). The lecture method bases itself upon the transmissive teaching model- that is, knowledge is an object that can be transferred from the teacher to the learner. Practically, it implies a lecturer holding a lecture for a group of people ((Marmah, 2014). Moreover, teachers are given the full initiative to assist the students in obtaining the required knowledge. The instructor is the central focus of information transfer. As a result, students are passive information receivers because the instructor will just stand in the class and present information for students to learn (Marmah, 2014).

In line with this, there had been studies which pointed out that lecture is still widely accepted instructional method (Turner, 2015). In fact, in many developing countries, lecturing is the most dominant and traditional method of instruction (Ali, Shah, Amad, & Amad, 2012), and the majority of the Mathematics teachers follow the traditional methods to teach Mathematics (Nafees, 2011). In addition, Harris & Pamapaka (2016) stated that conventional lectures are effective in organizing and transmitting content knowledge. Ali (2011) further reports that responses from students exposed to a lecture format included their preference for the lecture because this method allowed the teacher to lead in a structured way as compared to the group work were a discussion among students lead to unnecessary chatter. Other researches also revealed that there are no differences in terms of learning outcomes between the lecture method and other teaching methods (Hafezimoghadam, Farahmand, Farsi, Zare, & Abbasi, 2013) which can be concluded that traditional lecture method is still an effective strategy in presenting a lesson, especially in mathematics. In fact, a study conducted by Benson, Orr, Biggers, Moss, Ohland, and Schiff (2010) provides evidence that students place greater emphasis on the lecture. Most of the students rated the lecture method as the best teaching method. Reasons given by the students included; teacher provides all knowledge related to the topic. It is a time-saving method, and students listen to the lecture attentively and take notes.

However, according to Kaur (2011), the traditional method is not for long-term learning because it can stifle learner's creativity. This approach only allows students to be dependent on their professors and, as a result avoiding responsibility in their own learning (Zachry, Nash, & Nolen, 2017). Pure lecture fails to give feedback to both the teacher and the learners. Lectures cannot keep students' attention for a long time or for the whole lesson. Information is easily forgotten if taught through the lecture method. Lectures assume that all learners have the same learning styles (Ayodele & Fatoba, 2017). Lectures cannot teach motor skills, influence attitudes and values, teach application, analysis, synthesis, or evaluation (Finley, 2016).

It was also discovered from the study of Shaari, Yusoff, Ghazari, Osman, and Dzahir (2014) that students preferred interactive teaching techniques over traditional lecture methods because traditional lectures can only encourage a shallow approach to learning (Waldrop, 2015). Despite two opposing ideas towards the traditional lecture method, there is enough evidence from research studies indicating that most of the university teachers are not familiar with modern teaching methods and that traditional lectures are still the most popular instructional method in the universities (Adib-Hajbaghery & Aghajani, 2011). However, the findings from the study of Sakala (2012) showed that teachers had been exposed to a variety of teaching methods and techniques during their initial teacher training. It was further reported in this same study that down the line as they practiced their career, teachers resorted to using the lecture technique more than any other teaching techniques.

Henceforth, having these pieces of literature, it is confirmed that CRA is an approach we needed in actively learning math concepts. It should always be remembered that to promote active learning by students and to have meaningful learning to occur, and students must actively engage with the to-be-learned subject-matter through activities such as discussion, hands-on activities, and problem-solving (Freeman et al., 2014). Moreover, Maphosa, Zikhali, Chauraya, and Madznire (2013) also concluded that students perceived lecture with discussion as an effective pedagogical approach confirmed the importance of student involvement in learning as opposed to wholly lecturer dominated teaching sessions. This proves the fact that traditional lectures are perceived as effective and are appreciated by many if they are modified. In this case, it is not a lecture technique per se, but an eclectic approach to teaching in which a lecture technique is only a component. Other than that, the teacher's personality also weighs great deals in the effectiveness of the lecture method. Evidence shows that students' mathematics learning is influenced by the teaching they experience at school (Sullivan et al., 2015). Students' understanding of mathematics, their ability to solve problems, and their confidence in and their disposition towards mathematics are all shaped by the teaching they encounter in school, and the success of the students depends most of all on the quality of teaching offered by the teacher.

Concrete-Representation-Abstract Approach and Mathematics Performance

Predicting students' performance at school is considered crucial for students, educators, policymakers, and stakeholders; and therefore, the factors that can be linked to academic achievement have been investigated by many research studies. However, it is accepted that the role of the teacher is pivotal in the Mathematics achievement of a student. At the same time, it is also very crucial how the teacher provides meaningful representations and situations to the students (Kang, 2012). Effective mathematics instruction is an appropriate balance of the participation of the teacher and his/her learners (Kilpatrick, Swafford, & Findell, 2001; NMAP, 2008). Instead, the balance of instruction is determined by the needs of the students and the nature of the instructional content. Well-designed curricula, in association with competent teachers, aid student learning (NCTM, 2010).

In connection, in Singapore's mathematics curriculum CRA stands out in helping the students improve their academic performance (Kaur, Tay, Toh, Leong & Lee, 2018; Men, Ismail, & Abidin, M, 2018; Salingay & Tan, 2018; Toh, & Kaur, 2019). Researchers have shown that the use of the CRA sequence of instruction has been very effective and beneficial to learners who struggle with understanding mathematical concepts and procedures performance (Flores, 2009; Putri, 2015; Salingay & Tan, 2018; Witzel, Riccomini, & Schneider, 2008;). As a whole, it is pointed out that in order to have a positive result towards students' Mathematics performance, the proper sequencing of the identified stage must be observed. Even a single stage that was not properly worked out and even a single mistake upon implementation of this approach can affect the whole performance of students in learning and will not demonstrate the significant gains in mathematics (Mancl, Miller, & Kennedy, 2012).

Theoretical Framework

This study was anchored on two theories namely Activity Theory based on the work Vygotsky and his student Leont'ev from their studies of cultural-historical psychology in the 1920s (Verenika, 2001); and second is Jerome Bruner's "Theory of Representation of Knowledge" (1966).

Activity Theory pointed out that humans are not separated from their social environment, and their actions are mediated by tools. This theory uses the whole work activity as the unit of analysis, where the activity is broken into the analytical components of subject, tool, and object, where the subject is the person being studied, the object is the intended activity, and the tool is the mediating device by which the action is executed (Hasan, 1998). The use of tools is a means for the accumulation and transmission of social knowledge. It influences the nature, not only of external behavior but also of the mental functioning of individuals.

In this particular study, CRA employs a series of activities using mediating tools such as manipulates and technologies. This was employed to provide students with scaffolding. It is posited that by providing manipulatives, it would effectively influence the mental functioning of the students towards grasping difficult topics in mathematics. The researcher, acting as the teacher, presented different stages for the mediating tools. At first, the students created a manipulative and used it during the discussion to represent the abstract ideas in mathematics. Then, a certain technology was used to give an illustration or picture of the topic and present it to the students.

Moreover, this study was also anchored on Bruner's Theory of Representation of Knowledge. This explains that the acquisition of knowledge has three stages, namely enactive, iconic, and symbolic (Leong, Ho & Cheng, 2015; Teng, 2014; Wong, 2015). According to Bruner (1964), conceptual learning begins with experience from actions undertaken through the support of manipulatives (enactive), then it was subsequently translated into images of the experience formed (iconic). With an accumulation of enactments and their corresponding iconic representations, links are formed to connect some of the representations into a collective structure. The criteria for selection into the collective structure is governed by a certain rule derived from organizing common attributes found embedded in those qualified representations. Eventually, this rule ascends above the enactive and iconic representations to stand exclusively by itself and is denoted by a symbol (Bruner & Kenney, 1965).

The first stage is the enactive or concrete stage; the learners learn about the world or can understand abstract ideas through actions on physical objects or manipulatives. Thus, mediating tools are highly needed, especially in an activity. It is suggested that manipulating familiar and confidence-inspiring entities, whether they are physical (blocks, sticks, counters, rods) as Bruner suggested, or meta-physical (numerals as numbers, letters as variables or as generalities, familiar diagrams, screen manipulable objects, and many more).

Second is the iconic stage or representation. Tools are still needed since the students' learning can be obtained through the use of models or pictures of the given topic because the knowledge is still stored primarily in the form of visual images. The learner can use mental images to stand for certain objects or events.

Third is symbolic or the abstraction stage, mediating tools are not needed. This last stage of representation of knowledge stressed out that learners have developed the ability to think in abstract terms. This uses symbol systems such as language and mathematical notations to encode knowledge.

Conceptual Framework

The conceptual framework of the study follows the interrelatedness of the approaches in teaching Mathematics—the Concrete-Representational-Abstract Approach and the Conventional Approach and the Mathematics achievement of the students.

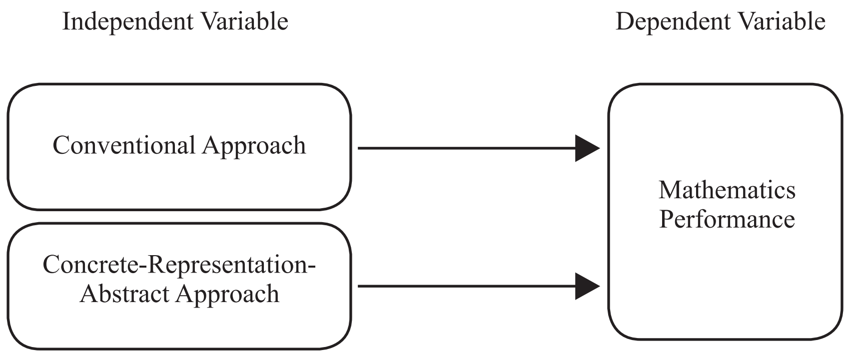

Figure 1. Conceptual Framework

The figure represents the flow of the study, which illustrates the effectiveness of the Concrete-Representation-Abstract approach and the conventional method, which are the independent variables. The performance of the students was based on their pre-test and post-test mean scores as the dependent variable. The control group was given the conventional approach, whereas the experimental group was given the Concrete-Representation-Abstract Approach.

Objective of the Study

This study aimed to determine the effect of CRA in enhancing the performance of students in Mathematics. Specifically, the study sought to investigate if there is a significant difference between the pre-test mean scores of experimental and control groups. Then it also investigated if there a significant difference between the pre-test mean score and the post-test mean score of students in the control group and experimental group. Finally, it also examined if there a significant difference in the post-test mean score of control and experimental groups while controlling the pre-test scores.

METHOD

This study used a quasi-experimental design. This design is suitable to be employed when it is not feasible to randomly design participants of control and experimental groups for comparison (Cook, Campbell & Shadish, 2002). Further, this employed pretest-posttest non-equivalent design to compare the effectiveness of the two teaching methods—Conventional Approach and Concrete-Representation-Abstract Approach using the mean scores. The subjects were the intact groups of college freshmen students who were officially enrolled in Gen Education 4 subject in a naturally accumulated classroom setting.

Below is the Nonequivalent Control Group Design presented by Campbell and Stanly (1966) which was employed in this study:

$$
\begin{array}{ccc}
O_1 & X & O_2 \\
\hline
O_3 & & O_4
\end{array}
$$

where:

X	=	*Experimental Treatment*
O1	=	*Pretest of the Experimental Group*
O2	=	*Posttest of the Experimental Group*
O3	=	*Pretest of the Control Group*
O4	=	*Posttest of the Control Group*
------	=	*Non-randomized selection of the students*

This design used a pre-test and post-test tool for both the control and experimental groups, identical in all aspects except that there was a non-random assignment of treatment. Finally, according to Shaughnessy, Zechmeister, and Zechmeister (2014), the quasi-experimental is appropriate to employ if the purpose is to analyze the difference of the pre-test mean scores between the experimental group and control group and the post-test mean scores of the groups. The respondents of this study were the freshmen college students who were officially enrolled in General Education 4 (Mathematics in the Modern World) subject for the school year 2018-2019 second semester. Moreover, this study utilized simple random sampling, specifically the toss coin technique. The toss coin technique was used to avoid bias in choosing who among the two blocks will be the experimental group and the control group. The proponents of this study utilized a 35-item teacher-made multiple-choice questionnaire as an instrument to measure students' performance in Mathematics. This questionnaire underwent a series of tests before it was used. First, it was subjected for validity test, which was validated by three qualified validators, namely Dr. Jonald Fenecios, Dr. Joy Picar, and Dr. Ronald Decano was asked to assure the validity of the said self-made questionnaire. The validation sheet was given to the validators using the format used by Cor Jesu College Graduate School. Results from content validity reveal that the overall mean score is 4.58 and is interpreted excellent. This result indicates that the instrument is excellent in terms of its clarity of directions and items, presentation and organization of items, the suitability of items, adequateness of items per category indicator, attainment of purpose, and objectivity. After integrating the minor corrections on terminologies, the instrument was then finalized.

Table 1. Results and Interpretation of Content Validity

Area	Mean Score	Interpretation	Overall Mean Score	Interpretation
Clarity of Directions and Items	4.33	Very Satisfactorily	4.72	Excellent
Presentation and Organization of Items	4.67	Excellent		
Suitability of Items	4.67	Excellent		
Adequateness of items per category indicator	4.67	Excellent		
Attainment of Purpose	5	Excellent		
Objectivity	4.67	Excellent		
Scale and Evaluation Rating Scale	5	Excellent		

Second, it had gone through the reliability test through pilot testing. The result of pilot testing was subjected to statistical analysis using Cronbach's alpha. Results of reliability statistics on table 2 show that Cronbach's alpha where all above 0.65, which implies that all items tested passed the test of reliability. The abovementioned questionnaire was composed of 35 items consisting of items taken from the five identified learning competencies, namely: Euler circuit, Euler Path, Hamiltonian circuit, Hamiltonian circuit, Hamiltonian path, and weighted graph using the nearest neighbor algorithm and cheapest link algorithm. Exactly the same questionnaire was used to both control and experimental groups. Thus, the mathematics performance of the two groups was measured through students' scores from both pre-test and post-test given.

Table 2. Results and Interpretation of Reliability Test

Factor	Cronbach's Alpha	No. of Items	Interpretation
Euler Circuit	.801	8	Reliable
Euler Graph	.758	7	Reliable
Hamiltonian Circuit	.825	8	Reliable
Hamiltonian Path	.714	6	Reliable
Weighted Graph	.680	6	Reliable

The following scales were utilized to interpret the mean scores of the respondent in Mathematics using a grading point system in the college department, and the interpretation was based on the Department of Education K-12 curriculum.

Table 3. Table of Interpretation for the Students' Mean Scores in the Pre-test and Post-test

Numerical Equivalent	Description	Interpretation
31.51-35.00	Advanced	The student, at this level, exceeds the core requirements in terms of knowledge, skills, and understanding and can transfer them automatically and flexibly through authentic performance tasks.
27.51-31.50	Proficient	The student, at this level, has developed fundamental knowledge, skills, and core understandings and can transfer them independently through authentic performance tasks.
23.51-27.50	Approaching Proficiency	The student at this level has developed the fundamental knowledge, skills, and core understandings with a little guidance from the teacher and/or with some assistance from peers who can transfer these understandings through authentic performance tasks.
21-23.50	Developing	The student, at this level, possesses the minimum knowledge and skills and core understandings but needs help throughout the performance of the authentic tasks.
21-below	Beginning	The student, at this level, struggles with his/her understanding, prerequisite, and fundamental knowledge and/or skills that have not been acquired or developed adequately to aid something.

The researcher sought permission from the dean of the Graduate School of the Cor Jesu College to conduct the study. When the approval was granted, the researcher then asked permission from the dean of the College of Education, Arts and Sciences (CEDAS) then to the program heads where the study was conducted. When the permission was given to conduct the study, the researcher administered the pre-test to the subject Gen. Ed 4 (Mathematics in the Modern World) in both the experimental and control group based on their class schedule on January 11. After conducting the pre-test, the researcher, then, started the intervention on January 14. The results of the pre-test were properly recorded and retained. Then, after using the two different approaches to two different groups, the researcher gave specific instructions about the nature of the post-test and how to perform it. Afterward, the scores from the pre-test and post-test were collated, tallied, tabulated, analyzed, and interpreted by the researcher with the aid of the statistician. In analyzing the data, mean was used to identify the mean score of Mathematics performance of the students in the experimental and control group. Then, a paired sample t-test was employed to find the difference in the pre-test and post-test of the students in the control group, as well as to determine the significant difference in the pre-test and post-test of the experimental group.

Independent t-test was used to find the significant difference between the pre-test mean scores of experimental and control groups. Finally, analysis of covariance as employed to find if there is a significant difference in the post-test mean scores of control and experimental groups while controlling the pre-test mean scores.

Results

This section explains the presentation, analysis, and interpretation of the data gathered using the most appropriate statistical tool. It starts by discussing the significant difference in the pre-test scores of the students in Mathematics performance of experimental and control groups. The presentation continued by discussing the significant difference between the pre-test mean score, and the post-test means score of students in the control group. Then, next to it was the discussion on the significant difference between the pre-test and post-test scores of students in experimental groups. The chapter ends by discussing the significant difference in the post-test mean score of control and experimental groups while controlling the pre-test scores.

Significant Difference in the Pre-test Scores of the Students in Mathematics Performance of Experimental and Control Groups

In this study, the researcher tried to determine if there is a significant difference between the pre-test means scores of experimental and control groups. In order to answer the research problem, a T-test for Independent Sampled was used. Results reveal that the students in the control group show a higher level of mathematics performance with a mean score of 14.84 as compared to those students who are in the experimental group with a mean score of 13.5.

Table 6. Significant Difference in the Pre-test Scores of the Students in Mathematics Performance of Experimental and Control Group

Groups	Mean Score	Significance (2-tailed)	Decision	Interpretation
Control	14.84	.090	Fail to reject the null hypothesis	Not Significant
Experimental	13.5			

However, when attempted to determine whether such difference can be considered as significant, the results reveal a significance value of 0.090, which is found to be higher than the 0.05 level of significance set for this study. This implies that the difference in the mean scores of the two groups of students is found insignificantly different. Therefore, the null hypothesis has failed to be rejected. It can be argued, therefore, that before the treatment was employed, students of the two groups have most likely the same level of mathematics performance, which is at the beginning stage. They have difficulty in understanding the mathematics of graphs, especially the five identified subject matter.

Significant Difference Between the Pre-test Scores and Post-test Scores of Students in Control Group

The study aimed to determine whether the conventional teaching method is effective in enhancing mathematics performance. The level of mean scores of mathematics performance was determined before and after the intervention or treatment. Mean scores were calculated, and a Paired-sample t-test was employed in order to establish whether there is a significant difference in the performance of students in mathematics before and after the treatment is used.

Table 7. Significant Difference in the Pre-test and Post-test Scores of the Students in Mathematics Performance of Control Group

Tests	Mean Score	Significance (2-tailed)	Decision	Interpretation
Pre-test	14.84	.000	Reject the null hypothesis	Significant
Post-test	19.32			

Results showed that the level of mathematics performance of the students before the treatment was at 14.84 or interpreted as the beginning. Then, after the students were exposed to the treatment or intervention, the level of their mathematics performance rose to 19.32 for an increase of about 4.47, but still belongs to the beginning stage. Moreover, the difference in the mean scores was found to be significant, as manifested by the result (2-tailed) value of 0.000, which is found to be below the 0.05 level of significance set in this study. Hence, this still indicates that the level of improvement of the mathematics performance of the students after being exposed to the treatment is found to be considerable or significant and that the treatment can be considered as a helpful tool in enhancing Mathematics performance. Thus, the null hypothesis is rejected.

Significant Difference Between Pre-test Scores and Post-test Scores of Students in Experimental Group

Another aim of this study was to determine whether the Concrete-Representation-Abstract method is effective in enhancing Mathematics performance. The level of mean scores of Mathematics performance was determined before and after the intervention or treatment. Mean scores were calculated, and a Paired-sample t-test was employed in order to establish whether there was a significant difference in the mathematics performance of students in the experimental group before and after the treatment was employed.

Table 8. Significant Difference in the Pre-test and Post-test Scores of the Students in Mathematics Performance of Experimental Group

Tests	Mean Score	Significance (2-tailed)	Decision	Interpretation
Pre-test	13.5	.007	Reject the null hypothesis	Significant
Post-test	22.45			

Results show that the level of Mathematics performance of the students before the application of the Concrete-Representation-Abstract Approach was at 13.5. Then, after the students were exposed to CRA for a period of time, the level of mathematics performance rose to 22.45 for an increase of about 8.95.

Interestingly, the difference in the mean scores was found to be significant, as manifested by the result (2-tailed) value of 0.007, which was found to be below the 0.05 level of significance set in this study. This indicates that the level of improvement of the mathematics performance of the students after using the CRA Approach is found to be significant and that the CRA Approach can be considered as an effective tool in enhancing mathematics performance where students' performance in Mathematics at this time is at developing stage. Thus, the null hypothesis is rejected.

Significant Difference Between the Post Test Mean Scores of the Students in the Control and Experimental Groups While Controlling the Pre-test Scores

This study tried to determine if there is a significant difference in the post-test scores of control and experimental groups while controlling the pre-test scores. Analysis of Covariance (ANCOVA) was utilized.

Table 9. Significant Difference in the Post-test Scores of Control and Experimental Groups while Controlling the Pre-test Scores

Source	Sum of Squares	df	Mean Square	F-value	Sig.
Group	167.639	1	167.639	12.019	.001
Pre-test (covariate)	144.393	1	144.393	10.352	.002
Error	934.536	67	13.948		
Total	30613.00	70			

Results reveal that the mean score of the control group in the post-test was 19.32, while the experimental group was 22.45, which is 3.94 higher than the control group. Interestingly, the difference in the mean gain scores was significant, as manifested by the F-value of 12.019 and supported by a sig (2-tailed) value of 0.001, which is found below the 0.05 level of significance set in this study. This indicates that there is a significant difference in the post-test scores of control and experimental groups while controlling the pre-test scores. This means that there is a greater improvement in the mathematics performance of the students in the experimental group than that of the control group. This upholds that the employment of the Concrete-Representation-Abstract approach is more effective than the Conventional Teaching Approach in enhancing students' Mathematics performance.

Discussion

Examining the effect of the CRA approach in enhancing the performance of students in Mathematics could be beneficial for both administrators, teachers, students, and future researchers. The results of this study could help the administrators which would provide with new ideas which they can recommend for the further implementation of the curriculum, for Math Teachers to use this creative teaching strategy for their subjects so as to aid them in improving the students' academic performance, especially in mathematics, for the students to develop higher-order thinking skills which makes them capable of understanding different content in Mathematics.

As tried to determine if there is a significant difference between the pre-test means scores of experimental and control groups, no significant difference was found. The result only proves that low performance in mathematics exists wherein none from the group have reached the proficient level. These low performing students, perhaps, cannot identify and carry out routine, distinct procedures, and they are incapable of employing basic algorithms, formulas, procedures, or conventions to solve problems and interpret results literally (European Commission, 2013c, 2014; OECD, 2014c).

A significant difference was found between the pre-test scores and post-test scores of the control group. The result connects to the investigation done by Covill (2011). It has been found out in her study that students considered the conventional lecture method to be more comprehensive. They were reported to have great involvement in the teaching-learning process and becoming more involved in independent thinking and problem-solving. Also, according to Harris & Pampaka (2016), the lecture-style of teaching remains the preferred way of students in higher education very much. Ali (2011) further reported that responses from students exposed to a lecture format enclosed their preference for the lecture since it allows the teacher to guide them during a structured manner as compared to the group work where discussion among students result in reserve chatter.

With regard to the significant difference between pre-test scores and post-test scores of students in the experimental group, a significant difference was also found. The result of this study supports the claim of previous researches that students who are identified to have learning mathematics difficulty learn better when CRA approach is used since the test result shows that the students of the control group, the one who uses the CRA approach, has higher test result (Flores, Hinton, Stroizer & Terry, 2014; Stroizer, Hinton, Flores, & Terry, 2015; Yakubova, Hughes, & Shinaberry, 2016) It is in line with the study of Putri (2015) which concludes that the implementation of CRA approach in mathematics learning can enhance the ability of mathematical representation and spatial sense.

As to the significant difference between the post-test mean scores of the students in the control and experimental groups, while controlling the pre-test scores, a significant difference was also found. The result of this study confirms the findings of Salingay and Tan (2018) confirmed that students under the CRA Approach have significantly performed higher than those under the non-CRA. Calfoforo (2013) also supports, thus indicating that students exposed to Multiple Representation-Based Instructions are significantly higher than the control group. Carbonneau, Marley, and Selig (2013) also emphasize that using manipulatives in mathematics instruction produces a small- to medium-sized effect on student learning when compared with instruction that uses abstract symbols alone.

Conclusions

Findings reveal that after the traditional lecture approach was employed, students' Mathematics performance found to have increased. Thus, the effectiveness of such an approach had been established. Then, after the CRA approach was utilized, students' Mathematics performance also improved. Hence, the effectiveness of the CRA had been established. Thus, students exposed to the CRA approach perform significantly better than those students in the traditional lecture approach. Since the results concluded that Concrete-Representation-Abstract Approach was found to be better than the conventional or traditional lecture approach in enhancing students' mathematics performance.

Recommendations

In light of the findings and conclusions of the study, the following recommendations were offered: School administration should strongly consider the application of CRA as a teaching approach to teach mathematics from basic education to higher education. Also, the school administration should conduct a series of training to enhance the skills of mathematics teachers on how to effectively employ CRA in the classroom. Moreover, the least acquired Mathematics competencies of students should be regularly evaluated so that results can be used in providing materials needed to implement the CRA approach by the teachers. Lastly, similar experimental studies should be conducted involving more students with longer time duration to establish the effectiveness and functionality of the CRA approach fully.

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