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Design Research Approach in Developing Technology-mediated Learning Modules in Practical Mathematics for Technical Vocational Education

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APPROVAL SHEET

The dissertation attached hereto, entitled "**DESIGN RESEARCH APPROACH IN DEVELOPING TECHNOLOGY-MEDIATED LEARNING MODULES IN PRACTICAL MATHEMATICS FOR TECHNICAL VOCATIONAL EDUCATION,**" prepared by **BENEDICTO NORBERTO V. AVES,** in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Education (major in Mathematics Education), is hereby accepted.

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DEDICATION

To my late Dad and Mom whose deep affection and unwavering faith in my capacity has kept me inspired to soar high in life

Abstract

This study aimed to develop technology-mediated learning modules in practical mathematics for the technical vocational track of the K to 12 curriculum using the design research model of Mckenney and Reeves (2003). It also sought to:
a) characterize the these learning modules in terms of the selected design principles; b) determine their effectiveness; c) determine how beneficial the design research approach is in developing these modules compared to a traditional curriculum development approach; d) compare the practical mathematics test scores of the design research group and comparison group; and e) make improvements on the learning modules. The theoretical and practical outputs of the study are of significant use to curriculum developers, mathematics teachers, technical vocational schools, and practitioners of design research. Two iterations were done in developing the modules, where data were gathered from randomly selected samples from a private sectarian college using researcher-made instruments. Test result indicated a non-significant difference in the gain scores of the design research group and the comparison group. However, research participants' assessment of the modules show that the modules developed using the design research were effective in learning practical mathematics concepts. The focus group discussion with research participants and the review of a subject expert both show preference in the modules developed using design research. The study thus recommends the use of design research in developing technology-mediated learning modules in mathematics for the technical vocational track of the K to 12 curriculum, and the use of its practical output in the online learning and teaching of practical mathematics concepts.

Keywords: design research, practical mathematics, design principles, technology-mediated learning modules

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Chapter 1

INTRODUCTION

This chapter presents the background of the study which leads to the statement of the problem. It also describes the significance of the study as well as its scope and delimitation.

Background of the Study

One exciting development in the educational landscape that pushed further the frontier of distance learning was the emergence of online learning. In this learning format, students learn mostly through Internet resources and communication technologies—at their own pace and convenient time. Many institutions of higher learning are now finding online learning as a viable option to traditional learning (Summers, Waigandt & Whitaker, 2005). In 2012, almost 70% of American universities and colleges (Allen& Seaman, 2013), up from 56% in the middle part of 2000 (Allen & Seaman, 2005), saw online education as critical to their long-term strategy. The use of online learning, moreover, extends to technical vocational education. The China Online Education Report (2014, p.1) showed that online learners in China numbered 67.2 million in 2013 and furthered that "38.6% of these learners were enrolled for online vocational education."

Indeed, online learning has assumed a significant role in the delivery of technical vocational education—an important component of national development. Technical vocational education is so vital in the creation of employable skills for poverty reduction and sustainable development (Oseni, Ehikioya & Betty, 2011). Such importance has attracted policy attention among developed countries on using distance learning as a primary strategy in the reform of technical vocational education (Stevens, 2001). For instance, Australia, Canada, and the European community have each crafted a national program or strategy to expand the application of distance and flexible learning technologies. Such has been crafted for the reform of vocational education and training system, workforce development, and for addressing current shortage of IT workers (Stevens, 2001). In these countries, online learning is the latest mode of delivery of instruction for learners of vocational education.

In the Philippines, a good number of short-term courses were offered by the Technical Education and Skills Development Authority (TESDA) through this online learning technology. These courses, which require very little mathematics requirement or none at all, were available as online learning modules. This study, however, has yet to find an application of online learning technology in the core courses of the technical vocational education in the Philippines. Because of this gap in research literature, this study has taken great interest to apply online technology to the technical vocational education in the Philippines. Such interest is very relevant especially now that technical vocational education has become one of the four major tracks in the recently implemented K to 12 curriculum (Ocampo, 2014). In particular, this study wants to develop technology-mediated learning modules in practical mathematics for the vocational technical track of Grades 11 and 12. These online learning modules will provide a learning environment of convenience, instructor availability, and online interactions in a technical vocational course, like practical mathematics especially, to students who are time-bound or place-bound due to distance or physical limitations (Juan, Steegmann, Huertas, Martinez & Simosa, 2011).

The increasing use of online learning speaks volumes of many other benefits for its users like students in the technical vocational schools. An ongoing large body of literature shows that online learning format is an effective way of building learning engagement of students (Lewis & Allen 2005; McConnell, 2006). In a meta-analysis of 20 years' research on the academic performance differences between traditional and distance learning, it was found out that the "experimental probability of attaining higher learning outcomes is greater in the online environment than in the face-to-face environment" (Shachar & Neumann, 2010, p.327). Moreover, this latest distant mode of learning yields prospects for promoting a reflective and collaborative learning environment (Bates, 1997; Eastmond, 1995). This characteristic of online learning was validated by a study of El Mansour and Mupinga (2007) who reported that, among others, online interaction was one positive aspect experienced by the participants of the study. From the instructors' point of view, they found online teaching advantageous because they can: a) plan their courses in advance; b) maintain personal communications with their students; c) have access to a variety of students; d) gain opportunity to improve their pedagogy skills; and e) have more control over the learning environment (Telmesani, 2010).

The sustained effort for a technology-based mathematics curriculum has mediated online learning of mathematics. Such technology has provided tools which make such online learning more convenient, effective, and engaging. The computing technology – like the scientific and graphing calculators, and computer programs with a multitude of mathematics functions – has freed up learners from the routinely mechanical task of calculating and allowed them the joy of discerning and exploring mathematics (Heid, 1988). Moreover, computer-assisted instruction in mathematics reinforces learning, achieves better student retention, and provides paced learning (Barrow, Markman & Rouse, 2009; Pilli & Aksu, 2013). The multimedia presentation of mathematical knowledge through digital board and Internet has fostered greater student engagement and connected mathematics abstractions to the real world (diSessa, 2001). In a statewide online program of more than 3,000 online courses delivered to more than 250,000 student enrollees since 1996, online teaching of mathematics was a significant predictor of faculty satisfaction with online teaching (Shea, Pickett, & Sau Li, 2005).

In the development of these technology-mediated learning modules, this study will use design research as an approach—characterized as interventionist, iterative, process-oriented, utility-oriented, and theory-oriented (Kelly, 2003). This approach offers a twofold yield: a research-based intervention and a generation or validation of theories (Plomp & Nieveen, 2013). The first yield, a research-based intervention to solve a complex problem in educational practice, is the result of an iterative process of analysis, design and implementation, and evaluation. This process, in turn, advances our knowledge about the characteristics of the intervention and the steps of designing and developing it. Such approach will be appropriate for the present study as it aims to develop technology-mediated learning modules in practical mathematics for students in the technical vocational track of the K to 12 curriculum. The intended users of the modules are expected to pursue the practical vocations in life after high school and are thus disposed to the practical side of learning. Using the iterative process of developing these technology-mediated learning modules will progressively craft an intervention as useable and practical as possible in the learning of mathematics skills and knowledge required in the technical vocational track. Moreover, the same iterative process will help validate some educational theories that this study will use to provide a student-centered, constructivist, and a technology-enhanced learning environment for its intended users. Thus, the second yield of this study will be a set of validated design strategies that will strengthen educational practices of learning and teaching practical mathematics in an online environment. Also, this set of validated design strategies will add to the body of knowledge of developing technology-mediated learning modules in the mathematics curriculum of technical vocational schools.

Statement of the Problem

The study aimed to develop technology-mediated learning modules in practical mathematics by using the design research approach for the technical vocational track of the K to12 curriculum. Specifically, it sought to answer the following questions:

1. What are the characteristics of technology-mediated learning modules in practical mathematics for the technical vocational track in terms of the following:
    a. context of the students;
    b. online learning approach;
    c. online roles of teaching;
    d. technology tools used;
    e. presentation of the online learning modules?

2. How do the first iteration group and second iteration group differ in terms of student evaluation of the effectiveness of the technology-mediated learning modules in practical mathematics?
3. How do the design research group and comparison group differ in gain scores in practical mathematics test?
4. How beneficial is the design research approach in the development of technology-mediated learning modules in practical mathematics compared to the traditional curriculum development approach used in a private sectarian college?
5. What improvements are done on the learning modules based on the feedback of the student participants, class observer and/or the researcher?

Significance of the Study

Under the K to 12 curriculum of the Philippines, the mathematics curriculum for the technical vocational track is either newly-developed or is still being refined. Such may either be the case because its implementation is still at its infancy. In this regard, the present study of developing technology-mediated learning modules in practical mathematics for the technical vocational track may be of significant use to several groups described in the succeeding sections:

Curriculum Developers of Technology-Mediated Materials in Mathematics. This study may provide useful inputs to curriculum developers of technology-mediated learning materials in mathematics for technical vocational track under the K to 12 program. Particularly, the re-conceptualized framework of the study, which presents the validated design principles as well as the relationships between these design principles and student performance, may serve as the design framework. As a design framework, it may guide the curriculum developers in creating and designing the content and processes of a technology-mediated mathematics curriculum using design research. Also, these curriculum developers may find the design framework as an input for further design efforts on other technical vocational courses, which will be delivered online. Such design efforts are needed especially that the implementation of the K to 12 curriculum of the technical vocational track is still on its early years and current enrollment in the technical vocational track has accounted for almost forty percent of the more than 1.5 million students enrolled in the senior high school (Mateo, 2017). In particular, the enrollment figure greatly underlines the importance of making the curriculum of the technical vocational track more engaging, authentic, and more relevant to what its enrollees need. Such kind of curriculum is even more needed by those who will decide to find work after graduation from senior high school.

Mathematics Teachers. Those teachers in the technical vocational track who plan to conduct online classes in practical mathematics may greatly benefit from using the practical and theoretical outputs of the study. Such practical output consists of online learning modules on selected but important topics in practical mathematics. They may consider the possibility of allowing their students to learn these topics online with the use of these online learning modules. This learning approach reduces face-to-face classroom meetings—a positive development for time-bound or place-bound students. Also, embedded in these modules are design principles—the theoretical output—validated by this study to be effective principles for teaching and learning practical mathematics in an online environment. These validated design principles will inform and guide these teachers on what and how to conduct effectively their online practical mathematics classes in terms of learning and teaching approaches, technological tools, and the presentation of the online learning modules. The theoretical output of this study will also benefit online teachers of mathematics subjects other than practical mathematics for technical vocational education. Among others, these validated design principles deal well on the processes of teaching and learning, which basically would address how to teach and learn effectively in an online environment. Hence, these principles may also well inform and guide the teaching and learning of other mathematics subjects. In general, mathematics teachers will find the design research approach of the study as a great opportunity to engage both in research and curriculum development. Many curricular revisions before were anchored on research work done separately by a research practitioner while teachers were relegated to the implementation of the curriculum with a proposed intervention. With the design research approach, mathematics teachers are treated as collaborating partners in the work of research and curriculum development. Such approach enables mathematics teachers to participate in the iterative process of analysis and selection of proposed design principles, design and construction, and implementation. The whole iterative process provides mathematics teachers with an enriching experience for professional development and a sense of ownership of the outcomes of the process—production of knowledge of intervention with accompanying validated design principles.

Technical Vocational Schools. The learning modules developed in this study may serve as models for technical vocational schools that plan to offer online courses in mathematics. The modules provide ample opportunities to students—especially those who are time-bound or place-bound—to learn mathematics while overcoming the constraints of time and distance. It is a curriculum material where the students can relate mathematics to their chosen technical vocational courses and find mathematics as used in their future workplace.

Practitioners of Design Research. The innovation introduced by this study in the conduct of the design research process may well be considered by practitioners of design research in further improving the validity of the results of the iterative process of design research. In such modification, a comparison group—using online learning modules revised according to the traditional curriculum development approach of a private sectarian college—was introduced and compared to the design research group in terms of test performance after the second iteration of the study. In this traditional curriculum development approach, a teacher does the work of revision which includes, among others: a) aligning the objectives of the learning modules to the overarching objectives of a private sectarian college, and b) organizing the learning experiences based on TESDA format and characterized by teacher-student interaction and individual learning. Moreover, some selected participants of the comparison group as well as a subject expert were asked to compare these two kinds of learning modules used respectively by the two groups. Feedback obtained from the innovation process have provided more empirical results and insights on the effectiveness of the improved learning modules based on the design research relative to learning modules tried by the comparison group. This innovation introduced by the study can well be a contribution to the body of knowledge of design research.

Scope and Delimitation of the Study

In the newly implemented K to 12 curriculum, there is an emerging need to develop instruction in practical mathematics that appeals to today's younger generation. This study thus intended to develop technology-mediated learning modules anchored on learner-centered strategies and authentic tasks. Due to time and resource constraints, this study has some limitations on the number of iterative process of the design research, the number of learning modules developed, time zones, and the number of participants of the study. Three online modules with seven lessons were developed on the three topics of practical mathematics, which included conversion of units, calculations on algebraic expressions, and ratio and percentage. For curriculum development, the design research approach used two iterative processes, in which each is a process of analysis/exploration, design/implementation, and evaluation/reflection. These processes were implemented by three samples of students from a private sectarian college which has, among others, a senior high school program and a technical vocational institute. The first iteration sample was taken from both the technical vocational track of its senior high school and the technical vocational institute. The second iteration samples were taken from an intact class of the technical vocational track of its senior high school. The implementation of the online learning modules in the first iteration was done in almost ten weeks and ten weeks in the second iteration. Due to the difference of time zones (i.e. participants' time zone is ahead by five hours relative to the time zone of the researcher), online discussions with the presence of the facilitator usually started at night in the place of the participants.

A major provision of the study was an Internet allowance given to the participants who used it to gain Internet access for online study of practical mathematics. Such allowance enabled them to have Internet access until completion of the ten-week online study.

This study used student feedback, and observations of the class observer and the researcher as a facilitator in order to characterize the technology-mediated learning modules in terms of the design principles of the study and to assess how well the online learning modules facilitate the learning of practical mathematics concepts. Also, the study compared the test performances of the design research group and the comparison group, conducted a focus group discussion of the comparison group, and sought a review of the two kinds of learning modules by a subject expert. The test results, data from the focus group discussion, and the review of the subject expert were used to determine how beneficial the design research approach was in the development of the online learning modules compared to the traditional curriculum development approach of a private sectarian college.

Moreover, due to the small sample size of the study, it was difficult to make an assumption of normality of data. Thus, Mann-Whitney U test was used to compare the gain scores between the comparison group and the design research group.

This study is context bound as it aims to produce curricular objects and processes for online learning of practical mathematics in a technical vocational track. Thus, be that as it may, one cannot make any context-free generalizations out of the findings of the study (van den Akker, Gravemeijer, Mckenney, & Nieveen, 2006). It should also be noted here that collection of quantitative and qualitative data came from a small sample with eight student participants in the first iteration implementation and twelve student participants in the second iteration implementation. As such, one cannot also make generalizations of the findings based on statistical techniques, focusing on generalizations from a sample to a population (Plomp & Nieveen, 2013).

Chapter 2

REVIEW OF LITERATURE AND CONCEPTUAL FRAMEWORK

This chapter presents the review of related literature. It also discusses the conceptual framework and presents the research hypotheses, and definition of terms of the study.

Related Literature

This section provides the review of literature on mathematics in the technical vocational curriculum, technology-enhanced instruction, online teaching and learning in applied mathematics, technology-support to online collaborative learning, designing online learning materials, curriculum development in mathematics, and design research approach.

Mathematics in the Technical Vocational Curriculum

There are three main types of vocational education in many countries which are: apprenticeships, vocational options within an otherwise general curriculum, and full-time vocational education. Mathematics in any of these types of technical vocational education is generally basic because it is the one used in the workplace. Taught in the first few years of the secondary, this level of mathematics is simple but its applications in the workplace need complex reasoning (Rose, 2012; Zwart, 2000). As an example, Rose (2012) showed that students, studying to become welders, performed elementary mathematical operations as they analyzed the meaning of mathematical scribbles left at the side of the blueprint from an actual workplace. However, the reasoning required to interpret its meaning is complex. Thus, in the latter part of the secondary curriculum, 2014). The succeeding discussions will show the instruction of mathematics and use of distance learning technology in the technical vocational education in the Philippines and those developed countries.

Technical Vocational Curriculum in the Philippines. Don Bosco School, a religious-run institution, has championed the cause of technical vocational education in this part of the world. Since 1951, it has produced thousands of technical vocational graduates who are gainfully employed here and in others part of the world. The current curriculum of its technical vocational training centers offers a 10-month acquisition of industry skills and another 5-month period of on-the-job training (Inocencio, 2014). Among other academic subjects in the curriculum, mathematics is taught twice a week, one hour for each session, for a total of 40 hours of study in the first 10 months. The course is described as practical mathematics, which is part of the academic subjects (comprising 30% of the total subjects) while the remaining 70% includes technical subjects. As observed by Inocencio (2014), this is in direct contrast to the proposed curriculum for the Technical Vocational Livelihood track of the senior high school of the country's Department of Education (DepEd), where 70% of the subjects are academic and 30% technical.

In the Technical Education and Skills Development Authority (TESDA) curriculum, one of the competencies required of a level II technical vocational trainer is to be able to identify mathematical manifestations in the course content and workplaces. The identified content of mathematics as applied to technical training includes basic arithmetic, the four fundamental operations, and elementary algebra. This content is already embedded in many vocational courses offered by TESDA. The common mathematical skills needed to complete these courses are the skills in mensuration—which is performing measurements on geometric figures and basic calculations (TESDA, 2015).

Many technical vocational education and training programs are provided by the school-based private sector. These schools have provided classroom instruction on the academic component of the program including mathematics and workshops for hands-on training (Syjuco, 2005). In the public sector, though, there is an offer of twenty-nine online technical vocational courses from the Technical Education and Skills Development Authority (TESDA). These are offered free to jobseekers and students who want to acquire more skills at their own pace. It has been observed that these online courses do not require the development of competency in mathematics.

Vocational Education in Canada. Whether one is still studying in high school, a recent high school graduate, who wants to advance in current occupation or considers a career change, faces a range of training programs from the vocational and technical schools in Canada. These programs have included health care, business, beauty, skilled trades, and others. These schools are either public or private institutions, and provide career training and apprenticeship programs which are classified into four main categories: construction, manufacturing, service, and transportation ("Find a Vocational School", n.d.).

In Quebec, students who opt for vocational careers in life may enroll either in a secondary-level vocational training program or in technical training program. Those who choose the secondary-level vocational training program must complete, as a minimum requirement, the secondary IV mathematics course. This course has three streams:

Cultural, Social and Technical, Technical and Scientific, and Science (QEP, 2004). Of the three streams, mathematics for Technical and Scientific streams offers a lot of opportunities for application of its content like analyzing instruments and finding optimal solutions to real world applications. This course, though, has not been designed to prepare students for vocational related careers because it leaves to the students to explore connections between its content and its application to vocational courses (QEP, 2004).

Vocational Education in Singapore and Germany. In many countries, vocational education generally has a lower status than the general education. However, vocational education is a respected option in both Singapore and Germany. The Institute of Technical Education (ITE) of Singapore provides 2-year courses to secondary school leavers. Upon completion of these courses, students are given 4 levels of certifications—the first two levels of which are the national ITE certificates (NITEC) and the higher national ITE certificates. A course of study in ITE consists of a series of modules, divided into four different types: core, specialization, life skills, and elective. The mathematics taught in a NITEC course consists of technical mathematics and mathematics ‘O’. These mathematics modules are taken as electives to give students more breadth and depth in their chosen course. In higher NITEC, some mathematics modules are taken as core like engineering mathematics while others are electives like calculus in process plant design course. Statistics on the other hand, is offered as an elective while accounting as a core in some courses in Business and Services (Hodgen et. al., 2013).

In Germany, all students in technical vocational courses and 90 percent of those pursuing other vocational courses are required to take mathematics. Their mathematics, whenever possible, is always connected to the vocational courses (Hodgen et al., 2013). As one of the three academic streams after elementary schooling, the lower *Hauptschute* prepares its students to attend a combination of apprenticeship and vocational courses. While learning general education courses like languages, students in *Hauptschute* are also taught mathematics which is basic and has emphasis on real-world applications (Hodgen et al., 2013).

Since the technical vocational education and training programs in Singapore and Germany are school-based, one can expect that the instructional delivery of mathematics in these programs is classroom-based. However, the European Community, which counts Germany as one of its members, created a number of complementary programs in support of the adoption of distance learning in the technical vocational education. Some of these programs are the Community Research and Development Information Service (CORDIS) and the Leonardo Da Vinci Program. First, CORDIS is the European Community's largest research and development effort to advance learning technologies and to finance applied research and demonstration projects in a wide range of areas including the technical vocational education and training (TVET) and worker training. Second, the Leonardo Da Vinci Program has focused on strengthening the technical vocational education and training, and on the development of knowledge and skills required of the individual's integration into working life and society (Steven, 2001).

Vocational Program in US and UK. In response to the disproportionately large number of students who have difficulty and poor motivation to learn mathematics in the vocational schools or centers, two countries, among others, have developed ways in order to increase engagement and generate interest of students in mathematics. In the US, the National Research Center for Career and Technical Education (NRCCTE) developed a new approach described as *Math in CTE*. CTE, otherwise known as Career and Technical Education (CTE), is the new name adopted in the US in lieu of technical vocational education. In the project *Math in CTE*, mathematics and CTE teachers collaborated to identify mathematics content already present in various CTE courses and made lesson plans to make such content much more explicit and consistent with the terminology used in the core academic courses. The project's specific methodology has a positive impact on student learning and test scores, and is being replicated across the country (ACTE Issue Brief, 2009). Another project, the STEM Transition Initiative, led to the development of 61 curriculum projects that integrate, among others, mathematics into rigorous CTE applications. The project's context-based instructional materials provide faculty with teaching resources that will further improve the academic and career-related skills of their students by integrating mathematics instruction within the context of a technical discipline.

While CTE courses are offered using classroom-based instruction, there is currently a large number of CTE courses offered online. The community colleges, in particular, are actively offering distance-learning programs in CTE. More than 76 percent of these colleges have offered CTE online courses due to the following objectives: a) reach nontraditional students, b) reduce time constraints of students, c) increase access to new audiences, and d) increase student access to academic courses (Benson et al., 2005)

In the UK, there is a new proposal for a new General Certificate for Secondary Education (GCSE) mathematics which is, in the main, to use vocational context in teaching mathematics to vocational students. Among others, these contexts would include financial, quality control, use of resources, profitability, and customer satisfaction. Some topics of GCSE mathematics lend themselves to a wider application in vocational courses while other topics have limited applications. At the start of a vocational course, students should expect contexts much connected to their chosen vocational study but they should be ready to work in a variety of contexts during the course (Hodgen & Marks, 2013).

The instructional delivery of the GCSE mathematics in state-funded schools is campus based. However, online courses in GCSE mathematics are being offered by a good number of learning centers in UK. In this online course, each student is provided with a dedicated tutor who extends all the support a student would need to help him succeed. He is guided well by his tutor as he goes through the material he needs to study to complete a course. He takes a weekly online test and works on an assignment given every three weeks ("Maths GCSE Online", n.d.)

Technology-Mediated Instruction in Mathematics

The continuing innovations in information and communications technology (ICT) have provided better tools for greater interactivity, more convenience, and wider access to resources in the teaching and learning of mathematics and in the online learning environment. These ICT tools range from computers to laptops and Internet to Internet-based tools. According to Ng and Gunstone (2002), the use of technology-enhanced instruction has motivated the students to be actively engaged in the learning of mathematics. Students who are actively engaged in the learning process learn more, earn better grades and are more inquisitive (Felder, 1992). Souter (2001) has shown that students under the technology-enhanced instruction in algebra achieved better grades and improved their attitudes towards algebra when compared to those of students under the traditional approach towards teaching and learning mathematics. Such traditional approach consisted of an instruction in algebra with the use of print technologies and an overhead projector. These studies have shown how technology influences how mathematics is taught and how it has contributed significantly to better student outcomes.

The introduction of personal computers and laptops has led to a more widespread use of computer technology from the primary school education through the university level. Some applications of this technology to mathematics education are the computer-assisted instruction (CAI) and the mathematics software. When the technology is integrated meaningfully in the instruction of mathematics, the computers and laptops have proven to be useful tools in improving student proficiency in mathematics and other student outcomes (Souter, 2001). According to Cheung and Slavin (2012), mathematics programs that supplement traditional mathematics instruction with additional computer-assisted instruction at the students' individualized assessed level of need have the maximum positive impact on student achievement in mathematics. In the meta-analysis of findings from 254 controlled evaluation studies that compared students taught with and without computer-assisted instruction, Kulik

(2003) showed that students taught with computer-based instruction performed better in the test and developed favorable attitudes. From the studies mentioned earlier (Cheung & Slavin, 2012; Kulik, 2003; Souter,2001), it is notable that there are ample pieces of evidence that computer technology significantly enhanced student learning of mathematics concepts.

One great use of the Internet is an increased access to reference materials and data on instruction and learning, management of educational systems, and scientific and methodical work, among many others (Barron & Orwig, 1995). According to Owston (1997), the Internet is a truly open technology and allows users to access information from the network, regardless of the location of data and knowledge bases. Teachers could quickly obtain information from the Internet for enrichment of lesson plans while students do the same for completion of homework and other school requirements. Having use efficiency, the Internet has significantly reduced the cost of information delivery to the users (Ponniah, 2001). Most state-run schools, for instance, have limited budget to acquire the necessary quantity of printed copies of the most authoritative reference and informative publications. Through the Internet, though, these schools with their computer hardware and software are able to avail the same resources online like the encyclopedia Britannica Online, the dictionary Merriam-Webster Online, and the atlas Altapedia Online (Khannanov, 2003).

The research literature has shown some benefits of the use of Internet in teaching and learning of mathematics. A major benefit is the access of both teachers and students to the wide range of available educational resources (Macdonald et al., 2001). Students studying mathematics can have access to the vast sources of interactive and illustrative materials available in the field of mathematics. The same sources would offer excellent opportunities for exploration especially by stronger students who want to engage more in mathematics beyond their course work (Engelbrecht & Harding, 2004). Through the Internet, course information can be quickly distributed to students and updated (Tan & Huang, 2002). There is also the advantage of a notice board website where students can post relevant learning materials and which they can have access to whenever they want. This website offers an ideal opportunity for problem exposition which solution requires group collaboration and adequate time beyond the students' scheduled classes in mathematics. Moreover, the asynchronous nature of learning through Internet has helped students to become more independent and reflective learners. Hence, students who are exposed to online learning in mathematics tend to be more academically mature than their counterparts in traditional courses (Engelbrecht & Harding, 2004).

Use of Internet-based Tools. Uploading and downloading data to and from the Internet makes possible the use of Internet-based tools like video streaming, video and voice calling, instant messaging, file attachment, and e-mails as a support to collaborative learning in an online environment. These tools help facilitate sharing of information, an important feature of collaborative learning. Moreover, they enable learners to engage in the two most common learning methods in the online environment: asynchronous and synchronous discussions. But the use of these tools can only be as effective as the speed of the Internet. This is a major issue on the Internet especially in developing countries. Philippines, for instance, was pinpointed in 2014-2015 as having the slowest Internet speed in Southeast Asia and one of the slowest in Asia (Venus, 2016). Unless this is not resolved, the use of these tools for online learning through asynchronous and synchronous discussion cannot be fully optimized.

Video Streaming and Learning. This communication technology facilitates asynchronous Internet-based course content as it provides "access to large video and audio files on the Internet over relatively slow connections by using highly compressed files and intelligent buffering at the receiving site" (Wilson & Weiser, 2001, p.2). Through video streaming, a student can watch and re-watch prerecorded video files like tutorials or lesson presentation at a place and time according to his convenience.

Studies have shown positive effects of streaming video on student achievement and attitudes. For instance, streaming lectures can be successfully used to prepare students for class (Keefe, 2003). Between eighth-grade classes who used videos for learning purpose and who did not use, those who used significantly performed better in the test than their counterparts (Boster, et al., 2006). In another study among sixth-grade and eighth-grade students, those who used videos had better achievement in mathematics than the non-users (Boster, et al., 2006). Other studies have recently bared out the positive effects of programs that used videos to illustrate concrete teaching situations for teachers to reflect on and to analyze cases. In the MATH project, Lampert and Ball (1990) concluded that a productive outcome occurred from the discussions between teacher educators and student teachers on instructional problems illustrated by videotapes of classroom lessons. Using Video Cases for Mathematics Professional Development (VCMPD), Mumme and Seago (2003) enabled teachers to perform video-based tasks designed to enhance their understanding and competence to teach linear relationship. Maloy, Edward, and Anderson (2010) conducted a study on the use of the 4th Grade Massachusetts Active Learning Intelligent Tutoring System (4MALITY), an online tutorial system providing support to the fourth graders in preparation for the statewide mathematics achievement test. Of these graders who took the pretest and posttest—which test items were taken from the past statewide mathematics achievement test—seventy percent of them have significantly improved their performances from the pretest to the posttest. At the graduate school level, DeVaney (2009) conducted a study about the impact of video tutorials in an online educational statistics course. Among others, he found that the participants of the study indicated positive perceptions of the tutorials and even suggested that video tutorials were an essential part of the online course. Although there was no significant difference in the academic performance between those with access to video tutorials and without access, the study suggested that video presentations used as supplemental materials may provide a good tool to create online courses which are as effective as the campus-based courses.

Video and Voice Calling. Video calling allows a visual communication between any two people in the world with stable and fast Internet connection. In particular, video conferencing". allows for more than two people to communicate simultaneously. Skype has popularized this type of visual communication and, in 2010, introduced a software that allows five people to participate in a video call.

On the other hand, voice calling is also described as "Voice-over IP" (VoIP). This tool is "a set of facilities used to manage delivery of voice information over the Internet" (Rouse, 2008, para.1). As a click-to-call technology, VoIP offers immediate voice connectivity in real time and can be used with any computer that is connected to the Internet through the Web browser. Phone number appears as hyperlink on the web page to which the browser is connected. The call is initiated by clicking on the hyperlink.

Video and voice calling are synchronous tools and enable students and teachers to communicate in real time in a virtual learning environment. These tools are most effective when used to support synchronous e-learning which is based on the personal participation of the learners. This personal participation consists of discussing less complex issues, planning some tasks, or just promoting social presence (Hrastinski, 2008).

Some studies showed positive perceptions of online learners about videoconferencing –which is about video and voice calling between a teacher and one or more learners –due to live interaction among online participants, the experience of social presence while learning, and the immediacy of feedbacks (Candarli & Yuksel, 2012; Gillies, 2008; Grant & Cheon, 2007). These studies and others though would also point out the shortcomings of videoconferencing which included technical and connectivity issues. When these occurred, online learners became isolated and felt no longer part of the class (Knipe & Lee, 2002), would have negative perceptions about the online learning process (Candarli & Yuksel, 2012), and viewed themselves as if they were unreal students (Gillies, 2008).

Instant Messaging (IM) and E-mails. One of the fastest-growing forms of communications, IM can be viewed as a text-based computer conference between two or more people. From the public online chat room of 1990s and 2000s, IM has evolved into what is now as a popular and cheaper way of conducting a text-based communication between users (Gil, 2012). With this IM communication service, two or more people can engage in a private chat in real time over the Internet. On the other hand, electronic mail or more popularly referred to as e-mail, is a method of exchanging digital messages from one to another or more recipients. Based on a store-and-forward model, email servers accept, forward, deliver, and store messages. An email may contain text, files, images, or other attachments.

Both IM and email system can either be asynchronous or synchronous tools of learning. When email users are both logged in and monitor their received messages as they want to establish social presence before embarking on a lesson task, the email is used synchronously. The same holds true for the IM users when both are online and expect immediate reply from each other. However, when an email or IM user logs in to communicate without expectation of immediate reply to another user who is not logged in, then the communication between the two is asynchronous. This communication occurs when students are faced with a complex learning issue and need time to reflect and resolve the complex issue at hand.

A good number of research studies about the impact of instant messaging and emails on online learning are now being undertaken. Nicholson (2002) reported positive experiences of student users of instant messaging that included easy communication with one another, strong sense of community of learners, and more ways of informal and social communication on class materials, school and common degree program. Also, Farmer (2003) found a heightened social presence and a growth of collaborative activities among distance learners using instant messaging. Still others reported the student use of instant messaging facilitated immediate feedback from teachers, improved academic performance of student IM users relative to that of students using emails, and increased class satisfaction (Jeong, 2007; Kuyath, Mickelson, & Winter, 2013). On the other hand, some disadvantages on the use of instant messaging have also been cited in these studies. Among others, Farmer (2003) enumerated these disadvantages like instant messaging has put more layers to the online learning environment, increased expectations among learners of unrestricted access to the instructor, and related issues of time and availability of the faculty.

Research has also shown the positive and negative impact of the use of emails on distance learning. On the positive side, Heinman (2008) revealed that distance learning program, based on regular email support, had students with positive perceptions of academic and social support, and with higher degree of satisfaction. In the course of three studies, Smith et al. (1999) found the use of email as a viable alternative means of course delivery. In the study of Debard and Guidara (1999), email, as a source of greater student interaction, can create a more active and engaged online learning. Other studies revealed that the use of email promotes cognitive growth on computer knowledge and skills (Yu & Yu, 2002), encourages authentic communication and creates new learning opportunities (Tao & Boulware, 2002), and allows more opportunities to ask instructors (Vonderwell, 2003). Other studies though reported negative impact of the use of emails on learning such as potential social negatives like user isolation, user depression and loneliness, and lack of belongingness to the community of learners (Woods & Keeler, 2001). Included also could be a rise of misunderstanding and conflict in the absence of a face-to-face meeting as well as one's easy accountability for what was typed in an email—because it is a written record—stays permanent (Block, 2002).

Social Networking Sites (SNSs). Boyd and Ellison (2007) have defined SNSs as web-based services that allow individuals to construct profiles, display user connections, and search and traverse within that list of connections. SNS encompasses all social media and computer-mediated communities like, for instance, Facebook, Twitter, LinkedIn, Pinterest, Google + and many others. These sites have used Internet tools—also described as social media technology that enables social behavior, through dialogue in a multiple-way discussion, to discover and share new information. Today, there is a growing perception that SNSs can also be used as a good support for online collaborative learning. Gross (2004) noted that students also use SNSs for online learning, and more meaningful and serious deliberations.

A good number of educational technology researchers lent support to the use of SNSs in online learning endeavors and emphasized the advantages of such use in K-12 formal learning setting (Barbour & Plough, 2009; Greenhow et al., 2009) and also in higher education (Veletsianos, 2011; Webb, 2009). Studies show that these SNSs contributed much to the promotion of interaction, collaboration, active participation, information and resource sharing among online learners (Mazman & Usluel, 2010). Also, the use of network sites has enhanced social presence and created a community of learners fully engaged in the interactive discussions of lessons (Brady et al., 2010; Lee & McLoughlin, 2010). Student users of these participatory technologies were given control of their own learning environment, shared knowledge through the network site tools (i.e. texting, voice and video media), and found better learning opportunities for enhancement of their educational performance (Al-Mukhaini & Al-Qayoudhi, 2014). Though in some studies, using these network sites for academic work in higher education may be fraught with potential risks which include, among others, lack of trust in peer feedback, ownership issues relative to public and collaborative spaces, and difficulty in adopting publicly available tools and protecting the anonymity of the students (Greenhow & Robella, 2009). As suggested by Madge et al. (2009), network sites are better used for informal rather than formal learning since majority of the participants in the study never used these network tools and believed that network sites have no place for academic endeavors.

Online Teaching and Learning in Mathematics

The constant innovation in information and communications technology has also required rethinking oZf the ways of teaching and learning online courses including applied mathematics. Such rethinking effort has transformed the teaching-learning process from a traditional, teacher-centered approach to a constructivist approach. There exists an ample literature about positive student outcomes of collaborative learning—a constructivist approach— as implemented in a face-to-face class (Johnson & Johnson, 1986; Totten, Sills, Digby, & Russ, 1991). However, today's challenge lies on building up research literature on the impact of constructivist approach in teaching and learning a course via a virtual learning environment (Brandon & Hollingshead, 1999). Paulus (2005) revealed that interaction is now increasingly viewed as a crucial component of successful online learning. Such interaction is greatly fostered in collaborative learning through asynchronous and synchronous discussions—both constructivist approaches where online teachers have assumed the role of facilitators, among others (Hege, 2011).

Student Context. Personal characteristics and background of students in technical vocational education such as job skills specialization, motivations, interest in mathematics, familiarity with ICT, and socio-economic status have bearing on mathematical learning and achievement (Zwart, 2000; Rose, 2012; ACCTE Issue, 2009; Michaelides et al., 2019; Kim et al., 2008; Kubiatko & Vlckova, 2010; Knapps & Woolverton, 2004; Persell, 1993; Sahinkayasi, 2008; Papanastasiou et al., 2003). According to Rose (2012), vocational students, who specialized in welding, were performing mathematical operations in analyzing work blueprints in an actual workplace. Zwart (2000) reported that the learning focus of students with job skills specialization is mastery of knowledge and skills in basic mathematics, not in higher mathematics.

Students' motivations and attitudes affect learning and performance in mathematics. Michaelides, et al (2019) reported that students—who have greater self-efficacy, interest in mathematics, and higher value on mathematics—achieved better mathematics outcomes but the relationships are oftentimes modest. In US, a project, which is a collaboration between mathematics teachers and career and technical education (CTE) teachers, was implemented successfully in order to address a large number of students who were poorly motivated and struggling to learn mathematics in the vocational schools or centers (ACTE Issue Brief, 2009). This was a production of a lesson plan with mathematics content made more explicit and consistent with how it is taught in core academic courses. In UK, vocational students have to expect more contexts to their chosen vocational study but to be ready as well to learn a variety of contexts for the duration of the study (Hodgen & Marks, 2013).

Described as digital natives, students borne in the 21st century have been raised in an environment home to ICT (Prensberg, 2005). Thus, they are familiar and comfortable with the use of ICT tools for various educational purposes. They are digital learners and can easily adapt to technological change (PPRC, 2010). Research has shown mixed results about the influence of familiarity with ICT—indicated by access to, use of, or self-confidence in ICT—on academic achievement. Some studies reported a significant positive relation between the frequency of ICT use and student achievement (Kim et al., 2008; Kubiatko & Vlckova, 2010) while others showed a negative or insignificant relationship between these two variables (Papanastasiou et al., 2003; Wittwer & Senbeil, 2008). Sahinkayasi (2008) found mostly negative and small associations between familiarity with ITC and mathematics achievement scores of all participating countries in PISA 2003. In another study, Internet and entertainment use, and software use had a negative impact on mathematics achievement but confidence on Internet tasks and ICT high level tasks had positive impact on mathematics achievement for the majority of the participating countries in PISA 2006 (Güzeller, 2014).

A significant number of students, enrolled in technical vocational education, came from low income groups (Foley, 2007). Partly due to their socio-economic status, these students, majority at 45 percent, chose "getting a job" as a motivation for enrolling in technical vocational courses. Other reasons included the following: gaining skills, upgrading of skills, or for personal use (Orbita & Esguerra, 2016). A socio-economic status has predicted mathematics achievement (Lidong et al., 2014; Hernandez, 2004). Lidong et al. (2014) found SES status, indicated by parents' educational attainment and family income, to have a significant negative relationship with the mathematics achievement of students at an American county public school (Hernandez, 2004). In general, studies have shown students with higher socio-economic status have higher probability of reaching higher levels of education and academic achievement (Knapps & Woolverton 2004; Persell, 1993).

Constructivism and Online Learning. The online collaborative learning through asynchronous and synchronous discussions, is anchored on the theory of constructivism. As a learning theory, constructivism proposes that learning is an active, contextualized process of constructing knowledge rather than acquiring it from the traditional teacher—the sage on the stage. The learner's mind is not an empty vessel to fill in but an active constructor of knowledge. Knowledge is constructed based on the learner's prior knowledge, personal experiences, and hypotheses of the environment. These hypotheses can be new ideas or experiences which are matched against existing knowledge, or tentative solutions to a problem. Such hypotheses are tested through social negotiation (Good & Brophy, 1994). Constructivism has broad implications for the teaching-learning process for this study. The teacher plays the role of a facilitator and the learner assumes greater responsibility of learning. It is rooted in cognitive psychology and biology, and emphasizes creation of knowledge while exploring the world.

The online collaborative learning is influenced to a greater extent by Vygotsky's theory of constructivism. Vygotsky (1978), the proponent of social constructivism, contends that a learner will have a deep conceptual understanding with the significant support of his knowledgeable peers or expert. Moreover, an individual's constructions of meanings are mediated by cultural experiences and interactions in the social settings (Scribner, 1985). According to Vygotsky, the gap between the learner's independent abilities and with social support is described as the Zone of Primal Development (ZPD). Elevating a learner's independent ability through this significant social support in this zone is then called as scaffolding. Social constructivism is a sum of its characteristics. These characteristics include: a) social interaction facilitates learning; b) real-world tasks increase learning; c) development occurs within the zone of development; and d) scaffolding provides temporary support until higher level is reached. These characteristics manifest themselves in a constructivist learning setting. In this setting, learning activities are varied, lessons are connected to the outside world and future work environment, and evaluation strategies focus more on the process than the product itself. Additionally, a teacher possesses qualities of empathy and support that would help facilitate students' learning and students have more opportunities to develop their reflective thinking and negotiation skills (Taylor, Fraser, & Fisher, 1997).

In synthesizing the empirical research on the effects of the social context when students learn using computer technology, Lou et al. (2001) found that, on the average, small group learning was significantly better than individual learning on student achievement and affective outcomes, and group task performance. In the study of Johnson et al. (1985, 1986), the social isolation present in individual learning with computer technology was not an issue among students learning in small collaborative groups and that students in small collaborative groups achieved better academic outcomes than students in the individual condition. But Schlechter (1991), who reviewed twenty studies comparing small group collaborative learning (i.e. with two or more students per computer on the same task in a face-to-face setting, or two or more students collaborating either synchronously or asynchronously on the same task electronically) and individual learning (i.e. with one computer per student, each working on his or her own task), found that there was no collective evidence to show the more effective type of learning. This inconsistency of the research results might suggest other differences in conditions for effective small group or individual learning. These characteristics might be learners' experiences with the computer, design characteristics of the computer program or group learning strategies such as whether collaborative learning strategies are employed for effective learning (Jackson, Fletcher, & Messer, 1988; Lou, Abrami, & D'Apollonia, 2001).

Asynchronous Discussion. A popular mode of conducting online learning is collaborative learning through asynchronous discussion (Andressen, 2009). Hiltz and Goldman (2005) defined asynchronous discussion as a kind of discussion used online where the information or messages being contributed by the involved parties do not occur at the same time or period. Participants work from the location of their choice and do not need to be online simultaneously. They contribute to the discussion within a restricted time span. Their contributions are written and delivered in an online discussion board on a web platform. The entries remain visible to others during the course of the discussion. This online learning approach, anchored on constructivism, must enhance learning of applied mathematics. As explained by Schiffer and Fosnot (1993), a student, using constructivist way of learning, needs to engage in the process of concept construction and active interpretation within a meaningful context in order to achieve mathematical understanding of a concept. Such process provides him time and opportunities to share his ideas with others, learn what he needs to know, and to negotiate with others a solution to a problem, anchored on a real-world situation. In an asynchronous discussion, learners are given ample time to share, reflect and learn, and to negotiate meanings on a mathematical problem.

In an online course in mathematics, collaborative learning through asynchronous discussion can be organized around a problem relating to any real-world situation. Jennings (2006) revealed that an online collaboration, anchored on a problem-based scenario, elicited maximum interaction as participants were fully engaged in the task of problem-solving, "sharing experiences and visibly contributing new knowledge" (p.105). In comparing between asynchronous and face-to-face discussions, Jonassen and Kwon (2001) found asynchronous discussion more suited to solving ill-structured problems based on real-world situations which do not have one correct outcome but multiple outcomes. Such discussion provided ample time and opportunities to students to reflect and perform the task. Besides, they furthered that the structure of asynchronous discussion was compatible with the process of problem-solving which included problem definition, orientation, and development of a solution.

Some reasons were offered to explain the attraction of asynchronous discussion to online learners. Hiltz and Goldman (2005b) explained that an online learner who had busy work and personal life found accommodation in this learning approach because he was not obliged to study in a fixed time and place and could attend to asynchronous discussions at his convenience. As concluded by Swan (2001), the satisfaction of an online learner was in direct proportion to the interaction in asynchronous discussion. But online collaboration also had its share of disadvantages. The desired learning outcomes were not always achieved (Lou, Abram, & Appolonia, 2001) and some online learners were not at ease with performing a given task in a collaborative manner (Bishop, 2002). Literature has also shown less participation or its absence existed in asynchronous discussion because of the difficulty to motivate online learners to contribute to the discussion with the desired frequency. The absence of non-verbal cues in a virtual environment, furthermore, did not help provide a clear communication of the expectation and requirements of online learning (Garrison, Anderson, & Archer, 2000).

Synchronous Discussion. It is another most common learning type in an online environment (Simonson, Smaldino, Albright , & Zvacek, 2012). It occurs when online learners participate in a discussion or attend a lesson presentation in real time or in a specific point in time. Any such discussion can be complemented with face-to-face meetings (Hrastinki, 2008). In her study, Litz (2007) showed that students, supported by chat service tools, were using synchronous discussion in a set of collaborative problem-exercises. This engagement was called "Virtual Math Teams (VMT) Chats" where 8th to 11th grade students, in a virtual learning environment, collaboratively solve geometry and algebra problems. Moreover, Hrastinki (2008) explained that synchronous discussion promotes social presence and sense of belongingness among learners, thereby, building a community of learners. Supported by the tools of synchronous discussion, these online learners and teachers can get immediate attention and quick answers on social as well as academic concerns. Moreover, Haythornthwaite and Kazmer (2002) contended that synchronous discussion helps resolve the problem of isolation because online learners feel themselves as participants of a group rather than as isolates who are just communicating with the computers.

The strengths of asynchronous discussion are the limitations of synchronous discussion. Working on complex tasks cannot be accommodated well by synchronous discussion because it does not provide ample time for understanding the complexity of the task and reflection on how it should be solved (Hranstiki, 2008). By its nature, synchronous discussion requires immediate response from all involved parties. Otherwise, the discussion becomes asynchronous. At the class level, synchronous discussion is not flexible as it requires participants to attend a session at a specific point in time—similar to a face-to-face session—but this time in a virtual learning environment.

Size of a Discussion Group. The literature has shown ongoing debates on whether a small group or a large group is the most conducive size for an asynchronous discussion. On one hand, advocates of small group size argued that the best collaborative learning takes place in a group of two to six students (Barkley, Cross, & Major, 2005) while others have suggested a maximum of five participants for a discussion group (Spokane Falls Community College, 2005). On the side of students as reported by Du, Durrington, and Mathews (2007), they expressed a preference of four to six students to constitute a discussion group. Fernandez (2007) proved in his study that an effective discussion group was composed of three learners. In a study on student interactivity with different group sizes in an online environment, Kim (2013) found that small-group discussion forums significantly fared better than large-group discussion forums in eliciting higher level of interactivity among students. He further concluded that a large online class should be sub-divided into smaller discussion groups for a high quality participation of students during discussion time. Moreover, Akcaoglu and Lee and (2016) reported students, who attended two graduate-level online courses, perceived a higher level of social presence in terms of sociability and group cohesion in small-group discussions than in whole class discussions. In another study on student perception of the effect of the size of discussion group on student learning, small discussion groups got the highest student satisfaction and were most effective in stimulating critical thinking. All-class discussions, on the other hand, were not favored by the student participants (Hamann, Wilson, & Pollack, 2010).

On the other hand, a number of studies have offered arguments for a larger group. Fisher, Thompson, and Silverberg (2015) recommended a group size of twenty-five students as an optimal size for asynchronous discussion. According to Orellana (2006), a highest level of interactions could be achieved if the ideal online class size was between 12 to 16 students. Also, a survey of online faculty and students revealed a preferred size of ten to fifteen students and that the smaller group size did not cater to diversity of viewpoints (Reonieri, 2006).

But some studies have shown that group sizes, no matter how large or small they are, created no difference on student outcomes. For instance, Bristol and Kyarsgaard (2012) compared between a larger group of 23 students and a smaller group of 12 students, and found no statistically significant difference on student outcomes for group size. The data though have suggested that a smaller group size helps students dig deeper into the content being explored.

Teacher's Online Roles. According to Andressen (2009), there exists an inherent difference between online teaching and classroom teaching. One should therefore expect some changes in the roles of a teacher as he delivers an online course and monitors asynchronous discussions. Morine-Dershime (1996) reported that facilitation has provided online learners a scaffold that enabled processing of greater complexity of information and a richer understanding of a complex problem. As more online courses have been offered in higher education, there is a growing perception of the primacy of the facilitative role of a teacher in this virtual learning environment (Liu, Bonk, Magjuha, Seung-hee, Lee, & Su, 2005). According to Bischoff (2000), the instructor's ability to facilitate significantly contributes to the effectiveness of learning and teaching in an online environment. Being a guide on the side should be the role of an instructor in leading a virtual learning community (Collison, Elbaum, Haavind, & Tinker, 2000).

The online roles of teaching are based on the dimensions of online instructor roles as proposed by Berge (1995) and expanded by other theorists. These would include the three dimensions: pedagogical role, social role, and managerial role.

Pedagogical role. An online instructor is a facilitator who helps students understand the content of the course (Berge, 1995). Towards this end, online instructors should engage students in knowledge-sharing and knowledge-building through interactive discussion, provide timely feedback , and should make referrals to outside resources or experts in the field (Ashton, Roberts, & Teles, 1999). Moreover, they are also called to facilitate development of metacognitive skills to enable online learners to become self-directed and well-motivated individuals. Through the years, however, the scope of this facilitative role has been expanded to ensure student understanding of the course and their critical thinking skills.

Social Role. Online learners must feel welcomed, comfortable, and a strong sense of belongingness to a learning community before they are expected to share and build knowledge with the group. The social role of an online instructor is to develop and maintain a learning community which is harmonious, cohesive, and has a collective identity (Berge,1995). To effectively assume the social role, an online instructor must possess some nurturing skills on fostering student engagement, providing feedback and rewards, and on addressing individual concerns. He is able to build with the online students an atmosphere of respect, tolerance, acceptance, warmth, and friendship. His social presence, therefore, is a model to what ought to be to achieve a learning community conducive to collaborative learning.

Managerial Role. An online instructor should perform a managerial role to establish order and provide educational experience in a learning community. Towards this end, he should structure well the content, manage effectively online discussions, communicate expectations and requirements, and lay down the rules at the start of the online course. Managing well an online environment is a support to the learning process because students would know what is expected of them, what to do, how to do, and when to make submissions to the teacher (Berge, 1995).

The literature has also clarified more the online teaching roles of management task, social presence, designing a course, and feedbacking. Collis and Nijhuis (2000) viewed management task of an online instructor as a task exclusive of any content-specific work. The challenges of such task, among others, include managing online communications, encouraging participation, managing workload, and managing online student behavior (Ko & Rossen, 2001). On the other hand, social presence is an important element necessary to achieve a successful collaboration (Garrison & Anderson, 2003). A learner needs to feel he belongs to a learning community before he is expected to share and discuss ideas with the group. An important role of an instructor therefore is to establish and nurture social presence between learners and to model social presence in the virtual learning environment. One study laid much emphasis on the other equally important online roles of a teacher like designing of the course, providing timely and high quality feedback, building social rapport, and organizing online learning activities (Liu, Bonk, Magjuha, Seung-hee, Lee, & Su, 2005).

Technology-Support for Online Collaborative Learning in Mathematics

Putz and Arnold (2001) observed that all concerned stakeholders are facing great challenges in the integration of flexible online learning technology into the educational system. While educators have viewed online learning positively and students can readily acquire the computer skills requirement of online learning, educational institutions have offered formal computer training to less than half of the students and only a little less than half of all teachers have sufficient skills to use the necessary technology for online collaborative learning (Thomas, 2002). Overall, practice in the use of technology for online collaborative learning did not match its theory.

Literature on computer-supported collaborative learning (CSCL) has shown that collaborative learning has positive impact on academic outcomes. However, these outcomes were limited to elementary and secondary schools. Most of them, according to Brandon and Hollingshead (1999), were situated on classroom-based environments, not on online environments. They furthered that such a dearth in research literature begets a question on how effective collaborative learning is on academic outcomes in a virtual learning environment. Thus, there is a need to build up existing research literature on online collaborative learning, let alone in the field of mathematics.

From available literature, however, one may glean from three studies about technology support in online collaborative learning. Litz (2007) made a study on finding the causes of low participation rate of high school students in the "Virtual Math Teams" (VMT) Program of the school. This program invited high school students to use chat service tools in order to solve online a set of mathematics problem exercises. Among others, she found that the intended users had difficulty understanding how to use the chat service tools of the VMT Program and that the users indicated there were not enough motivators to encourage them to join the Program. Moreover, two studies—both using design research method—were conducted to design a collaborative learning in an online setting. First, Wang (2013) designed an online learning environment that used internet-based tools to support learners' collaboration on course group assignments at the National Institute of Education in Singapore. After completing his two-stage design research, he concluded, among others, that the effective strategies for collaborative learning on course assignments were: a) using both asynchronous and synchronous tools to support the group interaction; b) the use of friendship to form small groups—each group consisting of four students; c) using meaningful and authentic tasks in the course assignments; and d) allowing groups to choose and use any of the social network sites (i.e., drop.1.0, Google Group, wiki, and Facebook) as a platform of group interaction and collaboration. Second, Smits, Voogt, and van den Akker (2013) conducted a design research on finding the right design principles—based on the criterion of usability— to transform four face-to-face Master Special Education needs to e-learning. The findings of their study resulted to the adoption of 14 design principles, grouped into four clusters: interaction between students, structure, teaching behavior, and learning materials. In particular, the interaction cluster showed the positive learning effect of collaborative learning through asynchronous discussion on the participants of the study as well as the positive affective outcomes of social interaction between participants. However, the use of synchronous office hours—when students can communicate with their teachers in real time—was discarded because of the differences in time availability between them and their teachers.

Social networking sites have been used for academic purposes in the formal learning context in K-12 (Barbour & Plogh, 2009) and in the higher education setting (Webb, 2009). They enabled the practice of constructivist pedagogies which addressed well the problems of traditional online learning: lack of social presence and participation in interactive discussion, and a weak sense of community-building. For instance, Veletsianos and Navarette (2012) showed a case study of learners' perspectives and experiences in an online course taught using ELgg online social network. They found that learners, because of the affordances of the social networking site, did benefit from positive learning experiences, mutual support, and enhancement of learning experiences. Also, the learners' use of the site was focused though on the course-related and graded activities, not on the other social uses of the site. Another study (de Villiers & Pretorius, 2013) used Facebook as an environment for collaborative learning on "Concepts and Principles of E-learning" at the University of South Africa for a postgraduate cohort. It revealed that Facebook provided a conducive learning environment that has fostered better interpersonal relationship between distance learners, independent research, effective peer learning, and a successful social negotiation. Still in another study (Mora-Soto, Sanchez-Segura, Medina-Dominguez, & Amescua, 2015), one social networking site, described as Microsoft SharePoint 2007, was shown as an enabler of group learning and collaborative work. The participants, divided into several working groups, were tasked to make a software system to manage a video club. Personal blogs were used by students in sharing experiences, email system in contacting their teachers, and the homepage of the social networking site was used as a forum for discussion. This study concluded that the social networking site facilitated the learning process and encouraged student collaboration.

But there has been issues raised against using SNSs as an educational platform. Selwyn (2009) likened the kind of learning that took place in Facebook interactions among undergraduates to just plain talking at the back row of the lecture hall. Also, in a list of potential issues arising from the use of social networking sites for higher education setting, Schroeder, Minocha, and Schneider (2010) cited, among others, the lack of confidence in peer feedback, ownership issues with regards to public and collaborative spaces, difficulty in adapting tools which are used by a large number of people, and difficulty in securing the anonymity of students. One study (Madge, Meek, Wellers, & Hooley, 2009) even suggested that SNSs might be more useful for the informal rather than formal learning as 91% of the student respondents did not use SNSs to communicate with the university staff, and 43% believed that SNSs have no potential for academic work.

Designing Online Learning Materials

Rovai (2002) stated that the course design – and not how the course is taught – is the determining factor in achieving better learning outcomes. Thus, an educator must be knowledgeable about the epistemology of learning. This is especially true for online learning, where instructors and learners are physically separated because of distance. Thus, the development of effective online materials should be grounded on proven and effective learning theories (Pange & Pange, 2011).

No one school of thought of learning can lay claim to be the only basis of designing effective online materials. There should be a combination of learning theories to address the design task (Anderson, 2008). Moreover, the learning strategies are selected to motivate the learner, facilitate deep processing, cater to individual differences, enhance meaningful learning, encourage collaborative study, provide relevant feedback, use contextual learning, and provide scaffolding during the learning process.

Upon scrutiny of the behaviorist, cognitivist, and constructivist schools of thought, one finds a multitude of overlaps in the ideas and principles of these schools of thought. The design of online learning materials can use the principles from all three schools of thought. Ertmer and Newby (1993) contended that the three schools of thought can, in fact, be used as a taxonomy for learning. Behaviorists' strategies can focus on the what (facts); cognitive strategies can elaborate on the how (processes and principles); and constructivist strategies can deal on the why (higher-level thinking that promotes personal meaning, and situated and contextual learning).

The behaviorists' strategies would aim at learning in terms of change of knowledge through controlled stimulus/response conditioning (Pavlov, 1927; Skinner, 1938). Applied to education, these strategies help a learner adopt knowledge from a teacher through the use of the learner's senses. Particularly, the teacher demonstrates factual knowledge or a skill, then observes, measures, and modifies behavioral change according to a desired outcome. This desired outcome is articulated in a behavioral objective, a competency-based standard or in a goal of skill development and training. In Bloom's Taxonomy, these behavioral objectives, also described as learning objectives, are categorized into six levels according to cognitive difficulty, from simpler to more complex forms. These include the following: knowledge, comprehension, application, analysis, synthesis, and evaluation (Bloom et al., 1956). Being hierarchical, the cognitive domain of Bloom's Taxonomy requires acquisition of prerequisite knowledge and skills at lower levels before one can move on to the next higher levels of cognitive difficulty. But some revisions were made in the cognitive domain to include changing the names in the six categories from noun to verb forms, rearranging the two highest levels, and creating processes and levels of knowledge matrix (Anderson et al., 2001). The revised taxonomy has the following categories: remembering, understanding, applying, evaluating, and creating.

The constructivist strategies lean more on Vygotsky's social constructivism which proposes that people work together to construct knowledge and have a deeper and newer way of understanding. These strategies would include contextualized approach to instruction that use concrete problems to launch the teaching learning process. The problem provides the introduction to the teaching-learning process and a trigger for the application of problem-solving skills as well as the study of information needed to understand further the problem and its resolution (Barrows & Tamblyn, 1980). This approach is viewed as problem based learning which is structuring a curriculum around a problem that serves as a trigger for interaction and learning (Boud & Feletti, 1997).

Of the cognitive theories, the cognitive theory of multimedia (Mayer, 2001) is a good basis for the selection and presentation of instructional materials. The cognitive theory of multimedia is founded on several other cognitive theories including Baddeley's model of working memory, Paivio's dual coding theory, and Sweller's theory of cognitive load. The multimedia theory, moreover, is made up of the following components such as: a) dual structure of visual and auditory channels; b) the limited capacity of each channel; c) the sensory, working, and long-term memory stores ; and d) cognitive processes of selecting, organizing, and integrating. In this theory, Mayer (2001, p. 47) states that "people learn deeply from words and pictures than from words alone". He furthered that the human mind does not conceive a multimedia presentation of words, pictures, and auditory information in a mutually exclusive manner but that the elements are selected and organized to make a meaningful and logical constructs or schema. Thus, the challenge is to use instructional media based on how the human brain works.

By far, multimedia research has shown mixed results on the impact of multimedia use on the learning process or has yet to provide an optimal integration of the multimedia elements within the multimedia system (Kuomi, 2003). On one hand, research literature is not found wanting on studies with significant results about the positive impact of multimedia use on learning (Najjar, 1998, 2001). On the other hand, the same literature offers a body of research that do not have significant results to warrant for the use of multimedia in the learning process (Hede, 2002).

Curriculum Development in Mathematics

The present literature has much to offer in terms of models and strategies for curriculum development. Some well-known models offered different approaches to curriculum development. Tyler's rational-linear approach (1949) has put much premium on a systematic design process, launched by clear and reasonable objectives. Walker's deliberative approach (1990) was to make a naturalistic model that mirrored the actual practice of curriculum development. Moreover, Eisner's artistic approach (1979) placed much importance in a more holistic approach to education where the teacher is the authority in the class and makes decisions about the curriculum based on his/her own vision and experience.

In many countries from east to west though, the curriculum development in mathematics veers towards the direction of a greater focus on problem solving and mathematical modeling. There is now a consensus among developers of mathematics curriculum that students should be provided with problem-solving experiences if they are to use and apply mathematical knowledge in meaningful ways. Through these experiences, students will gain a deeper understanding of mathematical ideas, become more engaged and interested in the learning process, and will appreciate the relevance and usefulness of mathematics in their present and future undertakings (Wu & Zhang, 2006).

The results of an early Third International Mathematics and Science Study (TIMSS) ushered in a lot of changes in the mathematics curriculum of Singapore.

Curriculum Development in Mathematics in Technical Vocational Education. In the past, mathematics in technical vocational education did not get its due attention from mathematics education researchers (Strasser, 2007). Learning mathematics was just an exercise of numeracy and literacy (Buckingham, 1998). Consequently, many technical vocational students failed to see the connections between mathematics and real world situations and, after finishing their courses, were unable to apply mathematical knowledge successfully in their workplaces (Pucel, 1992).

However, today's ongoing trend in curriculum development in mathematics in the technical vocational education is to put premium on connecting mathematics to the workplace and the new work order as well as the nature of the mathematical skills required in the modern workplaces, among others (Kent, Bakker, Hughes, & Noss, 2011). Towards this end, one approach being used in developing the curriculum in vocational and technical education is based on job analysis. This approach often employs techniques like expert judgments and group agreement to establish a list of mathematics skills needed for a specific job. It is so chosen to establish the mathematics requirement for the technical and vocational education (Pucel, 1992). Three kinds of job analysis are used to determine the mathematics requirements, namely: analysis of a specific job to find the mathematics skill requirements, analysis of occupational mathematics skills based on the requirements in an educational program, and identifying the general skills required of the occupations as a whole.

The recent publication of the Association for Career and Technical Education (ACTE; 2006), "Reinventing the American High School for the 21st century, would also exemplify the ongoing trend of the development of mathematics curriculum in the

Career Technical Education (CTE). This publication has shown the current state of curriculum integration between the academic and Career Technical Education (CTE) courses. In this integrated curriculum, CTE teachers will clearly integrate academic standards into their CTE courses and academic teachers should connect lessons to real-world context and use application from coursework that is more contextual (ACTE, 2006). Hernandez and Brendefur (2003) studied the effort of mathematics and CTE teachers in eight sites across the US as they developed the integrated mathematics formula. They found that the interdisciplinary teams of mathematics and vocational and technical education (VTE) teachers "can create high quality integrated curriculum units if certain conditions are met" (ACTE, 2006, p.17). Those conditions include support from the school's community, regular meeting of all team members, focused conversations toward student understanding, writing tasks that promote conceptual and integrated understanding of the concepts, and writing the unit together with reflective thought. But a study on the effectiveness of an integrated curriculum revealed no significant difference in mathematics performances between students of integrated curriculum and those of non-integrated curriculum (Pierce, 2013). Moreover, in Mustakim (2012), vocational technical students, taught in mathematics with context, obtained test scores no better than the test scores of another group taught in mathematics without context.

Development of Online Modules in Mathematics. Research literature has shown the drift of development of online mathematics modules towards the use of problem solving in launching the online learning process. For instance in the study of Wenner, Burn and Baer (2011), the Math You Need, When You Need It (TMYN) is a set of online learning modules that provides remediation on mathematical concepts in the context of geosciences. Each TMYN module puts a mathematical concept in multiple geoscience contexts, drawing from Harel's (1998) necessity principle—that students are actively engaged and learn deeply when certain mathematical skills or concepts are required to solve the problem at hand. Bailey (2000a) also posited that the learning approach of developing quantitative skills in context is helping students to succeed in geoscience courses. Each TMYN online learning module has a multimedia format and used asynchronous discussion, and just-in-time and necessity approach.

Another study has described the implementation of the same problem-solving activity in elementary mathematics in both online and face-to-face environments (Schwartz, 2001). The online version of the class consisted of modules—each module is to be accomplished by students using the asynchronous discussion within the space of one week. Moreover, a module would feature a problem-solving task to be performed each by various teams of the class. Each team, consisting of four to five persons, had their own discussion board which required the members of the team to post at least three different calendar days during the week. No whole class interaction was conducted until the second week when various teams were asked to post their strategies and deliberations on a whole class discussion board.

Jacobs (2005) investigated the use of interactive online visual tools for the learning of mathematics. In this study, online learning modules on differential equations were developed employing proven educational practices like the use of real-world examples, visualization, interactivity, constructivism, self-paced learning and self-paced testing. On top of these, the modules had innovative features that provided an effective learning of the course such as the use of interactive graphs, clear navigational structures, and animations. These graphs allow the users to interactively vary parameters which are accompanied by walkthroughs that break the mathematical content into manageable chunks. Then, there was a clearly labeled navigational structure that implies a linear order for each module while allowing users to jump forward or backward. Finally, animations had provided users with real world simulation that is an important conceptual bridge between reality and the graphs and equations of a standard mathematics course.

Design Research Approach in Curriculum Development

According to van den Akker (2010), problems of curricular development persistently manifests themselves in the gaps between the intended curriculum (expressed in policy rhetoric), the implemented curriculum (school realities and classroom practices), and the attained curriculum (learning experiences and outcomes). As an example of a gap problem, it is generally assumed that ICT has a high potential for improving education (intended curriculum) but research has yet to show a convincing evidence on positive impact of ICT on student outcomes (attained curriculum). A lot of curriculum reform efforts have been exerted to reduce these gaps but were found wanting. Three reasons were offered to explain the persistent gap problems. First, solutions, especially coming from government, were long in rhetoric but short on resources and action. Second, there is a lack of coherence between changes in the intended curriculum and other system components. Third, there is no timely and authentic involvement of all relevant stakeholders.

However, a bright spot in the reform horizon offers a blend of approaches to curriculum development that integrates various trends and characteristics of recent design and development approaches in the field of education and training (van den Akker, Branch, Gustafon, Nieeven, & Plomp, 1999). These characteristics include:

a) Pragmatism. No single perspective, overarching vision or socio-political group can resolve all the problems of curriculum development. The curriculum design and enactment, though, focus on the practical context and its users in resolving a particular curricular problem.

b) Professional development. A better integration of curriculum change and professional learning and development of all individuals and organizations involved will increase the prospect of a successful implementation of an educational intervention.

c) Communication. A communicative-relational style is used to accommodate the inevitable compromises between the stakeholders with various roles and interests and to obtain external consistency between all parties involved.

d) Successive approximation. A gradual, iterative approximation of an intervention is used to obtain an appropriate balance between the intended curriculum and educational outcomes.

As a research approach to curriculum development, the design research approach features many of the above characteristics like pragmatism, successive approximation and professional development. Additionally, it contributes to growth of knowledge in the form of design principles that provide heuristic advice to curriculum development teams (van den Akker, 1999). The gradual, iterative approximation of a curricular intervention would yield empirical evidence on the practicality and effectiveness of such intervention in real-world settings.

Still an emerging trend, design research as applied to curriculum development has a proliferation of terminology and a lack of consensus on definitions (Akker, 1999). Barab and Squire's broad definition (2004, p.1) though would encompass variations in the definition of educational design-based research when they stated:

> "Design-based research is not so much an approach as it is a series of approaches, with the intent of producing new theories, artifacts, and practices that account for potential impact learning and teaching in naturalistic setting."

Plomp (2013, p.15) defined it as a design and a development of interventions (such as programs, teaching-learning strategies and materials, products and solutions) to solve "a complex educational problem as well as to advance our knowledge about the characteristics of these interventions and the processes to design and develop them, or alternatively to design and develop educational interventions (about for example, learning processes, learning environments and the like) with the purpose to develop or validate theories." On the other hand, Mckenney and Reeves (2013) described it as a genre of research that uses the iterative process of developing a solution to a significant problem in educational practice and to contribute new knowledge that informs the work of others with a similar problem.

All of the above definitions and more, however, may have commonality in that they would yield two purposes of design research: first, to develop iteratively research-based solutions to complex problems in educational practice and, second, to develop or validate design theories. As further described by Mckenney and Reeves (2012), these two purposes are research on interventions and research through intervention. In short, educational design research is about studies of development and validation.

Practitioners of this genre of research though have used these two purposes simultaneously when, by trying to solve a problem in educational practice, they put knowledge to use and, through that process, generate new knowledge.

Characteristics of Curriculum Design Research. Even when design research lacks consensus on its definitions, one may draw an outline of a number of characteristics common to most design studies (Kelly, 2003; van den Akker, Gravemeijer, Mckenney, & Nieveen, 2006a). Taking up the first three common characteristics, design research is practical, interventionist, and collaborative. It is practical because it yields a usable outcome for improvement of educational practices and a theoretical outcome that informs the works of others whose research interests are similarly situated (Kelly, 2003). It becomes of greater use as it takes away the observed chasm between contemporary research and practice. As an interventionist, design research produces change which is its impact on a complex problem in practice. Such impact comes from a research-based solution—a best approximation of the ideal one—that effectively addresses a curricular problem in practice. Moreover, the whole undertaking of design research requires a partnership of experts who should work together to achieve the intended research goals. This group includes but not limited to the researcher, facilitators, subject matter specialist and an expert of the Information and Communication Technology.

Its last three common characteristics are: iterative, adaptive, and theory-oriented. Design research is iterative because it goes through a process—a cyclic one—of analysis, design and development, and evaluation and reflection. This process repeats until "an appropriate balance between the ideal ("the intended") and the realization has been achieved "(Plomp & Nieveen, 2013, p.17). Each time a cyclic process iterates, new empirical insights are obtained to become the basis of change or refinement of the practical and theoretical outcomes of design research. Design research is thus adaptive as these empirical insights are accommodated into its design strategies. Finally, it is theory-oriented because the design and development of the study are grounded on theories and its theoretical outcome--the design principles-- is used to broaden the scientific understanding (Mckenney & Reeves, 2013).

Process. No set process is followed in the conduct of educational design research (Bell, 2004). One may thus encounter in the literature a rich variation in the models and frameworks that guide the process of design research. After a survey of the various models for design research, Mckenney and Reeves (2013) built a generic model (see Figure 1) that presents only the core elements of the iterative process. Being done in a natural setting and yielding the dual outputs of knowledge and intervention, this process features three main phases: analysis/exploration, design/construction, and evaluation/reflection.

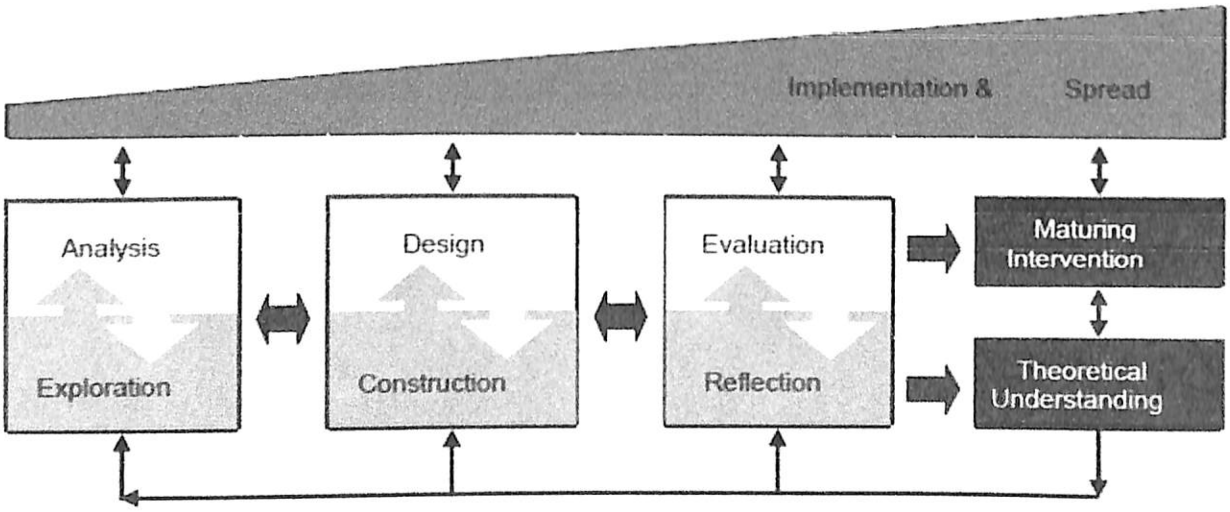


Figure 1. Generic model for conducting design research.

Plomp and Nieveen (2013) created another visual model (see Figure 2), cyclical in form but simplified, that still has 3 main stages: analysis, design and development of prototype and evaluation. Reeves (2006) portrayed the process of design research in four stages: problem analysis, solution development, iterative refinement, and reflection to produce design principles (see Figure 3). Barran-Ritland and Back (2008) showed a model (which they called as Integrated Learning Design-Framework) that has four main stages and 14 steps across those main stages in a continued approach to research and development. Moreover, Ejersbo, Frølunde, Hanghøj, Magnussen and Misfeldt (2008) put forward the Osmotic Model that shows two cycles this time—the design cycle and the research cycle where both would originate from one problem. These two cycles are presented as running simultaneously and parallel to each other. Different from the earlier process-oriented models, the model of Mckenney, van den Akker, and Nieveen (2006) is more conceptually-oriented as it shows principles to guide a research and development cycle in context and to yield the three main outcomes: the designed intervention, design principles, and professional development of the participants.

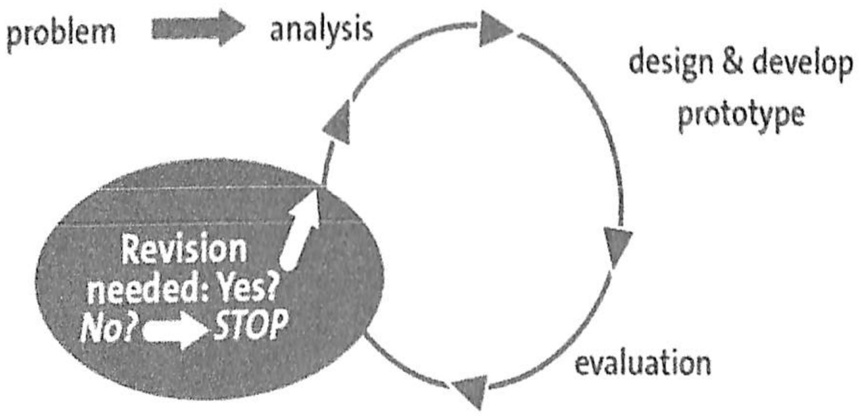


Figure 2. Iterations of systematic design cycle.

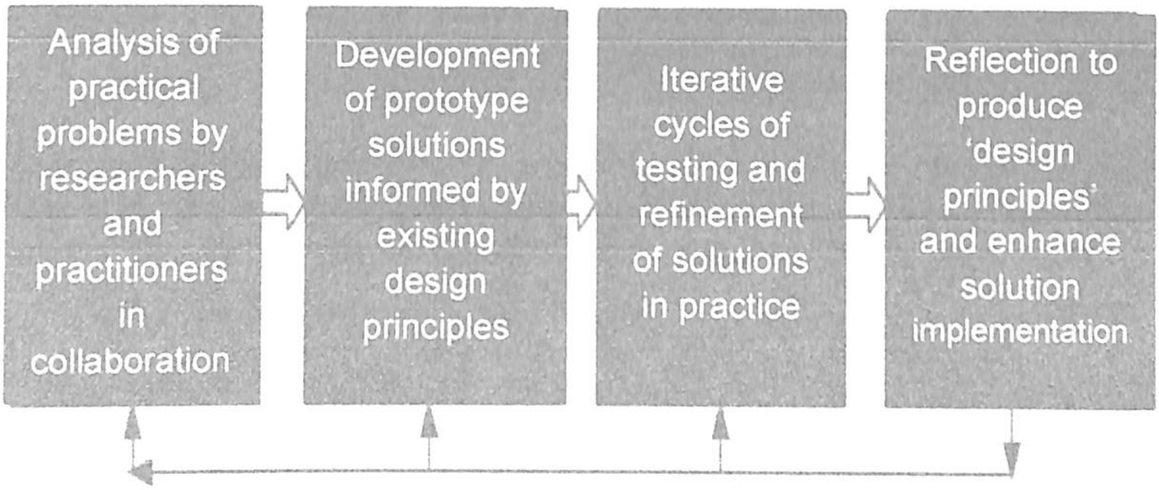


Figure 3. Refinement of problems, solutions, methods, and design principles.

All of the above models clearly show rich variation of details in their respective processes but their authors did agree that there exists commonality of phases found in the models. These include the preliminary phase, the design, and the assessment phase. The preliminary phase consists of needs and context analysis, and development of a conceptual or theoretical framework of the study. The second one is an iterative design phase, where each iteration from a series is a micro-cycle research. The most important research activity in this phase is the formative evaluation which will inform the improvement or refinement of an intervention. The last phase is a summative evaluation to make a conclusion whether the solution or intervention fulfills the pre-determined specifications. However, it becomes a semi-summative evaluation because, more often than not, this phase results in recommendations for improvement of the intervention.

Outputs of Curriculum Design Research. In most design studies, design research yields two major outputs: the theoretical and practical outputs. The theoretical output comes from the effort of making explicit the implicit decisions associated with a design process and transforming them into a set of guidelines on how to solve a complex problem in practice (Edelson , 2006; Barab& Squire, 2004). van den Akker (1999), Reeve (2006) and Wademan (2005) used the concept of design principles to refer to the theoretical output of design research, where others spoke of new theories (Barab & Squire, 2003). The practical output of the design research is the research-based solution which, in the curriculum domain, consists of curricular products or programs that would effectively address complex problem in practice. Aside from these two outputs, Mckenney, Nieveen and van den Akker (2006) presented a third output: the professional development of participants.

Design Principles and Curricular Products. The knowledge claim of design research in the curricular domain has a lot of descriptors that include: design principles (Linn, Davis & Bell, 2004; van den Akker, 1999), domain theories (Edelson, 2002), heuristics (Design-based research Collective, 2003) or lessons learned (Vanderbilt, 1997). While the knowledge claim has many descriptors, it has a common format as developed by van den Akker. This is thus expressed as:

> "If you want to design <intervention X> for the <purpose/function Y> in <context Z>, then you are best to advised to give <that intervention> the <characteristics A, B, and C>[substantive emphasis], and to do that via <procedures K,L, and M> [procedural emphasis], because of <arguments P,Q, and R>" (van den Akker, 1999, p.5).

These heuristic principles help in the selection and application of the most appropriate knowledge for specific intervention and development task. This most appropriate knowledge consists of procedural knowledge and substantive knowledge.

Procedural knowledge is the set of activities that contribute to the development of a most effective and usable intervention. This set constitutes the design principles of the design research. On the other hand, substantive knowledge comes from the essential characteristics of an intervention and can be extracted partly from the resulting intervention itself. In the curriculum domain, these essential characteristics are distilled from the curricular products or programs. These curricular products may include the following: manifestations of the written curriculum (e.g. national syllabus, teacher's guide or learner's guide); classroom materials (e.g. instructional booklets or software); and professional development aids (e.g. online environments for teacher communities).

Professional Development of Participants. The professional development of participants occurs when the research methods are creatively and carefully designed. For instance, well-structured and documented interviews, walkthroughs, discussions, observations and logbooks could stimulate dialogue, reflection or engagements among participants. Indeed, there is a natural synergy between curriculum development and teacher development and enhancing this natural synergy would generate more fruitful researches and development opportunities among participants.

A Note on Generalizability in Curriculum Design Research. All researchers strive for generalizability of findings of their studies—that is, extending the research results beyond the context of the study for use of others. Generalizabiltiy, though, means different things to different researchers. It is analytic generalizability from the standpoint of a practitioner of design research. According to Yin (1994, p.36), analytic generalizability is a process through which "the investigator is striving to generalize a particular set of results to a broader theory" which can be of use to others. This means that findings from design research can be replicated in more cases in various contexts with the goal of obtaining same results. Once these replications do occur, the results might hold for a larger number of similar contexts even though no further replications have been performed. Firestone (1993) termed this as case-to-case generalization as when a person in one setting adopts an intervention and its design principles in another setting. This is likened to an experiment where an experimental scientist would generalize from one experiment to another one. Thus, the knowledge producer—the practitioner—is obligated to write his work well enough so that others who want to adopt his work can read and understand well such work. He must describe well the characteristics of the intervention, the design principles of the study, and the context where the study is conducted. A well-written and detailed process can inform well the work of others.

Curriculum Design Research Studies on Online Learning and Mathematics Education. Wang (2013) developed an online learning environment based on an Information and Communication Technology (ICT) tool in order to support students' collaboration in completing their course group assignment—to design ICT-based learning package in the form of a website or a PowerPoint slide in a period of six weeks—at the National Institute of Education in Singapore. In the analysis phase of the study, a set of design strategies was formulated based on the review of related literature in order to solve a complex problem in practice—that is, how to coordinate and monitor the collaborative learning of students in an online environment. These design strategies or theories were: use of DriveHQ as an ICT tool, progress report of students, friendship as the basis of finding one's pair, meaningful learning task, pair work, and product versions. The study concluded yielding two outputs: the intervention itself—the online delivery of designing ICT-based learning package through students' collaboration—and the design principles of the study. These design principles, refined after two iterations, included two revisions—bigger group size of four members in lieu of a pair and additional ICT tools like Google group, Wiki, and Facebook groups—and retention of the remaining strategies (e.g. progress reports, friendship, meaningful learning task and product versions).

In another design research study, Oh (2011) dealt on how to optimize collaborative group work and student learning in an online higher education learning environment. The study, a two-year design project, used what Boote and Beile (2005, p.10) called the "compilation of research articles" format for dissertation. It consists of one published article, three submitted papers, one detailed methodology chapter, and one detailed results chapter. Oh (2011) has applied mixed methods across several semester-length iterations of an online course to yield thirty distinct design principles—the theoretical output of the study—and an online course design for a graduate level course based on authentic task and student collaborative work—the practical output.

Stephen and Cobb (2013) launched a design research study to create an intervention—a stable instructional unit for integer addition and subtraction to help middle grade students (12-14 year olds) learn the topic meaningfully. The iterative process of the study yielded three outcomes: a stable instructional theory for integer addition and subtraction, a strong instructional sequence of the topic, and the professional development of team members who conducted the study. Furthermore, Doorman et al. (2013) designed a technology-rich learning arrangement to help students perceive that the two views—operational and structural—are facets of the same mathematical concept. After three iterations, the study yielded two outcomes: the practical output consisting of the technology-rich learning arrangement and the theoretical output that guides the design of the study.

While there is an ample information about the theory and practice of online learning, the literature on online cooperative and collaborative learning is lacking (Stoerger, 2008). Also, research studies revealed that collaborative learning can be "effective in generating positive academic and affective outcomes" but these outcomes were limited to elementary and secondary students in a traditional classroom setting (Brandon & Hollingshead, 1999, p.110). Naturally, a question arises about how well the effectiveness of collaborative learning be carried over to an online setting and in a technical vocational setting. Addressing this question will not only build up the literature on online collaborative learning but can also inform decisions on widening access to online courses based on collaborative learning. This is not to mention that "the demand for distance learning in public schools, higher education and especially the corporate sector is on the rise" (Graham & Misanchuk, 2004, p.181). Thus, the study wants to contribute to this limited body of knowledge as it aims to design technology-enhanced online modules in practical mathematics for senior high school students enrolled in the technical vocational track. These students are viewed as those who prefer the practical vocations of life and are likely to join the labor force right after their senior high school graduation. Based on the K to 12 technical vocational curriculum, they will need to undergo instruction of mathematics for 80 hours (Ocampo, 2014) but an alternative curriculum, proposed by Don Bosco Schools—a leading technical vocational school in the Philippines—has suggested a 40-hour instruction of what they termed as practical mathematics (Inocencio, 2014).

Conceptual Framework

Figure 4 shows the conceptual framework of developing technology-mediated learning modules in practical mathematics using design research. The variables in the framework include the following: performance in practical mathematics, student context, online learning approach, online roles of teaching, technology tools used, and presentation of the learning modules.

The student context is based on the personal characteristics and background of the student participants. These include the job skills specialization, motivation and interest in mathematics, familiarity with ICT, and economic status. Students who intend to specialize in welding and many other technical vocational skills are required to master basic mathematics skills like the four fundamental operations, conversions of units, calculations on algebraic expressions, and computations of ratios and percentages. The focus of mathematics curriculum in technical vocational education should be the basic content of mathematics, not its higher content (Zwart, 2000; Rose, 2012). Student motivation and interest in mathematics are better addressed by online learning with problem-based tasks contextualized in real-world settings. These problem-based tasks with a variety of vocational contexts have been found useful for US vocational students with poor motivations to learn mathematics (ACTE Issue Brief, 2009), and are embedded in UK vocational curriculum (Hodgen & Marks, 2013). Students borne in the 21st century have been described as digital natives, being raised in an environment surrounded by ICT (Prensberg, 2005). Thus, technical vocational students of the 21st century are expected to be comfortable and familiar with the use of ICT tools like the Internet-based tools. The challenge of these students, however, is the continued access to Internet when engaged in an online study since many of them came from low-income groups (Foley, 2007). Any online course in mathematics extended to these students should take into consideration their economic status.

The online learning approach in the conceptual framework of the study is anchored on the constructivist perspectives. It approaches learning along the lines of social constructivism in that a learner constructs knowledge through the process of social interaction with others. Vygotsky (1978), the proponent of social constructivism, contends that a learner will have a deep conceptual understanding with the significant support of his knowledgeable peers or expert. Hence, knowledge construction is a shared rather than an individual experience. In the conceptual framework of the study, the first selected design principle, which is collaborative learning through asynchronous and synchronous discussions, follows from Vygotsky's belief that the nature of learning is active and collaborative. The learners of the study were divided into small discussion groups, each of size four. As another design principle of the study, this small group size enhances group work and discussion, and is best conducive for collaborative learning (Barkley, Cross & Major, 2005; Du, Durrington & Mathews, 2007; Fernandez, 2007). In each discussion group, the learners negotiated meanings, share ideas and experiences, reflect on what were shared, and make decisions. What they constructed in the process were mediated by their cultural experiences and interactions in the social settings (Colle, 1990).

To maximize interactions in a group, collaborative learning was organized around a problem-based task, ill-structured and with multiple outcomes or contextualized in a real-world setting. As a design principle, this task is an authentic one and comes from real-world situations in order to provoke communications and collaborative learning (Jennings, 2006). From the constructivist perspective, authentic problem-based tasks facilitate the transfer of skills and knowledge. Such a task starts the learning process and triggers the application of problem-solving skills as well as the study of information needed to understand further the problem and its resolution (Barrows & Tamblyn, 1980). The needed information consists of knowledge and skills from the lesson of the module which is yet to be taken up by the learners. The understanding of these knowledge and skills comes from the video streaming of a teacher who presents and explains the lesson of the module (Wilson & Weiser, 2001).

In a learning module of the study, a whole class discussion was provided in which any small group could present their output on the discussion board with the purpose of helping other small groups, especially those struggling in performing the problem-based task. Whole class discussion was found to be a factor in students' interactions in online courses (Hewitt & Brett, 2017). A number of studies has shown recommended group size of 25 students as an optimal size for asynchronous discussion (Fisher, Thompson & Silverberg, 2015) and preferred group sizes of 10 to 15 students to have greater diversity and number of viewpoints (Reonieri, 2006).

Bruner's constructivist theory (1966) showed that learning is an active process in which learners construct new ideas based upon current or past knowledge. In other words, the new information is always linked to prior knowledge. In the conceptual framework of the study, collaborative learning within a group involved sharing of what learners know and what they need to know in the course of analyzing the problem-based task. The introductory part of the learning module communicates the needed prior or past knowledge which combines with the new information to write a successful mathematical justification to the problem-based task.

The zone of proximal development, Vygotsky's dominant theme, showed a zone in between what a learner can achieve independently and what he may achieve with support. Bruner (1966), like Vygotsky, also placed much emphasis on the social nature of learning, stating that other people, the more knowledgeable peers or the teacher, should help a learner construct knowledge or develop skills through scaffolding. Such support or scaffolding may come from the more experienced peers or the teacher. In the conceptual framework of the study, the online teacher should thus be a facilitator and a guide on the side rather than a sage on the stage. Not only as a facilitator, he should also assume the other effective online teaching roles, as proposed by Berge (1995). These include the following: pedagogic role, social role, and managerial role. Berge (1995) posited that the assumption of these roles will help an online teacher become a better guide of students, more socially present in the online learning environment, a timely feedback giver, an effective manager, and a course designer.

Collaborative learning through asynchronous and synchronous discussions, mediated by technology, can enhance peer interaction and encourage group work. It further facilitates sharing and distributing of knowledge and expertise among community members (Lipponen, 2002).

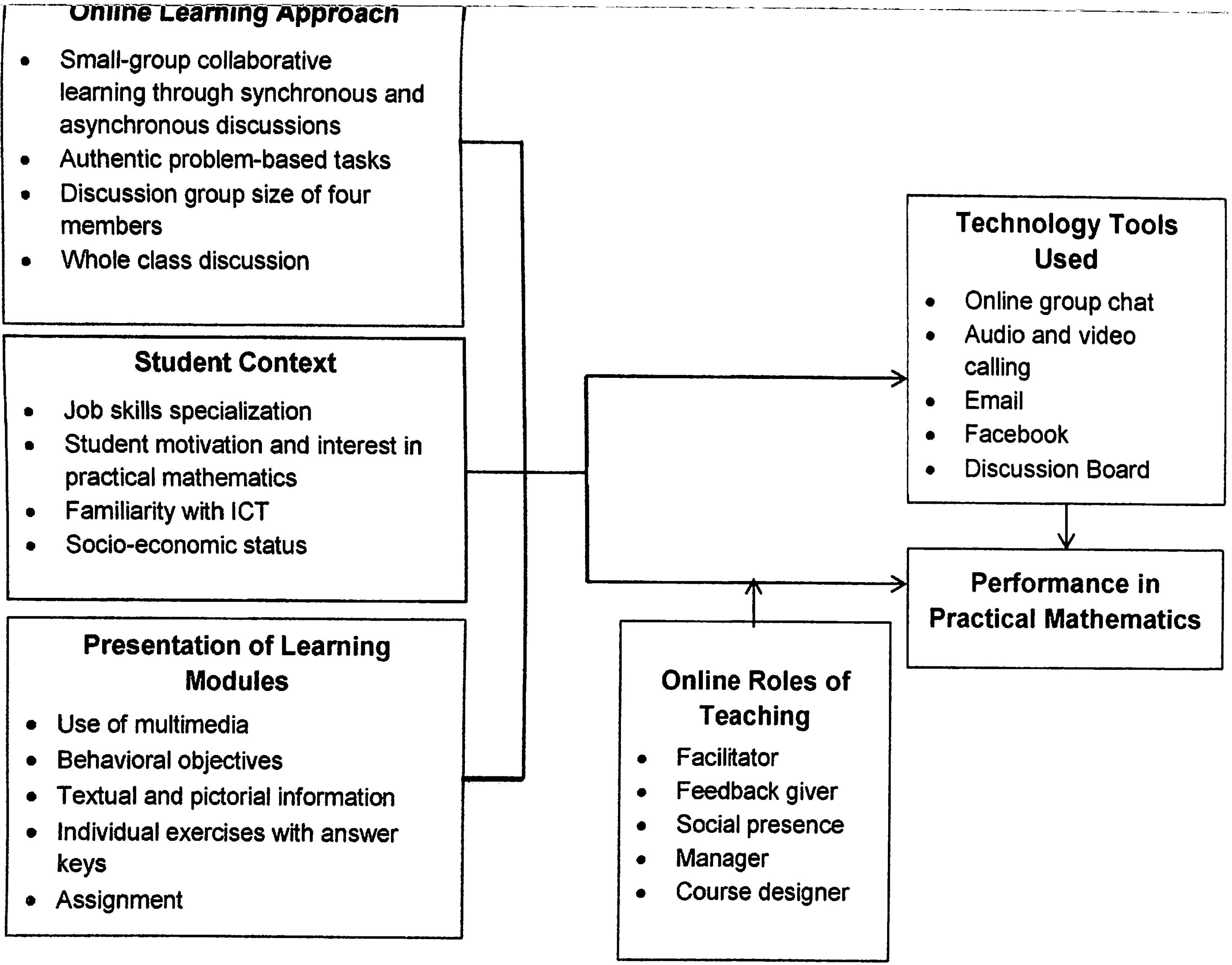


Figure 4. The conceptual framework of the study.

In this framework, the technology tools used in the study consist of a social network site and Interne-based tools. The online site of the study is a social network site which is a good support for collaborative learning, and serious deliberations (Gross, 2004; Mazman & Usluel, 2010). The asynchronous and synchronous discussions are supported by technology, consisting of the Internet and Internet-based tools. Specifically, these tools are e-mails, discussion boards, video and voice calling, video streaming, instant messaging (IM), uploading and downloading functions. The continuing innovations in the information technology have resulted to better technology tools which increase interactivity, convenience and access to resources in the teaching and learning of mathematics and in the online environment.

The cognitive theory of multimedia (Mayer, 2001) and cognitive load theory (Sweller & Chandler, 1991) have been applied in the presentation of the learning modules. The first theory states that readers will understand a material better when it is presented in words and pictures than in words only. They will not perceive words and pictures in mutually exclusive fashion but rather in a more meaningful and logical sense. Furthermore, in the latter theory, an extraneous load—how information is presented to the learners—may come in two forms: either in verbal or spatial form. Between the two forms, the spatial form reduces the extraneous load, thus enabling the limited cognitive resource to process the intrinsic load and germane load. The intrinsic cognitive load is the inherent difficulty in a specific instructional topic and the germane cognitive load consists of the processing, construction and automation of schema. Using the multimedia theory and cognitive load theory, the learning module of the conceptual framework does not only contain textual and pictorial information but also video information on the lesson of the day. The multimedia presentation of the lesson is very helpful in student construction of knowledge and in enhancing a constructivist learning environment (Neo & Neo, 2003).

A learning module in the framework of the study has a set of learning objectives, based on the cognitive domain of Bloom's Taxonomy. Such domain caters to the acquisition of knowledge and the development of intellectual skills (Bloom et al., 1956). Being hierarchical, this domain consists of six levels, from the simplest to the most complex. This implies that going to the next higher level requires having mastered the prerequisite knowledge and skills at the lower levels. In this study, a set of learning objectives, in hierarchical order, serves as goals of the learning process, which learners have to pursue and achieve after studying a learning module.

In this conceptual framework, the dependent variable is the test outcome in practical mathematics and the independent variables are student context, online learning approach, and presentation of the online learning modules. Student participants—who have mastered the skills and knowledge in basic mathematic, exposed to the vocational contexts of their chosen specialization, familiar with Internet-based tools, and are motivated to study mathematics—are likely to perform better in the practical mathematics test. With the use of online learning approach and presentation of online learning modules, they are also expected to achieve the same student outcome. The mediator variable of the study is the use of technology tools of the study. In the absence of these technology tools, online learning in practical mathematics is not possible. The moderator variable of the study is the assumption of online roles of teaching. How effective the assumption of these roles by the teacher will either weaken or strengthen the relationship between the independent variables and dependent variable of the study.

Assumptions of the Conceptual Framework of the Study

Learning is interactive, building on the prior knowledge. What a learner knows are based on his/her experiences and personal interpretation of the world. He/she learns through his/her interaction with others in the social setting. Thus, learners work primarily in groups. In a group, they negotiate meanings, share multiple perspectives and form a consensus through collaborative learning.

Teachers dialogue with students to help them construct knowledge. Their basic role is to facilitate the learning process of knowledge sharing and knowledge construction. They guide and motivate group discussions towards finding a common solution to the problem-based task of a group. Such task is contextualized and rooted in the real-world settings.

The process is as important as the product. What occurs in the process—viewpoints, observations, student works, formative assessments and others—should matter in the evaluation and reflection of student learning. Moreover, student participants of the study will provide truthful responses, opinions, and observations because of the assurance of confidentiality of the gathered data.

Since participation in the study is voluntary and can be withdrawn anytime, quitting of student participants will affect validity of the results of the study. A larger sample provides greater validity of the research results. Student participants will use the learning modules for the purpose of determining their effectiveness and usability and not for any other purposes (i.e. to be recognized or to get higher grades).

Hypotheses of the Study

This study would like to test the hypothesis on how well do the technology-mediated learning modules in practical mathematics facilitate the learning of practical mathematics concepts among technical vocational track students.

The alternative hypothesis for testing is stated as:

Ha_1 There is a significant difference in the evaluation mean scores between the first iteration group and the second iteration group.

This study would like to test second hypothesis that the design research group—the experimental group—and the comparison group have same level of knowledge in practical mathematics before trying out the learning modules in the second iteration.

The alternative hypothesis for testing is thus stated as:

Ha_2 : There is a significant difference in the pretest scores between the design research group and the comparison group.

Furthermore, this study would like to test third hypothesis on how beneficial the design research approach is in the development of the technology-mediated modules in practical mathematics compared to the traditional curriculum development approach of a private-sectarian college.

The alternative hypothesis for testing is thus stated as:

Ha_3 : There is a significant difference in the gain scores between the design research group and the comparison group.

Definition of Terms

In this study, the important terms were defined as follows:

Design Research. It is an iterative process being done in a natural setting in order to best approximate the design principles of the study and the technology-enhanced online learning modules in applied mathematics. This process features three main stages: analysis/exploration, design/construction, and evaluation/reflection.

Practical Mathematics. This is a mathematics course for technical vocational students enrolled in the technical vocational course described as "Shielded Metal Arc Welding" (SMAW) NC II. This course covers the unit of competencies in performing industry calculations. The unit has four topics on how to perform the following: a) the four fundamental operations; b) conversion of units; c) calculations on algebraic expressions; and d) computations of ratio and percentage. As bases of assessment, the course has nine performance criteria from simple calculations involving whole numbers, mixed numbers, fraction and decimal using the four fundamental operations to computation of ratio and proportion using the appropriate formula (see Appendix A).

Technical Vocational Education. It refers to those features of the education process that impart practical skills, attitudes, and knowledge to the students for gainful work—formal employment or self-employment—in the various sectors of the society. Towards this end, it has offered an array of courses, relatively shorter and with more focused training. The technical vocational track of the K to12 curriculum is one feature of this technical vocational education which aims at equipping senior high school students of this track with practical skills and knowledge for immediate gainful employment after graduation.

Performance in Practical Mathematics. As the dependent variable, it is a test-based performance in practical mathematics that covers the following competencies: a) the four fundamental operations; b) conversion of units; c) calculations on algebraic expressions; and d) computations of ratio and percentage. It indicates the participants' gain in knowledge and skills after trying out the seven learning modules in practical mathematics. Operationally defined, it is measured as gain scores of participants taken from the differences in scores between the practical mathematics pretest and posttest.

Student Context. As an independent variable, it consists of the personal characteristics and background of the student participants. These include job skills specialization, student motivation and interest in mathematics, familiarity with the ICT, and economic status. Each has the following indicators:

a) Job skills specialization consists of various job skills courses enrolled by the student participants in the technical vocational institute and technical vocational track of the senior high school of a private sectarian college.

b) Student motivation is measured by the reasons for enrolling in a job skills course.

c) Interest in mathematics consists of responses including yes, no, or indifferent to whether they like to study mathematics.

d) Familiarity with the ICT is based on the observations of the researcher acting as the facilitator and class observer on the use of Internet-based tools by the student participants.

e) Socio-economic status is indicated by the occupation of the breadwinner of the family of each student participant.

Online Learning Approach. As another independent variable, it is a cluster of design principles of the study which include small-group collaborative learning using synchronous and asynchronous discussions, authentic problem-based tasks, discussion group size of four, and whole class discussion. In the evaluation rubric, each design principle is a sub-criterion, scored ranging from one to four with the following descriptive ratings: 1- poor, 2 – fair, 3 – good, and 4 – excellent. In the observation guide, each design principle has a group of observation items in which each item has four various levels of observation with descriptors: 1 – not observed, 2 – not so evident, 3 – evident, and 4 – highly evident. In the interview protocol, each design principle is indicated by a group of predetermined questions, mostly open-ended ones. The theme, based on the response of the majority, is used to characterize each design principle of this variable.

Presentation of Learning Modules. As another independent variable, it is a set of design principles which include use of multimedia, behavioral objectives, textual and pictorial information, individual exercises with answer keys, and assignments with solutions. In the evaluation rubric, these design principles have indicators with the following scores and ratings: 1- poor, 2 – fair, 3 – good, and 4 – excellent. In the observation guide, each design principle has a group of observation items in which each item has four various levels of observation with descriptors: 1 – not observed, 2 – not so evident, 3 – evident, and 4 – highly evident. In the interview protocol, each design principle is indicated by a group of predetermined questions, mostly open-ended ones. The theme, based on the response of the majority, is used to characterize each design principle of this variable.

Online Roles of Teaching. As a moderator variable, it is a set of five online roles of teaching to facilitate online instruction of practical mathematics which include roles of a facilitator, feedback giver, course designer, classroom manager, and social presence. In the evaluation rubric, each role has a group of indicators with the following scores and ratings: 1 – poor, 2 – fair, 3 – good, and 4 – excellent. In the observation guide, each role is indicated by a group of observation items, each with the following levels of observation and descriptors: 1 – not observed, 2 – not so evident, 3 – evident, and 4 – highly evident. In the interview protocol, themes have been used to characterize these online roles of teaching.

Technology Tools Used. As a mediator variable, it consists of various Internet-based tools used to support online asynchronous and synchronous discussions of the study. It consists of emails and discussion boards, audio/video calling and online group chat, and use of Facebook. In the evaluation rubric, these tools have indicators with the following scores and ratings: 1 – poor, 2 – fair, 3 – good, and 4 – excellent. In the observation guide, these tools are measured by observation items, with the following levels and descriptors: 1 – not observed, 2 – not so evident, 3 – evident, and 4 – highly evident. In the interview protocol, themes have been used to characterize these Internet-based tools.

Chapter 3

METHODOLOGY

This chapter describes the research design, participants of the study, the technology-mediated learning modules, and the data collection procedure and analysis employed in the study.

Research Design

The research design of the study was anchored on the design research model of Mckenney and Reeves (2013) since this study focused on the design and development of technology-mediated learning modules in practical mathematics wherein research is embedded in the development process. Figure 5 shows the design research model of Mckenney and Reeves.

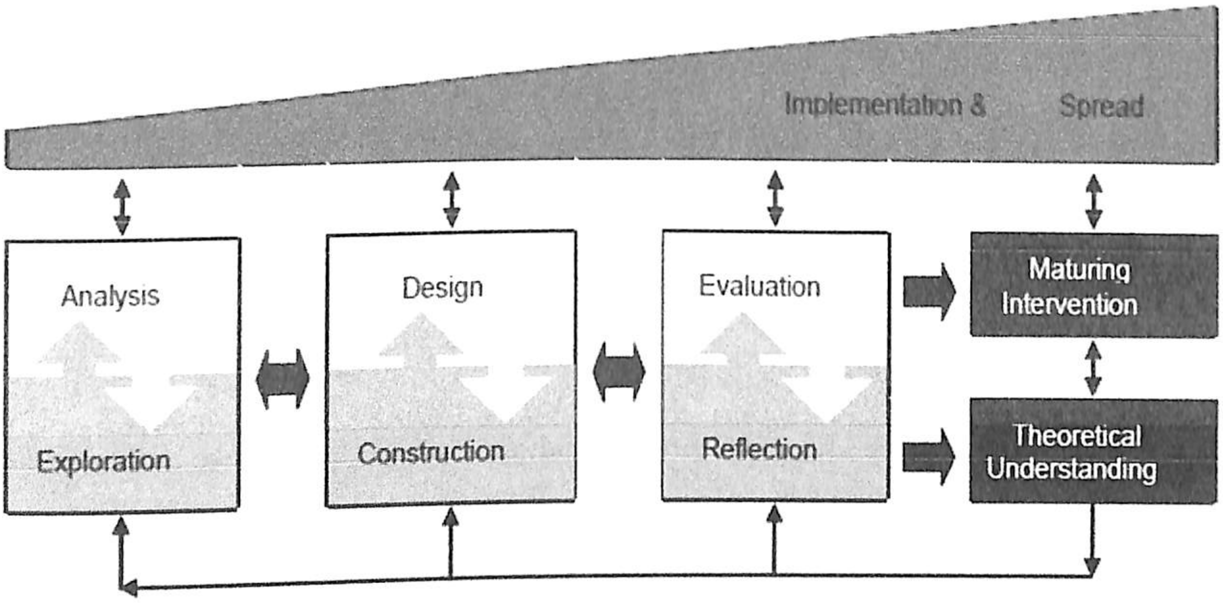


Figure 5. Design research model of Mckenney and Reeves (2013).

This iteration model consisted of three phases: the analysis and exploration phase, design and construction phase, and evaluation and reflection phase. The implementation of the three phases culminated into two outputs: the maturing intervention and theoretical understanding.

Based on the design research model above, the research and development process of the study (see Figure 6), referred to as an iteration, started with analysis and exploration. This initial phase involved analysis of the problem and its context, and a review of literature on developing technology-mediated learning modules in practical mathematics. The outcome of the initial phase informed the tasks of the next phase which is design and construction. The design task consisted of finding the appropriate design principles from the review of literature and the setting up of the conceptual framework which involved tying up theories as bases for developing technology-mediated learning modules. Second, the construction task required the development of a tentative set of three technology-mediated learning modules in practical mathematics with the design principles associated with the effectiveness and usability of these modules. The outcome of the second phase constituted the subject of the implementation of the study. Such implementation capped with evaluation and reflection, the third phase of the iteration. In the second iteration implementation, a pretest was administered before the implementation and a posttest after it.

In the first iteration implementation, a cohort of student participants used the three modules, and the data were collected from the participants, class observer, and the researcher through semi-structured interviews, evaluations, and observations. The data were analyzed and the results evaluated and reflected. The outcome of the first iteration then informed the tasks of redesigning and reconstructing these modules and their associated set of design principles in the second iteration of the study.

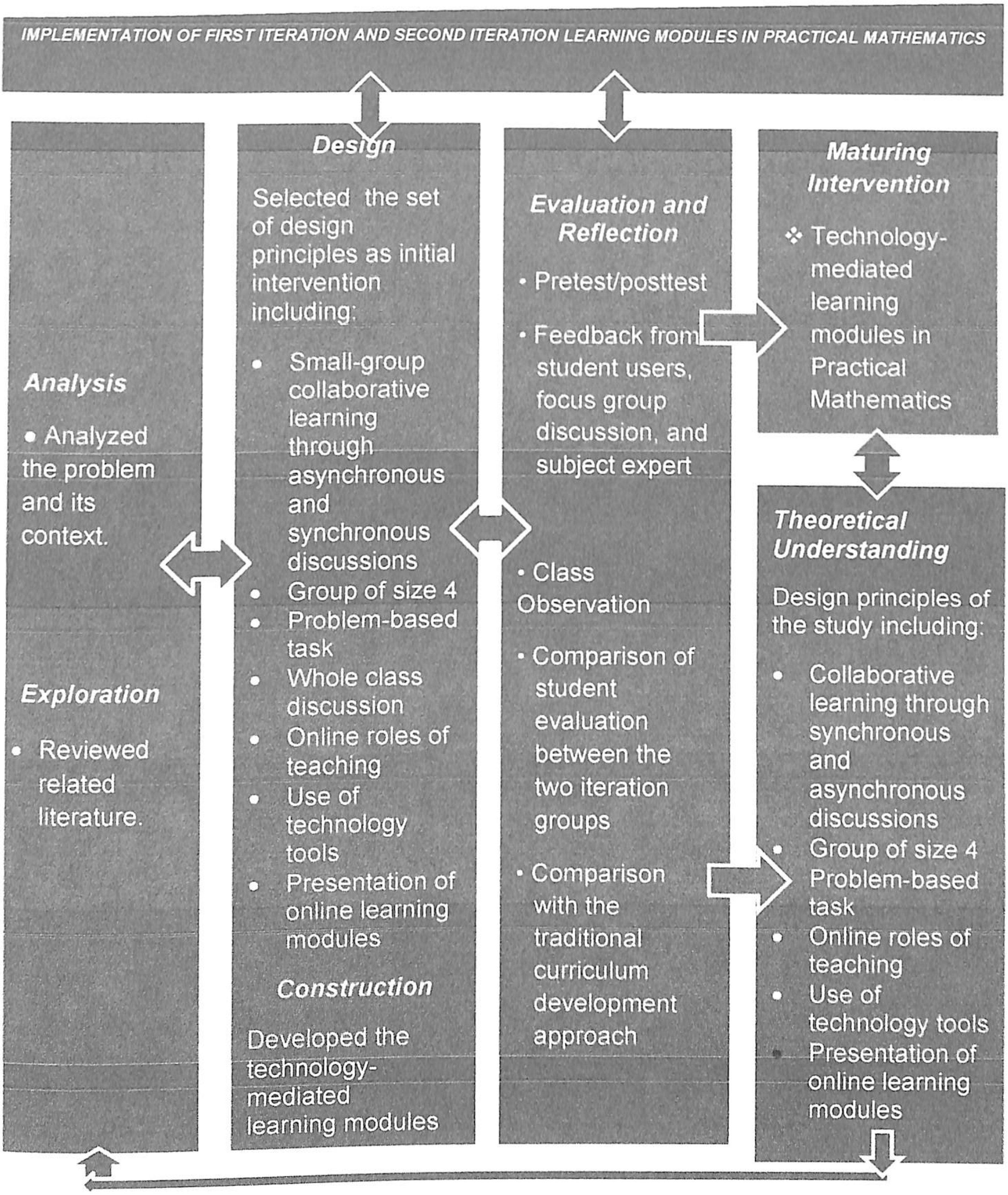


Figure 6. Research and development process of the study based on the research model of Mckenney and Reeves.

At the above portion of Figure 6, each of the double-headed arrows indicates a mutual influence between the implementation of the learning modules and each of the phases of the research flow. The influence of an iteration implementation on the first phase is indirect via the second phase. This implies that any output of the three phases is part of the learning modules for use of a cohort of student participants. Any favorable or unfavorable experience, reaction or observation from the use of the modules during the implementation provided feedback to the three phases in the next iteration.

Moreover, a double-headed arrow that appeared in between any two phases indicates a mutual relationship, where the two phases informed each other's set of tasks. For instance, borne out of the experience from the use of the modules during the first implementation, the evaluation results have shown the need for some revisions in the design principles and learning modules of the study. In the next iteration, these suggested revisions went through analysis and exploration in order to establish their literature and theoretical bases. When there was literature and theoretical support, these revisions became part of the redesigning and reconstructing effort. These revised design principles and learning modules then became the bases of implementation in the second iteration of the study. Before, during or immediately after the implementation, data were gathered from the observations of the researcher and a class observer, pretest/posttest scores, the experiences of student participants, focus group discussions, and the review of a subject expert. The data gathered informed the evaluation and reflection part and served as bases for further refinements that had to be done on the modules and the design principles. After the second iteration of the study, the research process culminated into two main outputs: the final technology-mediated learning modules in practical mathematics and the theoretical understanding of designing these modules. As indicated by an arrow pointing back to the first phase of the research flow, these two main outputs would add to the existing body of design research literature in developing technology-mediated learning modules in practical mathematics.

As an innovation to this model, this study introduced the traditional curriculum development process of a private sectarian college, simultaneously implemented with the design research process. In the first iteration, the same set of the tentative learning modules was revised by the traditional curriculum development approach of a college. The researcher revised the same tentative online learning modules based on the TESDA format. The revised online learning modules, described as the traditional learning modules, were then critiqued by two subject experts of a private sectarian college. In the second iteration, the traditional learning modules were tried out by the comparison group.

Participants of the Study

The participants of the study, for the first iteration, were 12 students enrolled in the technical vocational institute and senior high school of a private sectarian college in Southern Philippines. This college has a vocational technical institute and a K to 12 program with a spiritual formation. Student participants, enrolled in the technical vocation institute, were graduates of a nearby city high school and/or Technical Education and Skills Development Authority (TESDA) scholars sent to this private sectarian college. Other student participants in the senior high school were enrolled in its technical vocational track. Recommended by the management of this private sectarian college as suitable participants for this study, these students needed to study some skills and knowledge in mathematics as specified in the training regulations of TESDA. A mathematical requirement of the welding course and many other technical vocational courses is the mastery of industry calculations consisting of the following topics: 1) perform four fundamental operations, 2) perform conversion of units, 3) perform calculations on algebraic expressions, and 4) compute percentage and ratio (see Appendix A). Of the 12 participants who went through the online study of the three technology-mediated learning modules in the first iteration, eight completed the study while the rest dropped out. Among the eight completers, two are female and the rest are male – all belonging to the age brackets of 16-18 years old with a mean age of 17.1 years.

In the second iteration of the study, another 24 students were asked to participate in the online study of the learning modules in practical mathematics. These participants, who finished Grade 10 at various high schools in the city and the Province of Davao del Sur, were also enrolled at that private sectarian college in the pioneering technical vocational track of Grade 11 under the K to 12 Program. All belonged to the age bracket of 16 years - 18 years old with a mean age of 17 years. Of these 24 participants, 12 were randomly assigned to design research group who studied the three technology-mediated learning modules in practical mathematics, already modified based on the results of the first iteration. Of the 12 participants, three are female and the rest are male. On the other hand, the remaining 12 students, all male, were assigned to the comparison group using the technology-mediated learning modules in practical mathematics developed using the traditional curriculum development standard of the college. The technology-mediated learning modules for this group were revised according to the curriculum development standard of the private sectarian college and reviewed by a group of professors from the college. All participants from the two groups, belonging to the age bracket of 16 - 18 years old with a mean age of 17 years, completed the online study, and took the pretests and posttests.

The private sectarian college in the southern part of the Philippines was chosen as the place of this study because its access and convenience, rapid growth of its curricular programs, and the absence of online learning in its curricular offerings. In addition, for almost three years now, there has been a tremendous growth of curricular offerings under the progressive leadership of the school's management from four programs to the present fifteen programs. Such curricular growth has caused an increase in student enrollment of the college. This is not to include the expansion of the Basic Education Department of the school which has offered a senior high school in response to the challenge of K to 12 program of Philippine government. In its senior high school program, one of the tracks offered is the technical vocational track. At present, there have been four classes enrolled in the technical vocational track. This increase in the present and future demand for technical vocational education of the school will certainly impact its physical capacity to deliver the instructional services. Thus, allowing the school as a place of study is a timely endeavor as the results of this study will provide the school's management some policy inputs for its consideration of offering online courses as a viable and effective option of delivering instructional services in the face of a growing demand and a limitation of the school's physical infrastructure.

Research Instruments

This study used seven researcher-made instruments, namely, the practical mathematics pretest and posttest, an evaluation rubric, an observation guide, a semi-structured interview protocol, guide questions for the focus group discussion, and guide for review of subject expert. A panel of two subject experts was asked to examine and establish the content validity of the five instruments, namely: the pretest, posttest, evaluation rubric, observation guide, and the semi-structured interview protocol. A copy of the comments from the experts is found in Appendix B. Another subject expert was asked to comment on the content validity of the remaining instruments which were guide questions for the focus group discussion, and guide for review of the subject expert. Appendix C shows a copy of the comments from the expert. Moreover, a sample, similar in characteristics to the actual participants, was selected to pilot test four of these seven instruments in order to:

a) determine the reliability of pretest/posttest and the evaluation rubric;
b) establish whether the semi-structured interview questions are understood the way this study would want them to be understood.

The Practical Mathematics Pretest and Posttest

These tests assessed the knowledge and skills from the seven technology-mediated learning modules which were based on the three practical mathematics topics, namely: in performing conversion of units, calculating algebraic expressions and in computing ratio and percentage. Each test is a constructed response type, consisting of twenty-six items. Many of these items would assess test takers on how they apply knowledge, skills, and critical thinking abilities to real-world, standards-driven performance tasks. Each of the items in the test addresses a particular objective of a technology-mediated learning module.

To assess content validity of the pretest and posttest, two subject experts examined whether the test items of each test have covered the seven lessons of the learning modules. Results of such examination show that the 26 items of each test have adequate coverage and representativeness of the seven lessons. In percentages, these test items had been distributed across these seven lessons as follows: a) length – 19 percent; b) area and volumes – 15 percent; c) mass, weight, and time – 12 percent; d) current and voltage – 12 percent; e) polynomials – 15 percent; f) simple equations – 12 percent; and g) ratio and direct proportion –15 percent.

The pretest and posttest instruments were pilot-tested among Grade 11 students to test their reliability. These pilot-tested were students in the technical vocational track. The pretest and posttest, each consisting of 26 items, have a set of scoring criteria to guide the test raters. The scoring criteria have a point system from zero to a maximum score of 69 points. The intra-class correlation (ICC) was used to assess the inter-rater reliability of the pretest and posttest of the study because the test items, the variables to be tested, are measured in a ratio scale. Since the two raters were fixed for every evaluation of the students on each of the 26 variables and the students came from a randomly selected class, the study chose the two-way fixed model. In this model, the absolute agreement was selected to show the extent to which the scores of one rater are equal to the scores of the other rater. For the purpose of establishing the reliability of a single rater, a single-measures ICC was used to quantify the reliability of the ratings based on the ratings provided by a single rater. This study also used Cicchinti's (1994) qualitative descriptions on various ranges of ICC values.

The values of the single-measures ICC on all test items—except items 1, 19, and 24—ranged from 0.769 to 0.959 which indicate an excellent level of consensus between the two raters. With ratings ranging from 0.69 to 0.742, the exception though still showed a good level of consensus between the two raters. The results would indicate that the pretest has an excellent reliability in measuring knowledge and skills of students in practical mathematics. A copy of the sample items of the pretest is shown Appendix D.

For the reliability of the posttest, the values of the single-measures ICC on all test items—except item numbers 1, 5, and 7—ranged from .802 to 1.000 which indicate an excellent level of consensus between the two raters. With ratings ranging from 0.603 to 0.726, the exception though still showed a good level of consensus between the two raters. The results would indicate that the posttest has an excellent reliability in measuring knowledge and skills of students in practical mathematics. A copy of the sample items of the posttest is found in Appendix E.

The Evaluation Rubric

This instrument (see Appendix F) was used to evaluate the effectiveness and usability of the design principles of the study using the four criteria: learning approach, online roles of teaching, technology tools as learning support, and the presentation of the technology-mediated learning modules in practical mathematics. The subject experts' comments, made part of the rubric, introduced some modifications on the qualitative description of the scale in order to show clearer differentiation between rating scales. Each criterion has a set of sub-criteria, subject to the following rating scale: needs improvement, fair, good, and excellent. These criteria with corresponding sub-criteria are as follows:

1. Learning approach, the first criterion, is indicated by following sub-criteria:
    1a) learning together using asynchronous and/or synchronous discussions;
    1b) discussion group of size 4;
    1c) and the problem-based task.
2. Online roles of teaching are indicated by the following sub-criteria:
    2a) facilitating role;
    2b) social presence;
    2c) feedback giver;
    2d) and course manager and designer.
3. The use of technology tools as learning support consists of the following sub-criteria:
    3a) the use of emails or discussion board;
    3b) the use of video or voice calling and chat;
    3c) and the group's chosen social network site.
4. The online learning module criterion is defined by the following parameters:
    4a) clearness of the instructions;
    4b) word usage;
    4c) usefulness of the video presentation of tutorials;
    4d) lesson objectives;
    4e) lesson activities;

4f) presentation of the online learning modules.

The introductory part of the evaluation rubric contains items asking about the academic and socio-economic profile of the student participants. Such information enabled this study to provide the context of student participants. This study chose the two-way fixed model of the ICC to test the reliability of the rubric. As fixed raters, the three participants, chosen from among the first iteration group, provided ratings on the 19 rubric items. Based on the average scorings of these 3 raters and Cicchinti's (1994) qualitative descriptions on ICC, the test results showed an excellent level of consensus among them with an absolute agreement coefficient of 0.779 and an excellent level of correlation of scores with a consistency coefficient of 0.802. The results would indicate that the evaluation rubric has an excellent reliability in assessing the usability and effectiveness of the technology-mediated online learning modules.

The Observation Guide

Upon evaluating the content validity of the instrument, the same subject experts made suggestions on the descriptive measures used, ways to generate more observation, and inclusion of some items in the first cluster of the instrument. Adopting these suggestions as modifications of the instrument, the final version of the guide consisted of 28 items. This observation guide was used to note down observations on participants relative to the four clusters of the design principles: learning approach, online roles of teaching, use of technology tools, and the technology-mediated learning modules of the study. Each item was rated using the following: highly evident, evident, not so evident, and not observed. In particular, the researcher also observed the nonverbal expression of feelings, the asynchronous and synchronous discussions of a group, how participants relate to the different online roles of teaching, what technology tools are preferred and how they are used as learning support, and how the participants will relate to the online learning modules as they use them. Such observations were based on but not limited to the guide items listed in the observation guide for each cluster. A copy of the guide is found in Appendix G.

The Semi-structured Interview

It is another instrument used to gather qualitative data from the participants of the study. A copy of the guide is found in Appendix H. This instrument was designed according to the interview approach of Drever (1995) and modified by the comments of the subject experts. Drever (1995) stated that, in this type of interview, the interviewer decides in advance the ground to be covered and the main questions to be asked while the interviewee, in turn, has a fair degree of freedom on what to talk about, how much to say, and how to express it. As used in the study, this interview covered the four clusters of the design principles of the study. Each cluster contained a set of pre-determined questions which were mostly open-ended ones. These questions provided the participants an opportunity to answer as freely as they wanted to. In this manner, the researcher was able to obtain valuable information or insights from the participants which might not be captured by the other data-gathering instruments. Moreover, the comments of the subject experts dealt on wording out some questions for better understanding of the interviewees and greater elbow room for response.

Guide Questions for the Focus Group Discussion

This is a set of closed-ended and open-ended questions given to the comparative group after they tried out the learning modules of the private sectarian school. Upon examination of the guide content, a subject expert found it to be valid and adequate to generate responses from the participants for the purpose of comparing between the sets of learning modules in terms of effectiveness. A copy of the questions included in the guide is found in Appendix I. The questions asked the participants to compare the two types of the online learning modules, choose between the two modules, and make suggestions to improve the online learning modules.

Guide for Review of the Subject Expert

This is a set of questions used to guide the subject expert in his review of the two types of online learning modules. A copy of the questions in the guide is found in Appendix J. The subject expert, upon evaluating the content validity of the guide, suggested to add questions that deal on the interaction between students, and between students and the teacher as well as questions on the clarity and effectiveness of the online presentation of the modules. These questions were incorporated in the guide and, overall, that expert found the guide to be appropriate and adequate for a proper review of the two sets of learning modules.

Design Research Learning Modules in Practical Mathematics

This section describes the technology-mediated learning modules in practical mathematics which were developed in this study using the design research approach.

First Iteration Learning Modules

Three technology-mediated learning modules were developed based on the three topics found in the training regulations for "Shielded Metal Arc Welding" (SMAW) NC II. These three topics, which include conversion of units, calculations on algebraic expressions, and computation of ratio and percentages, are particularly taken from the training regulations' common competency entitled "Perform Industry Calculations." Copies of some of the lessons in these learning modules are provided in Appendix K. Each of these topics covers a number of lessons. Based on the first topic (i.e. conversion of units), this study developed the first learning module which has four lessons on the following:

1.1 Length

1.2 Areas and Volumes

1.3 Mass, weight and time

1.4 Current and voltage

Based on the second topic (i.e. calculations on algebraic expressions), this study developed the second learning module on two lessons, namely: (1.5) polynomials and (1.6) simple equations. For the third topic, (i.e. computation of the ratio and percentage), this study developed the third learning module with the last lesson on (1.7) ratio and direct proportion. Each of these lessons started with learning pre-requisites, a set of behavioral learning objectives, required materials and introduction of the problem-based task. This was followed by a set of activities that include: problem roll-out, student work time, workshop, sharing out and discussion, student work time, and final action on the problem.

Lesson Activities and Online Roles of Teaching. The design research process allowed a teacher to perform the five roles of online teaching (Berge, 1995; Liu et al., 2005) for an effective instruction of practical mathematics. Its first two phases engaged an online teacher to be a course designer by allowing him to select the most promising design principles from the review of related literature and studies, and to use these design principles in constructing the technology-mediated learning modules in practical mathematics. Before the implementation of these modules, an online teacher performed the other two online roles, being a classroom manager and having social presence in the online classroom. The last two online roles, as a facilitator and feedback giver, were performed during the implementation of the following lesson activities in a module.

1. Problem roll-out. An online teacher, as a facilitator, informed each small group about what were expected of them in this activity. That was, after reading the problem and its sub-questions, members of a group had to discuss among themselves what they knew about the problem, what they needed to know, and the potential next steps that they knew about.
2. Student work time. As the next activity, the group worked on the potential next steps that they knew about. Here, an online teacher would ask some probing questions beginning with what, how or why—challenging or leading the students to the right process or desired outcomes. A teacher could also remind them of a prior knowledge, as stated after the lesson objectives, to be helpful in the analysis towards solving the sub-questions of a problem-based task.
3. Workshop. In this activity, an online teacher announced that each small group could avail of a workshop should they come to the potential next steps of the problem that required what they needed to know. This entailed watching a video presentation on what they needed to know about the problem. They could replay any portion of the video presentation for as long as they needed it. Notice that the video tutorial was also provided by the teacher himself. To reinforce what they

learned from the video presentation, the group was given a set of exercises to solve. As the provider of the answer keys, an online teacher directed the group to self-check their answers with the answer key as uploaded in the website of the study.

4. Sharing out and discussion. This was the next lesson activity that allowed a volunteer group to present and discuss their output before the whole class. Further facilitated by an online teacher, an open forum would follow when groups, especially those struggling ones, could ask clarificatory questions or other groups could comment on the presentation of a group's output. Here, an online teacher could also comment or ask questions to ensure that what was presented to the whole class was accurate and clear for proper guidance of those groups who had difficulty in performing the problem-based task of a lesson.
5. Student work time. A group used this time to make some revisions or completely the write the solutions to the questions of the problem-based task. This activity was capped by a group doing some extension work.
6. Final action on the problem. At this time, small groups would submit reports of their outputs to the teacher that included solutions or mathematical justifications to the sub-questions of the problem-based task, and solution to the extension work. After which, an online teacher checked these submissions, could comment on them, and scored these submissions. As a teacher's feedback, these corrected outputs were returned to the groups for reflection on any errors committed or to keep them as part of the review materials.

Each lesson had a set of components which included a video tutorial, helpful notes from a video tutorial, an answer key, and a solution key to an assignment. As part of the multimedia presentation of a lesson, each video tutorial focused on what the participants need to know to help them solve a problem-based task and consequently understand the topic at hand (see Appendix L for screenshots and sample content description of video tutorials). Each video was numbered according to the descriptive number of a lesson where the video belongs to. Helpful notes are the important points from a video tutorial which are presented in a textual form. This is in line with the theory of multimedia adopted by the study. Aside from this, helpful notes, in written form, would greatly aid the group to understand and remember the important points in a video tutorial (see Appendix M for a sample copy of helpful notes). An answer key held the correct answers where the participants self-checked their own answers to the exercise of the module. A solution key to an assignment provided right procedure or approach to an assigned problem (see Appendix N for sample copies of an answer key and solution to an assignment).

Lesson 1.1 of the First Module. This lesson dealt with the topic on length and started with a problem-based task titled "Phase 1 of Ground Design of a Park". It asked mainly a group to design their own park, choose the appropriate measurements of the park's dimensions, and to make the necessary conversions between metric units involving length. This lesson had three objectives. The accompanying video tutorial of this lesson defined length and used the side of a rectangle as an illustration on length. The video also showed a table containing metric prefixes with corresponding symbols and explained when to use them. It comes with helpful notes which dealt with the two methods of conversion between metric units involving length. Added here were examples of conversion for each method for better illustration of the procedures involved. The answer key contained answers to the 20-item exercise in the lesson and the solution key provided the correct procedure in solving the assignment of the first lesson.

Lesson 1.2 of the First Module. With four objectives, this lesson dealt with conversion of units involving area and volume. The problem-based task, "Phase 2 of the Park Design", used the facts of the problem in lesson 1.1 with two more specifications of its own. It challenged participants to find the appropriate metric units of the selected dimensions of the park involving area and volume, and to make the necessary conversions between metric units involving area and volume. The first part of the accompanying video tutorial of lesson 1.2 defined the area, cited the common metric units of the area, and used the conversion factor to solve two problems involving conversions between metric units of an area. The second part defined the volume, showed the appropriate metric units of large or small measurements, and solved two conversion problems involving volume by using the conversion factor. The helpful notes showed the concepts of area and volume, and presented sample problems with solutions using the factor conversion method. The lesson's answer key provided two sets of answers. The first set pertained to answers on choosing the most appropriate unit in area or volume and the second set on converting between metric units involving area and volume. The solution key provided the correct procedure to the assignment of the second lesson.

Lesson 1.3 of the First Module. This lesson had four objectives and dealt with mass, weight, and time. The problem-based task, "A Budget Plan", showed a menu of four food items with corresponding lists of ingredients, number of orders, and time requirement for preparation and cooking. It asked participants to find the appropriate metric units involving mass and weight, and to make the necessary conversions between metric units. Included also in the lesson were the non-SI (non-international standard) units of time that challenged the participants to convert the preparation and cooking time to the familiar, non-SI units of time. The accompanying video tutorial discussed the concepts and conversion problems involving mass, weight and time, and metric units. The first part of the helpful notes included conversion problems with solutions using factor conversion method. The answer key contained the correct answers to the twelve items in the exercises and its solution key to the assignment in this lesson.

Lesson 1.4 of the First Module. This lesson had three objectives and dealt with conversion of units involving current, voltage, and ampere. To meet the objectives, the participants of the study read a problem-based task, "Power Usage", and were asked to make a report showing, among others, the estimates of the monthly power consumption of the selected electrical appliances. In writing the report, the participants needed to find the appropriate metric units and convert between the indicated metric units involving watt and voltage. The accompanying video tutorial of the module discussed the concepts on current, voltage, and wattage including their metric units of measurement. It also showed how to solve some conversion problems involving ampere, voltage, and wattage. The helpful notes presented the concepts and conversion problems with corresponding solutions involving current, ampere, and voltage. The corresponding answer key of the lesson contained answers to the ten exercises and the solution key provided the solution to the assignment of this lesson.

Lesson 1.5 of the Second Module. This lesson dealt with the operations of polynomials. With two objectives only, it offered a problem-based task, titled "Carton Box", that raised eleven questions involving operations of polynomials. To perform the task, each group had to calculate the dimensions of the carton box like its perimeter, area, and volume. In the video tutorial of lesson1.5, the facilitator discussed the concepts, operations, and measurement problems involving polynomials. Its helpful notes provided more examples on the operations of polynomials to help the participants master the necessary skills in the module. The answer key of the lesson contained solutions and answers to the four items in the exercises. These were solutions and answers to the problems on addition, subtraction, multiplication and division of polynomials. Its solution key provided the correct procedure for the assignment of the fifth lesson.

Lesson 1.6 of the Second Module. With four objectives, this lesson dealt with linear equations and applications and required each group to perform a problem-based task titled "Fund-Raising". This aimed to help them develop their knowledge and skills on mathematical translations and problem-solving involving equations in one variable. The accompanying video tutorial translated verbal phrases or sentences into mathematical expressions, and identified and solved linear equations in one variable. Aside from those obtained in the video tutorial, the helpful notes of the module added more examples on translation and word problems involving linear equations in one variable. The answer key presented the right translations to a set of phrases and statements as well as solutions and answers to the word problems in the module exercise. The right solution to the assignment of the sixth lesson was provided in the solution key.

Lesson 1.7 of the Third Module. With three objectives, this lesson on ratio and direct proportion put to task each group to solve a problem-based task titled "Round Trip From Paris to Rennes." This provided opportunities for the group to develop their knowledge and skills on ratio and direct proportion as they tried to solve the problem. The accompanying video tutorial of lesson explained the concepts of ratio and direct proportion, and cited real-world applications of these concepts. The helpful notes provided examples of ratio of two numbers, concept of direct proportion, and problems involving direct proportion. The answer key contained answers to the nine items in the module exercises. The solution key presented the right solution to the assignment of the lesson.

First Iteration Implementation

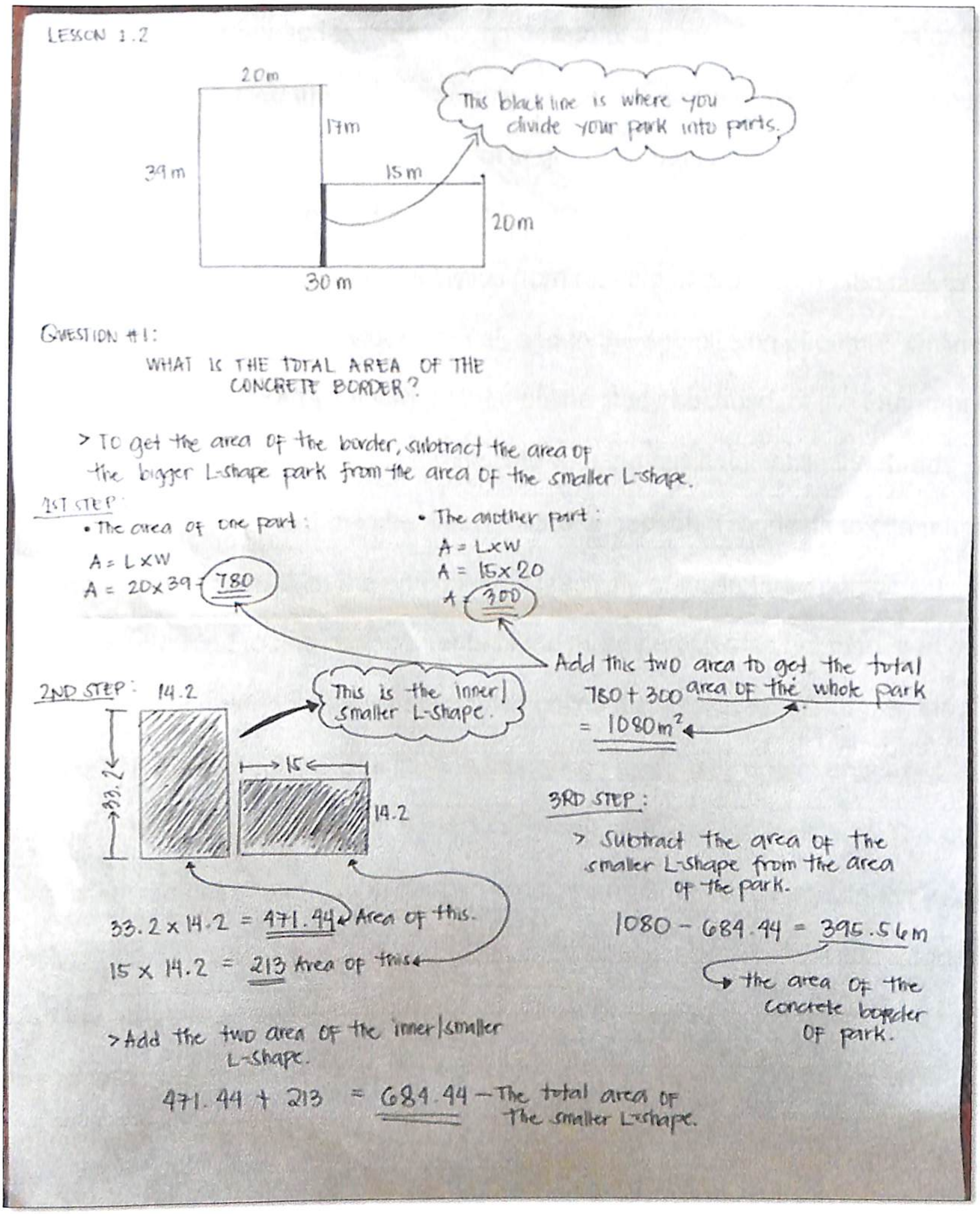
Prior to the first iteration implementation, 12 students, who participated in the first iteration, were divided into three small groups. Each group had four members. Created by this study, Facebook group accounts, assigned to these small groups, were described as Online Research Group A, Online Research Group B, and Online Research Group C. The participants tried out for the first time the first iteration learning modules. In this online implementation, the researcher was the facilitator and a high school mathematics teacher the class observer who observed the researcher's facilitation as well as the small groups' try out of the learning modules. The early part of the first iteration implementation started the facilitator's online orientation in each of the three small groups. The orientation dealt with: a) welcoming the participants of the study, b) providing the domain name of the website of the study and describing the learning process to be used, and c) narrating the activities of the lesson. The facilitator also asked the participants of each small group their email addresses, contact numbers, and self-introductions. The succeeding chats dealt on synchronous exchanges between the facilitator and each group that helped establish the social presence of all those involved in the study. After which, each small group was asked to read and discuss online the contents of the website that featured, among others, the first iteration learning modules and accompanying materials.

In trying out these first iteration modules, the three small groups, guided by the facilitator, followed the weekly schedules of the online study of the learning modules as well as the deadlines of the submissions of group outputs. This is shown in table 1. Each small group engaged in collaborative synchronous or asynchronous discussions on the problem-based tasks from lessons 1.1 to 1.7. The researcher facilitated those small-group discussions by providing illustrations, helping devise strategies to solve a problem, and posting encouraging remarks on participants' correct solutions, among others. Each group submitted online their output, which consisted of answers or solutions to the problem-based tasks of a lesson, to the facilitator (see Figure 7 for a sample output of Group C). An observation by both the facilitator and a class observer was conducted on the three groups as they tried out the online learning modules while being guided by the facilitator. After completing the online study, all participants answered the evaluation rubric to rate the learning modules they tried out. Moreover, six of these participants were interviewed by the researcher using the interview protocol. The gathered data from the participants, class observer, and the researcher served as the feedback of the study. This feedback was used to improve the first iteration learning modules.

Table 1

Weekly Study Schedule of Technology-Mediated Learning Modules in Practical Mathematics

Week Number	Description of Lesson and Day of Its Presentation	Deadline of the Submission of Group Requirements
1	Lesson 1.1. Length	On or before Sunday midnight
2	Lesson 1.2. Areas and Volumes	On or before Sunday midnight
3	Lesson 1.3. Mass, Weight and Time	On or before Sunday midnight
4	Lesson 1.4. Current and Voltage	On or before Sunday midnight
5	Lesson 2.1. Polynomials	On or before Sunday midnight
6	Lesson 2.2. Simple Equations	On or before Sunday midnight
7	Lesson 3.1. Ratio and Direct proportion	On or before Sunday midnight



LESSON 1.2

QUESTION #1:

WHAT IS THE TOTAL AREA OF THE CONCRETE BORDER?

> To get the area of the border, subtract the area of the bigger L-shape park from the area of the smaller L-shape.

1ST STEP:

• The area of one part:

A = L x W
A = 20 x 39 = 780

• The another part:

A = L x W
A = 15 x 20
A = 300

Add this two area to get the total area of the whole park
780 + 300
= 1080m²

2ND STEP:

33.2 x 14.2 = 471.44 Area of this.
15 x 14.2 = 213 Area of this

> Add the two area of the inner/smaller L-shape.

471.44 + 213 = 684.44 – The total area of The smaller L-shape.

3RD STEP:

> Subtract the area of the smaller L-shape from the area of the park.

1080 – 684.44 = 395.56m

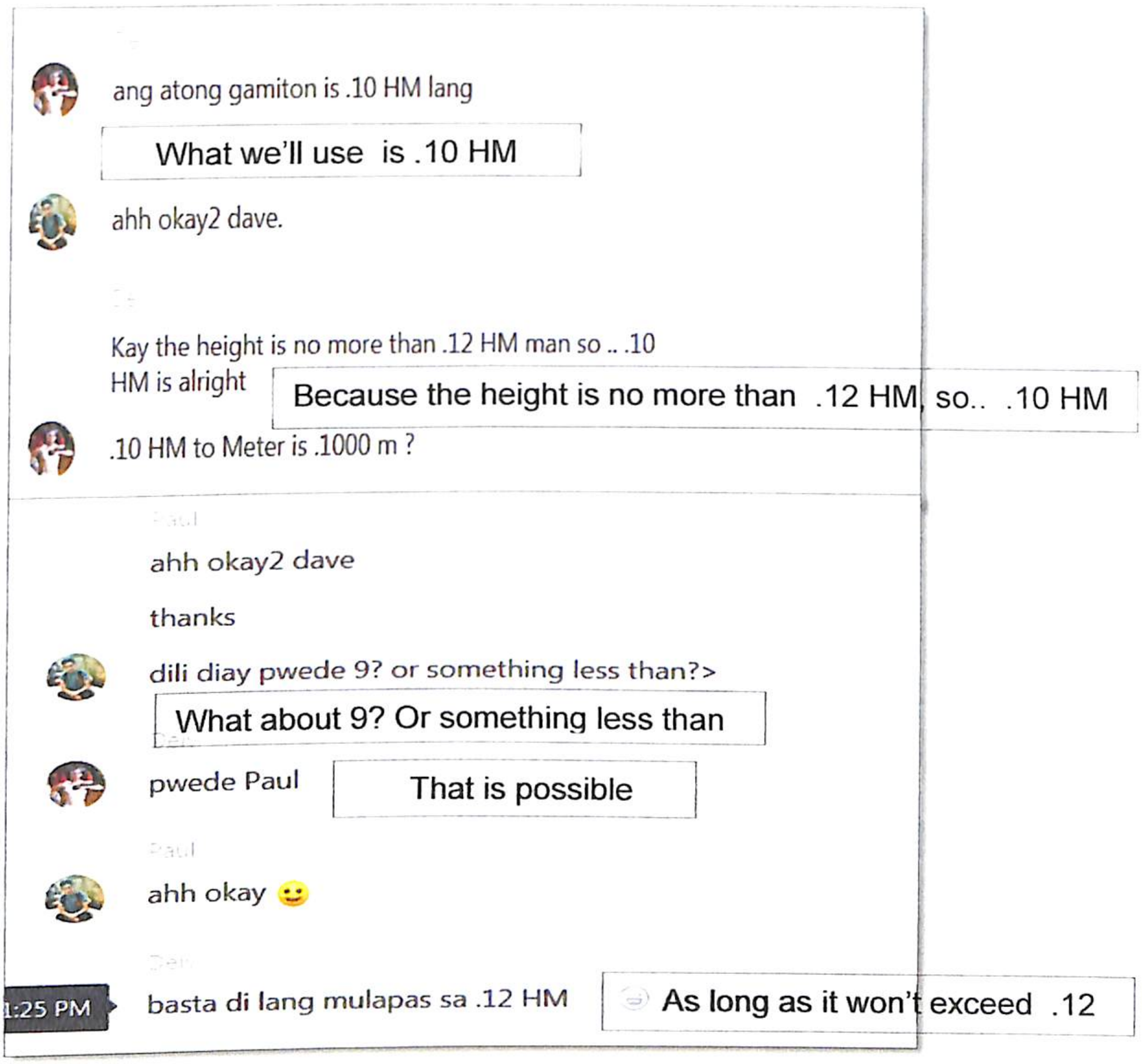
the area of the concrete border of park.

Figure 7. A sample group output in lesson 1.2 uploaded in a Facebook group account.

Lessons 1.1 and 1.2 of the First Module. Lesson 1.1 dealt with length and presented a problem-based task on ground design of a park. Three members of Online Research Group C used the collaborative synchronous discussion or asynchronous discussions (see Figure 8 for a screenshot of group chat and Appendix O for more sample excerpts of group chats).

They performed the lesson activities from reading of problem-based task in lesson 1.1, the viewing of the video tutorial, and to the submission of output. Online Research Group B started very late on their online study because, of the four members, only one participant managed to communicate with the facilitator while the three participants remained silent despite the facilitator's repeated requests to communicate through the group chat. With the unexplained inactivity of these three participants, the facilitator was forced to find replacements of the three participants but managed only to find two replacements. In another scheduled online discussion with Group B, the facilitator had a repeat of the one-on-one interaction since only one member of Group B, from one of the two replacements, joined the group chat with the facilitator. The other replacement did not attend due to his part-time job. Again, to keep up with the pacing schedule and the lateness of Group B's first online discussion, the facilitator started and ended the group chat with a single member. Thus, at the end of the group chat, the same request was given to the sole participant about collaborating with the absent members in the writing of lesson 1.1 output.

Having been reminded of the designed online learning approach for the present study, Group A started with only one member in attendance during the scheduled first online discussion of the problem in lesson 1.1. To keep up with the pacing schedule of the online study, the facilitator had no recourse but to proceed with the one-on-one chat with the lone participant. Such group chat was a synchronous question-and-answer discussion. The discussion culminated with a facilitator's request for the lone participant to ask her group mates to review the open chat and work collaboratively on the solutions to the problem-based task.



ang atong gamiton is .10 HM lang

What we'll use is .10 HM

ahh okay2 dave.

Kay the height is no more than .12 HM man so .. .10 HM is alright

Because the height is no more than .12 HM, so.. .10 HM

.10 HM to Meter is .1000 m ?

Paul

ahh okay2 dave

thanks

dili diay pwede 9? or something less than?>

What about 9? Or something less than

pwede Paul

That is possible

Paul

ahh okay 🙂

1:25 PM

basta di lang mulapas sa .12 HM

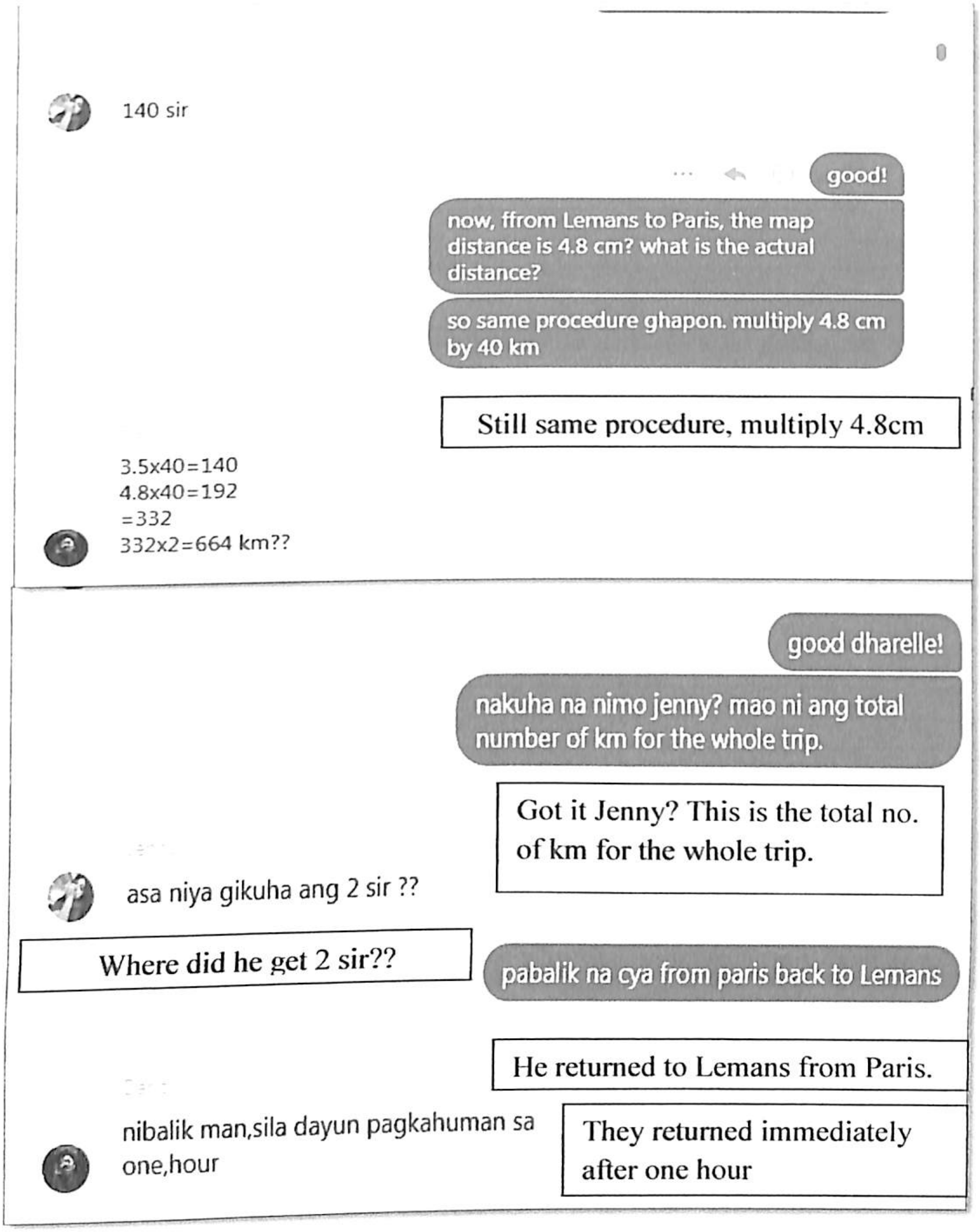
As long as it won't exceed .12

Figure 8. A screenshot of a group chat in a collaborative synchronous or asynchronous discussion.

At pace with the scheduled online discussion on lesson 1.2, Group C again had an attendance of three members during the appointed time with one member absent due to his part-time job as a waiter. They continued with the synchronous discussion on the lesson problem in a collaborative manner. On the other hand, attendance of Groups A and B recovered with three participants, each joining their respective group discussions on the problem-based task in lesson 1.2.

Lessons 1.3 and 1.4. During the online study of lesson 1.3, the facilitator scheduled the group chats according to the preferred time of the three groups. Again, each group chat was done in a synchronous manner. This was the facilitator asking or clarifying a question in the problem, and the participants solving each question raised and thereafter requesting for immediate feedback on their answers or solutions. On discussing lesson 1.3, Group C spent almost 3 hours of online discussion and agreed to solve time problem in the next scheduled group chat. Group A also spent close to three hours and Group B, the latest group to study lesson, had a discussion period of a little more than one hour. Such was the length of the discussion, shorter relative to those periods of Groups A and C, because only one member of Group B showed up for a one-to-one discussion with the facilitator on the present lesson. In lesson 1.4, each of these small groups engaged themselves in a synchronous discussion with the facilitator on the lesson's problem-based task.

Lessons 1.5, 1.6, and 1.7. To guide the group chats in module 1.5, the facilitator provided examples on how to solve the perimeter, area, and volume of the carton box based on what were given in the problem-based task. The groups generally found lesson 1.6 relatively easier, which dealt with simple equations. In lesson 1.7, these various groups with the guidance of the facilitator solved all the questions in the problem-task (see Figure 9 for an excerpt of a group chat guided by the facilitator).



140 sir

good!

now, ffrom Lemans to Paris, the map distance is 4.8 cm? what is the actual distance?

so same procedure ghapon. multiply 4.8 cm by 40 km

Still same procedure, multiply 4.8cm

3.5x40=140
4.8x40=192
=332
332x2=664 km??

good dharelle!

nakuha na nimo jenny? mao ni ang total number of km for the whole trip.

Got it Jenny? This is the total no. of km for the whole trip.

asa niya gikuha ang 2 sir ??

Where did he get 2 sir??

pabalik na cya from paris back to Lemans

He returned to Lemans from Paris.

nibalik man,sila dayun pagkahuman sa one,hour

They returned immediately after one hour

Figure 9. A screenshot of a group chat guided by the facilitator.

Second Iteration Learning Modules

The second iteration learning modules consisted of the three learning modules improved in this study according to the first iteration results. In general, the changes made on the first iteration learning modules were the removal of two lesson activities from the seven lessons. These activities were sharing out and class-wide discussion, and assignment. Also, some other changes were introduced particular to each of the following lessons (see Appendix P).

Lesson 1.1 of the First Module. The last specification that dealt with entrances and exits of the park was deleted because it was unnecessary relative to the set of questions raised in the problem-based task. The illustrated floor plan was replaced by a clear and better illustration, a pentagon-shaped park, in order to address the difficulty on how to design a park. Such illustration would show the following: a) concrete border and its width; b) ground covered with Bermuda grass; c) perimeter of the park.

Lesson 1.2 of the First Module . In the set of questions raised in the problem-based task, items 5, 6, and 7 were removed from the set in order to address the observed common difficulty of the participants in devising strategies on how to find the area of the concrete border and the ground covered with Bermuda grass. These removed items involved lateral areas. Seen more as a geometric problem, these items posed quite complicated tasks that would divert one's attention from addressing the objectives of the learning module. Also taken out was the second specification, the basis of the deleted items, from the second set of specifications in the problem-based task.

Lesson 1.3 of the First Module. One food item, Asian Adobo, was removed from the menu. In the second question of the problem-based task, the mode of computing the total value of each of the three selected ingredients was changed from weekly to daily mode in order to get rid of some tedious calculations which were unnecessary relative to the objectives of the lesson. These selected ingredients were noodles, chicken, and pork legs. By so doing, the length of time for synchronous discussion can be reduced in the light of the experience of the two online groups, who spent three hours discussing and finding the solutions to the problem during the first iteration.

Lesson 1.4 of the First Module. In the list of appliances in the problem-based task, two appliances, the refrigerator and dishwasher, were taken out. The power usage of refrigerator was already stated in kwh such that no conversion was needed and the conversions involved in the power use of dishwasher were similar to those in the power use of paper shredder. Moreover, the length of discussion time to solve the problem was quite long for two hours, more or less. This was because the group was asked to compute the amount of power usage and to convert the amount to its appropriate metric unit on each of the nine appliances.

Lesson 1.5 of the Second Module. Having same reason as to why those items in the problem-based task of lesson 1.2 were removed, items 6 and 7 involving lateral areas in the present problem-based task were also deleted. Besides, there were other items in the problem set that offered enough task of calculating area dimensions. In this lesson, participants of the study will be asked to have some asynchronous discussion so that they will have more time to reflect and understand the concept of a variable and how it is used to measure a particular dimension.

Learning Module 1.7 of the Third Module. Questions were revised in the problem-based task in order to confine the calculations of distance, fuel, and time to a one-way trip (from Rennes to Paris) so that the participants can focus more on the application of ratio and direct proportion in the problem.

The Second Iteration Implementation

This was the second and final implementation of the study. The second iteration learning modules were used by another group of 12 participants described as the design research group. Prior to this implementation, these participants were divided into three small groups. These small groups were assigned Facebook group accounts, described as Group 2A, Group 2B, and Group 3C. The second iteration implementation began with an orientation given to these groups, which was similar to the one in the first iteration. In this orientation, the facilitator posted a welcome message to each of the small discussion groups. He provided them access to the website of the study and further oriented them on the procedure and processes of the online learning that included the following:

a. Solving the problem-based task using collaborative learning through synchronous or asynchronous discussions;
b. The facilitative role of the online teacher;
c. The use of online group chat as a platform for small group discussion.

In trying out the second iteration learning modules, these small groups followed the same weekly schedule of study of these modules as the one followed by the first iteration group. They were engaged in collaborative learning through asynchronous and synchronous discussions. Group chat was used as a platform to conduct those small-group discussions. The researcher facilitated these discussions as well as observed these groups tried out the learning modules. Each group submitted their output, answers or solutions to the problem-based task of a lesson, to the facilitator at the end of a study lesson. Upon completion of the online study, all participants answered the evaluation rubric and five of them were interviewed by the researcher. Feedback gathered from the participants and observer were analyzed and used for further refinement of the second iteration learning modules.

Lessons 1.1 and 1.2. The participants of each small group worked collaboratively on the problem-based tasks of the two lessons. Each small group used synchronous discussion to seek clarification or feedback from the facilitator and to perform problem-based task on metric conversions involving lengths and areas. But on problem-solving strategies like finding the perimeter of the ground covered with Bermuda grass and the area of the concrete border, asynchronous discussion was introduced by first showing them an illustration, other than which was given in the lesson, and giving them enough time to reflect. In general, the three groups solved the questions in the problem-based tasks of the two lessons.

Lessons 1.3 and 1.4. The average discussion time of the three groups on the problem-based task of lesson 1.3 was not as long as the discussion time of the first iteration groups. In the online discussions of these groups, there was much focus now on the task of finding the appropriate metric units and converting between metric units involving mass, weight and time. In particular, the participants of the two groups—online groups 2A and 2B—collaborated first by comparing and commenting on each other's answers, and subsequently adopting a common answer or solution to a particular question. The learning experience in lesson 1.3 repeated itself in the study of lesson 1.4. In the study of both lessons, a technology issue was raised by the participants in that they had difficulty opening the video tutorials. Consequently, they used helpful notes, in lieu of the video tutorial which cannot be opened due to weak internet connection, to get the information on what they need to know to address the problem-based task.

Lesson1.5. Because of the schoolwork demand, only one participant in group 2B had a synchronous discussion with the facilitator on the problem-based task. In that discussion, the facilitator guided the lone participant to solve a few of the nine questions so that the participant may use the discussed solutions as patterns on how to solve the remaining questions together with his group mates when they could gather for the group chat. Having solved four out of the nine questions by themselves, group 2C used synchronous discussion to seek clarification from the facilitator as they tried to solve the remaining questions. Moreover, all four members of group 2A helped each other solve the questions in the problem-based task.

Lessons 1.6 and 1.7. One issue raised by one of the groups, online group 2C, was the weak Internet connection such that the group relied much on reading the helpful notes on video tutorial 1.6 to learn what they need to know to perform the problem-based task. To guide the groups' discussions on both lessons, the facilitator showed them how to construct the budget equation in one variable in lesson 1.6 and solve a problem on direct proportion in lesson 1.7.

Traditional Learning Modules In Practical Mathematics

Two faculty staff of a private-sectarian college were invited to critique the technology-mediated learning modules in practical mathematics as revised by the researcher of the study according to the traditional curriculum development approach of a private sectarian college (see Appendix Q). These invited faculty staff, a college professor and a mathematics teacher of the senior high school of the college, are experts in teaching mathematics and have considerable experience in the task of curriculum development. In the main, the revisions were made by the researcher of the study, who also has a considerable amount of experience in curriculum development as a previous college teacher of the same private-sectarian college for more than two decades. These revisions were based on the Tyler's rational-linear approach (1949). This approach, based on a systematic design process launched by clear and reasonable objectives, is articulated in a framework of questions that guided the researcher in revising the online modules. Known as the Tyler's rationale, this framework consists of the following questions:

1. Which objectives should education aim for?
2. Which learning experiences are most appropriate to obtain these objectives?
3. How could these learning experiences be organized effectively?
4. How do we determine if the objectives have been met?

In this work of revision, the researcher first took notice of the overarching objective of private-sectarian college, which is inspired by the charism of the religious congregation that owns and operates the school. The objectives set in the lessons of these traditional learning modules were aligned to the objectives of the technical vocational school of a private sectarian college, which, in turn, were also aligned to this overarching objective. The learning experiences and the organization of these learning experiences were based on the format of the Technical Education and Skills Development Authority (TESDA) (see Appendix R). The outcome of the revision is shown in the following general outline of a learning module named as the traditional technology-mediated learning modules in practical mathematics (see Appendix S):

- Objectives, prerequisites, materials, and assessment method
- Watch a video tutorial and read its helpful notes
- Individual exercises
- Whole class online discussion
- Assignment

In these learning modules, direct instruction and independent work over collaborative learning is used as an approach to learning practical mathematics. The online discussion board, the fourth lesson activity, would provide a venue for the participants to ask from their online teacher questions or more explanations that may arise from the video tutorials, helpful notes and/or individual exercises. The assignments are problem-based tasks which are applications of what was learned about a lesson. The participants are required to check by themselves their solutions and answers to individual exercises and assignments with the use of the answer keys and solutions to assignments included in a module.

Implementation of the Traditional Learning Modules

Prior to this implementation, another group of 12 participants, described as the comparison group of the study, were oriented on the procedures and accompanying materials of the traditional learning modules. In the implementation of the traditional learning modules which was simultaneous with the second iteration implementation, the comparison group tried out the traditional learning modules. They also followed the same weekly schedule of study and submission of group outputs as the one used by the design research group. Being in a traditional classroom but in an online setting, these participants engaged in independent work in learning practical mathematics. They first watched a video and read helpful notes for direct instruction of a lesson. As an application, they then solved a set of exercises individually and checked their answers with the provided answer key. Using a discussion board, they continued with a question-answer discussion, a teacher-student interaction where participants asked questions or sought clarifications and explanation directly from the teacher. Such discussion was co-facilitated by the class observer of the study. As a wrap-up, each participant solved the assignment, which was the last lesson activity of a lesson. After completing the online study of the traditional learning modules, five participants of the comparison group joined the focus group discussion managed by the researcher of the study.

Data Collection Procedure

Prior to the start of the first iteration implementation, the 12 participants were divided into three small groups. During the implementation of the first iteration learning modules, an observation was conducted among these small groups relative to the design principles of the study. After trying out the modules, all the participants rated the modules by answering the evaluation rubric. Of those who completed the online study, five participants were invited for a semi-structured interview.

Prior to the start of the second iteration implementation, all participants from both design research group and comparison group took the pretest in practical mathematics. While trying out the second iteration learning modules, the design research group was observed relative to the four clusters of the design principles of the study. After the online study, participants from both the design research group and comparison group took the posttest. Thereafter, the design research group evaluated the modules using the evaluation rubric and six participants from the same group were interviewed by the facilitator using the interview guide of the study. On the other hand, four members of the comparison group joined a focus group discussion, reviewing the traditional learning modules they tried out and reading a second iteration learning module of the design research group. A subject expert, a senior high school mathematics teacher, was also asked to review the two types of learning modules.

Data Analysis

This study used qualitative and quantitative techniques in analyzing the data gathered in this study. In both iterations of the study, descriptive statistics were generated to describe the evaluation of the learning modules by the students, and the class observer. The four ratings in the evaluation rubric were described as excellent, good, fair, and needs improvement. From excellent to needs improvement, these ratings were coded as 4, 3, 2, and 1, respectively. Based on the data obtained from the evaluation rubric, this study used percentage scores to characterize the design principles of the study. Mean scores were computed to determine the overall student evaluation of the effectiveness and usability of the first and second iteration modules. To establish how well the technology-mediated modules facilitated the learning of the concepts in practical mathematics, Mann-Whitney test was used to compare the mean scores from the evaluation rubric of the first and second iteration groups. This test is a non-parametric which is appropriate to the study because it compared the scores between two independent samples. Each of these independent samples had a small size and a non- assumption of normality of distribution. Moreover, observation and interview data were analyzed as follows: a) coding of responses; b) validating the codes; c) identifying themes; and d) consolidating themes and information. The results of which were also used to characterize the design principles of the study.

The pretest and posttest data were used to get the gain scores of the design research group and the comparison group. In the second iteration, the gain scores of the two groups were compared using the Mann-Whitney U test. Again, this test was used because each group was a small independent sample and had a non-assumption of normality of distribution. The test results were used to determine how beneficial the design research approach was in the development of the technology-mediated learning modules in practical mathematics compared to the traditional curriculum development approach used in the private sectarian college. Also used to address the same question were the results of the focus group discussion of the comparison group, and the review of the subject expert on the two sets of online learning modules (i.e. one set improved by design research process and the other set revised according to the traditional curriculum development standard of a private sectarian college).

Chapter 4

PRESENTATION AND ANALYSIS OF DATA

This chapter presents the first iteration results and discussions as well the findings and improvements done on the first iteration learning modules of the study. Moreover, it presents the second iteration results and discussions as well as the findings and further improvements on the second iteration learning modules.

The First Iteration

The results and discussion were presented for each of the problems of the study ordered as follows: a) characterizing the technology-mediated learning modules in terms of the context of the students and design principles of the study; b) the technology-mediated learning modules in practical mathematics facilitating well the learning of practical mathematics concepts; and c) improvements on the technology-mediated learning modules based on feedbacks of the student participants, a class observer, and the researcher.

Characterizing the Technology-Mediated Learning Modules in Practical Mathematics

This study used feedback of student participants, a class observer, and the researcher as a facilitator to characterize the technology-mediated learning modules in terms of the context of students and the design principles of the study. This feedback consisted of student evaluations of the online learning modules and interview responses of the selected users of the modules. The observations of the researcher and the class observer during the implementation of the modules also formed part of the basis for improving the online learning modules.

For student evaluation of the technology-mediated learning modules in practical mathematics, the evaluation rubric was used to gauge the perception of the participants on the effectiveness of the three technology-mediated learning modules. Data collected from the evaluation rubric of the participants were measured on the ordinal scale where measure of distance between response categories is not possible. For a meaningful analysis of this kind of data, this study used bar graphs for the presentation of the data. Also, descriptive ratings and percentage scores, based on the frequency counts from the response categories of the rubric items, were used to describe student perception of the various items of the evaluation rubric.

The researcher interviewed five participants after the completion of the online study of the three learning modules. The interviewees were asked questions clustered as follows: the online learning approach, online role of teaching, tools of technology, and presentation of the online learning modules. Their responses were coded and some themes, as presented in the discussion of results, were identified from these coded responses (see Appendix T).

Data were collected from the observations of the researcher and the class observer. They decided to agree on some common observations on the following areas of the study: online learning approach, online roles of teaching, technology tools and the presentation of online learning modules.

Student Context. Of the 12 students who participated in the online study of the three learning modules, eight completed the study, who were enrolled in the following courses: a) Mechatronics NC II, b) Computer Services NC II and c) Shielded Manual Arc Welding. The manual arc welding course, enrolled by the majority of the completers at 50 percent, requires mathematics competency in performing the four fundamental operations. This competency is the mathematics requirement embedded in the problem-based tasks of the technology-mediated learning modules in practical mathematics. These problem-based tasks were rated as good by the majority of the participants at 75 percent. Such rating was indicative that the participants found the mathematical tasks and level of difficulty to be manageable. Another majority of participants, 87.5 percent, rated the lesson exercises as excellent, indicating that these exercises helped them master mathematical skills required of a lesson.

With a mean age of 17.1 years and borne into the 21st century, these student participants could be described as digital natives (Prensberg, 2005) and were observed by both the facilitator and class observer to be proficient in the use of Internet-based tools during the first iteration implementation. Themes emerging from the coded responses of the student interviewees revealed that student participants were comfortable using the technology tools in the online study of practical mathematics. Also, all agreed that the technology tools they used were appropriate and adequate to support the learning activities of a module.

The vocational contexts of the problem-based tasks of the modules were relevant to the motivation of the student participants and had generated interest in mathematics among them. The vocational contexts—ranging from calculating dimensions with appropriate units, amount of ingredients of some food recipes, electric consumptions of appliances to calculating distances between two places—provided relevant learning experiences to the student participants. These experiences may help prepare them for their future workplaces as majority of them, 75 percent, wanted to work after graduation (see Appendix U). Moreover, the problem-based tasks with vocational contexts might have generated interest among 40 percent of them to study practical mathematics and elicited good interaction from three of the four members of a group during synchronous or asynchronous discussions. However, a majority of them, 60 percent, had an indifferent attitude towards the study of practical mathematics.

Having breadwinners who were either laborers or tricycle drivers, these participants needed some financial resource, which this study had provided them, during the implementation of the first iteration modules

Online Learning Approach. Various feedback from the eight participants, researcher, and class observer were discussed and analyzed in order to characterize the online learning approach in terms of the design principles of the study which include collaborative learning through synchronous or asynchronous discussions, small group of size four, problem-based task, and whole class discussion.

Small-group Collaborative Learning Through Asynchronous or Synchronous Discussions. Figure 10 shows the data on the perception of the first iteration participants about the effectiveness of the technology-mediated learning modules in terms of the online learning approach in practical mathematics. In the first cluster on learning approach, a majority of the participants, at 75 percent, rated learning together through posting of ideas online as good. This indicates that the participants were able to learn together or collaboratively as they can communicate well their ideas through posting, and understand and learn from others' ideas in the posts. This was also observed by the researcher and the class observer as they found the participants to be learning well using the open chat. This positive finding may serve as an input in addressing today's challenge which lies in building up research literature on the impact of a constructivist approach or learning collaboratively—in teaching and learning a course via a virtual learning environment (Brandon & Hollingshead, 1999).

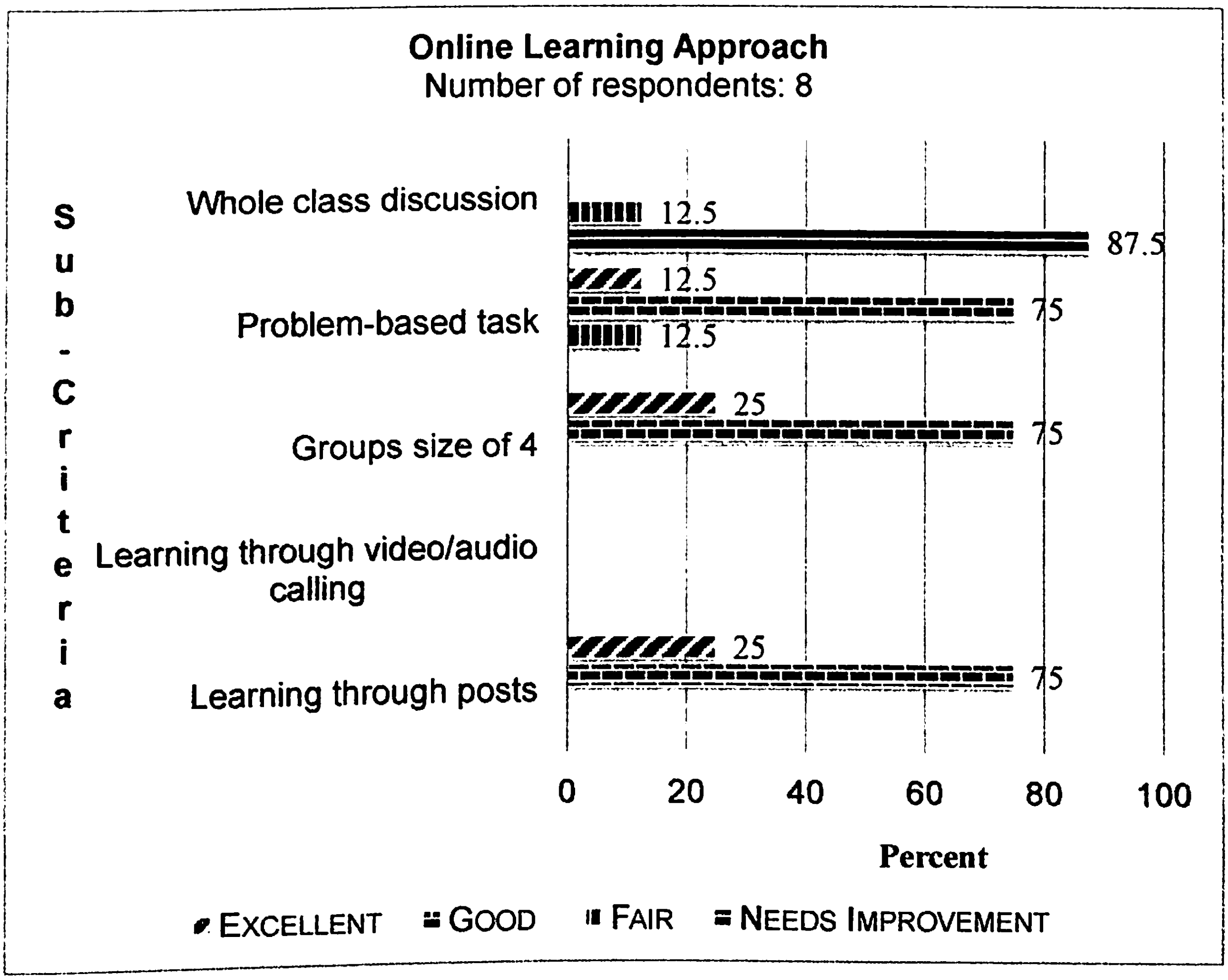


Figure 10. First iteration participants' perception of the online learning approach in practical mathematics.

In the interview of five students about how well they discussed with the other members of the group, two themes emerged from their responses. One theme showed a positive response in that they were able to discuss well with the other members of the group. Also, all were unanimous that the exchange of ideas during the online discussion was good. A significant part of the discussion dealt with the participants' questions for clarifications or enlightenment as well as the verification of the correctness of their solutions and answers. Such exchange of ideas was a positive development because, according to Paulus (2005), interaction is now increasingly viewed as a crucial component of successful online learning. Such interaction is greatly fostered in collaborative learning through asynchronous and synchronous discussions, both constructivist approaches where online teachers have assumed the role of facilitators, among others (Hege, 2011). The other theme though indicated a negative response in that they were not able to discuss well with the other members of the group because of the various reasons they offered as follows:

a) Some members of the group were just inactive because of their limited understanding on how to solve the problem.
b) Still others cannot catch up with the online discussion.
c) There was inhibition to discuss because they were not close to one another.
d) They were focused on the facilitator's inputs during the online group discussion.

When these student interviewees were further asked which form of discussion motivated them to perform a problem-based task, four of them chose synchronous discussion and one did not make any comment. Based on the typical response of an interviewee, such discussion enabled us "to do the task with teamwork and to exchange our ideas in real time." This characteristic response supported Hrastinki (2008) who explained that synchronous discussion promotes social presence and sense of belongingness among learners which are considered important elements in building teamwork in a community of learners. Supported by the tools of synchronous discussion, these online learners and teachers can get immediate attention and quick answers on social as well as academic concerns.

Both class observer and researcher observed that learning through synchronous discussion was the participants' preferred approach to the online study of the learning modules in practical mathematics. In this study, the participants were observed to thrive well because, among other things, they can get quick feedback on the answers or solutions to a problem-based task at hand. The participants' preference for synchronous discussion would reinforce an observation made in the study (Simonson, Smaldino, Albright & Zvacek, 2012) that synchronous discussion is another common learning type in an online environment. In her study, Litz (2007) also showed that the student participants, 8th to 11th grade students, used synchronous discussions to solve collaboratively a set of geometry and algebra problems.

Small Group Discussion and Whole Class Discussion. Still in Figure 9, a majority of them, at 75 percent, gave a good rating on a discussion group size of four because they found mostly three out of four participants interacting and helping each other perform the lesson tasks during the iteration. This student perception would favor the advocates of small group size who argued that the best collaborative learning takes place in a group of two to six students (Barkley, Cross & Major, 2005) or in a maximum of five participants (Spokane Falls Community College, 2005) as against the advocates of the larger group who preferred size of ten to fifteen students (Reonieri, 2006) or a group size of twenty-five students as an optimal size for asynchronous discussion (Fisher, Thompson, & Silverberg, 2015) . Moreover, this reality on the field, three out of four interacting on the task, could be viewed as the preferred discussion size of the participants since 88 percent of them gave the lowest rating, described as needs improvement, on whole class discussion on a shared output from a volunteer group. In trying to enlighten the small groups on how to design their own park, the facilitator posted a sample design of a park in hexagonal shape and Group C output on the discussion board. But as observed by the researcher and the class observer, such postings did not elicit the desired whole class interaction since there were no activities like questioning or making comments on the postings of the discussion board. Instead, each small group chose to rely on their discussion with the facilitator in designing their own park.

The student interviewees also found a small group size conducive to synchronous discussion, but the shared output on discussion board and its ensuing whole class discussion not useful. It was also observed by the class observer and researcher that the presentation of the shared output on the discussion board did not generate a class-wide interaction. Each small group was rather engrossed or focused on their online group chat with the facilitator when they performed a problem-based task. In the succeeding learning modules, not one group asked for a presentation of the shared output on the discussion board.

Authentic Problem-based Task. Again in Figure 9, a majority of the student participants, at 75 percent, perceived the problem-based task to be good which indicates that the participants were 75 percent sure of their solutions, and had enough time to perform the task and submit the output on or before the scheduled submission. In the interview of selected students, when asked about how they found the problem-based task of a module, the interviewees found its level of difficulty manageable. This was characterized by the response of one participant: "I find the problem-based task of a module not so difficult." Although they found, in general, the various problem-based tasks manageable, they still experienced difficulties in analyzing some problem-based tasks like metric conversions of metric units, and ratio and direct proportion. Emerging from the interview responses, the theme identified for individual exercises of the modules indicates that the number of items in the exercises were enough and their level of difficulty manageable. On the last activity, the student interviewees did not bother to solve most of the assignments because they already had enough knowledge on the lesson, enough of the lesson activities, and were also busy with their schoolwork. Also, they were amenable to the weekly deadlines of the submissions of group outputs as long as these would not compete with their schoolwork. As said by one interviewee, "weekly is fine if it is not in conflict with our schoolwork." He furthered that "these weekly deadlines gave us time to prepare and discuss well the lessons."

As a general observation in the problem-based task by each group, the class observer and researcher noted that the participants had managed to perform the problem-based task and to solve it before or on the scheduled time of submission. Moreover, in the problem-based task of the lesson 1.1, the researcher and the class observer noticed that a lot of questions were raised on the strategy to get the perimeter of the ground covered with Bermuda grass and on how to make the ground design of a park despite an illustration of a floor plan in the module as a guide in designing the ground of a park. In the problem-based task of the lesson 1.2, all groups were observed to have some difficulty of devising strategies to get the areas of the concrete border and the ground covered with Bermuda grass. Figure 11 shows the portion of an open chat of Online Research Group A that illustrated such common difficulty of the three groups. These observed difficulties and some others in the problem-based tasks of lessons 1.5 and 1.6 cropped up during the synchronous discussions on these problem-based tasks. Indeed, this situation was anticipated by Hranstinki (2008) when he wrote that the strengths of asynchronous discussion are the limitations of synchronous discussion. He went on to explain that working on complex tasks cannot be accommodated well by synchronous discussion because it does not provide ample time for understanding the complexity of the task and reflection on how it should be solved. One may also observe that the level of mathematics involved in lessons 1.1 and 1.2 is simple in its applications but may need the use of complex reasoning in solving the problem-based task (Zwart, 2000; Rose, 2012).

Relative to the objectives in the lessons 1.3 and 1.4, they further observed that some items in the problem-based tasks of these lessons were quite long and unnecessary. These included:

a) The list of food items in lesson 1.3;
b) The calculations to obtain the weekly total values of selected ingredients;
c) The list of appliances in lesson 1.4;
d) The question in lesson 1.3 soliciting possible reasons should there be any supply problems of these selected ingredients.

In the problem-based tasks of the succeeding lessons, the researcher and the class observer continued to observe the following:

a) In lesson 1.5, the participants of various groups initially were confused on how to find the width, length and height dimensions of the illustrated carton box and had some difficulty grasping the concept of a variable as a measure of dimensions of the carton box. Figure 12 portrays such situation.

b) They were able to solve the items in the problem-based task of lesson 1.6 after showing them examples on translation and solving equations involving one variable.

Online teacher	**For question no.1 of lesson 1.2, you are asked to get the area of the concrete border. Yes, based it on your previous drawing.**
Jelyn	Ahh ok sir. Isa rectangle among gamiton o duha kay L shape man gud to..naglibog me ug unsaon namo pag answer sir.. (Ahh ok sir. Are we going to use 1 rectangle or two because of the L-shape? We really are confused on how to answer this item.)
Online teacher	To get the area of the concrete border, subtract the area of the inside L-shape from the area of the bigger L-shaped park.
Editha	Wait..try nako og solve. (Wait... I will try to solve it.)
Online teacher	Is Alfred with you?
Andy	I will also try sir.

Figure 11. Portion of open chat on online Research Group A illustrating the common difficulty of the three groups in module 1.2.

Online teacher	
Roger	Confused ko gamay sir if asa gikuha ang numbers. (I am a bit confused where we'll get the numbers.)
Randy	Nalibog ko sa numbers sir. (I am confused on the numbers sir.)
Online teacher	We use letters here, Roger and Randy. We call them variables.
Roger	So every letter equivalent to 1?
Online teacher	and this variable may represent a number.
Randy	Ahh..okay sir..I thought there is a given number for every variable. That is why I am confused.
Online teacher	A letter or a variable may represent a number
Roger	At the same time sir, confused ko if asa ang height og ang width and length. (At the same time sir, I am confused where to find the height, width and length.)

Figure 12. Portion of Group C's open chat on polynomials.

Finally, in the problem-based task of lesson 1.7, the participants were more engrossed on calculations involving distance, amount of fuel needed and time of the whole trip than applying the concept of ratio and direct proportion. The four questions of the problem somehow detracted from the participants' effectiveness in addressing the objectives of the lesson.

Online Roles of Teaching. Feedback from student perceptions, interview responses, and observations were discussed and analyzed to characterize online roles of teaching in terms of the design principles which include: as a facilitator, having social presence, feedback giver, course designer, and as a manager.

As a Facilitator and Feedback Giver. Figure 13 shows the participants' perception on online roles of teaching. In the design principles used by this study for online roles of teaching, facilitating and feedbacking roles each got an excellent rating by all participants. In this second cluster, all participants found the online teacher to be an excellent facilitator and feedback giver. As the facilitator, he had always provided good inputs to guide the learning process and always used strategies to keep the participants fully engaged. As a feedback giver, he had provided all answer keys to the exercises in the learning modules and checked all the group outputs. Such perception would confirm Bischoff (2000) that facilitating well impacts significantly on the effectiveness of learning and teaching in an online environment. It can also add support to the study of Liu et al. (2005) that providing timely and high quality feedbacks is equally an important role of an online teacher. The student perception on the teacher's performance of facilitating and feedbacking roles was also validated by the class observer. The filled-up observation guide of the class observer showed as highly evident the online teacher's assumption of the role of a facilitator and as evident on his being a feedback giver (see Appendix V). Noted as highly evident was the facilitator's satisfactory guidance of the online learning process and his ability to respond satisfactorily to the concerns and questions of the participants.

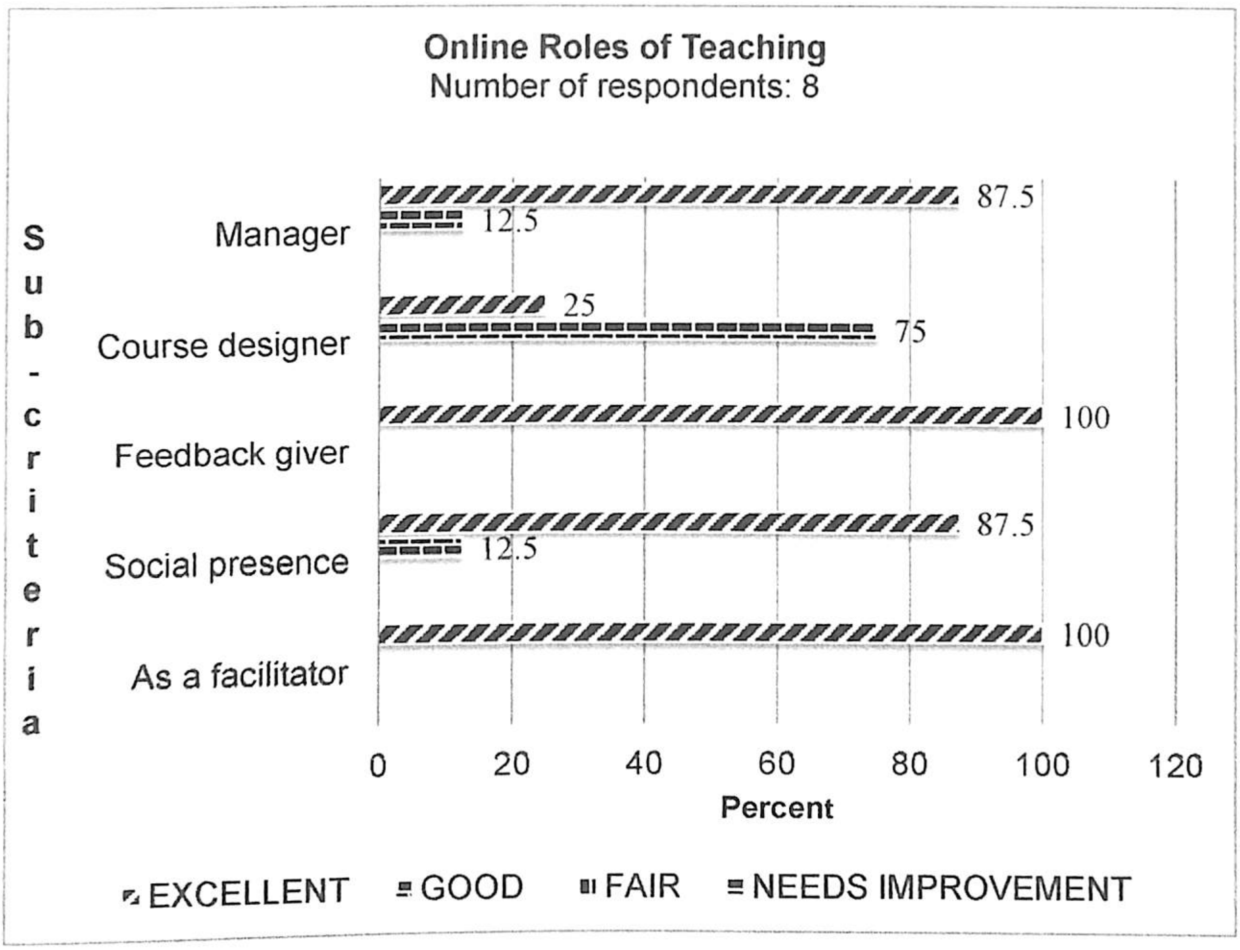


Figure 13. First iteration participants' perception of online roles of teaching practical mathematics.

Among others, two themes emerged from the interview responses on being a facilitator and a feedback giver by the online teacher. Presented below were the responses of the interviewees on how well they were facilitated by their teacher:

a) " In every discussion, our facilitator is always present and guiding us in every task."

b) "The teacher helps us understand the problem. He gave us a formula and example about the problem."

c) "Yes, as I have said it a while ago, he is responsive in guiding us...because if he notices that the group is still not sure in their answers or in a loading mode, our teacher finds ways to develop our skill (i.e. he gives us a guide or answers the first question, gives exercises during the chat and also asks for a recall). "

On the feedbacking of the online teacher, one interviewee commented: "It was great." Another would say that the teacher's feedback on our mistakes had guided us until " we can get the correct solution and answer."

Having Social Presence, as a Manager, and a Course Designer. A large 88 percent of the participants rated excellent the teacher's social presence in the online setting. Such presence consisted of being a friend and not only as an instructor, having introduced himself and allowing the participants to introduce themselves. Noted as evident by the class observer was the self-introduction of the online teacher as well as the opportunity given to the participants to introduce themselves. When asked how they experienced the presence of the online teacher, majority of the interviewees felt very well his presence during group work and reported that the teacher knew them well. The participants' perception of friendship with the online teacher is indeed a very important because, according to Berge (1995), learners must feel welcomed and have a strong sense of belongingness to an online learning community before he is expected to participate and engage with other members in performing an online task. As also emphasized by Garrison and Anderson (2003), social presence is an important element to achieve a successful collaboration.

Another majority, 88 percent of the participants, rated the online teacher to be an excellent manager which indicates that he gave a very satisfactory orientation on the house rules of online learning and responded very satisfactorily to all the participants' concerns and questions that affect online learning of this course. The house rule orientation and the teacher's satisfaction of participants' concerns were also noted as evident by the class observer. On teacher's management of activities, the student interviewees had these positive remarks like "teacher's adequate time for group discussion in his presence" and "his encouragement for us to perform the task until its completion." A smaller majority, at 67 percent, found the online teacher to be a good course designer as they agreed that activities found in all of the seven lessons were planned and organized very well. Upon closer examination of the technology-mediated learning modules, the class observer, affirming the student perception on course design, found the module's instructions clear and the lesson objectives' being clear, measurable, and achievable.

These positive perceptions on the managerial and designing aspects are the desired outcomes of the proposal of Berge (1995) on the online roles of teaching. According to Berge (1995), structuring well the content, managing effectively online discussions, communicating expectations and requirements, and laying house rules at the start of the online course would establish order and provide better educational experience in a virtual learning community.

Technology Tools Used. Figure 14 shows the participants' perception of the technology tools used in the online learning of practical mathematics. In the third main cluster on technology tools, 100 percent of the participants perceived online chat as an excellent tool which indicates that all of them used it to communicate ideas about what they know and how to solve the problem-based task of a lesson. The participants' most favorable response on the use of online chat aligned itself with the observation of Gil (2012) that, from the public online chat room of 1990s and 2000s, instant messaging, or also called online chat, has evolved into what is now as a popular and cheaper way of conducting a text-based communication between the users. Another 75 percent viewed Facebook, the chosen social network site of the study, as most conducive for online learning of the courses since they rated the social network site another excellent technology used in the study.

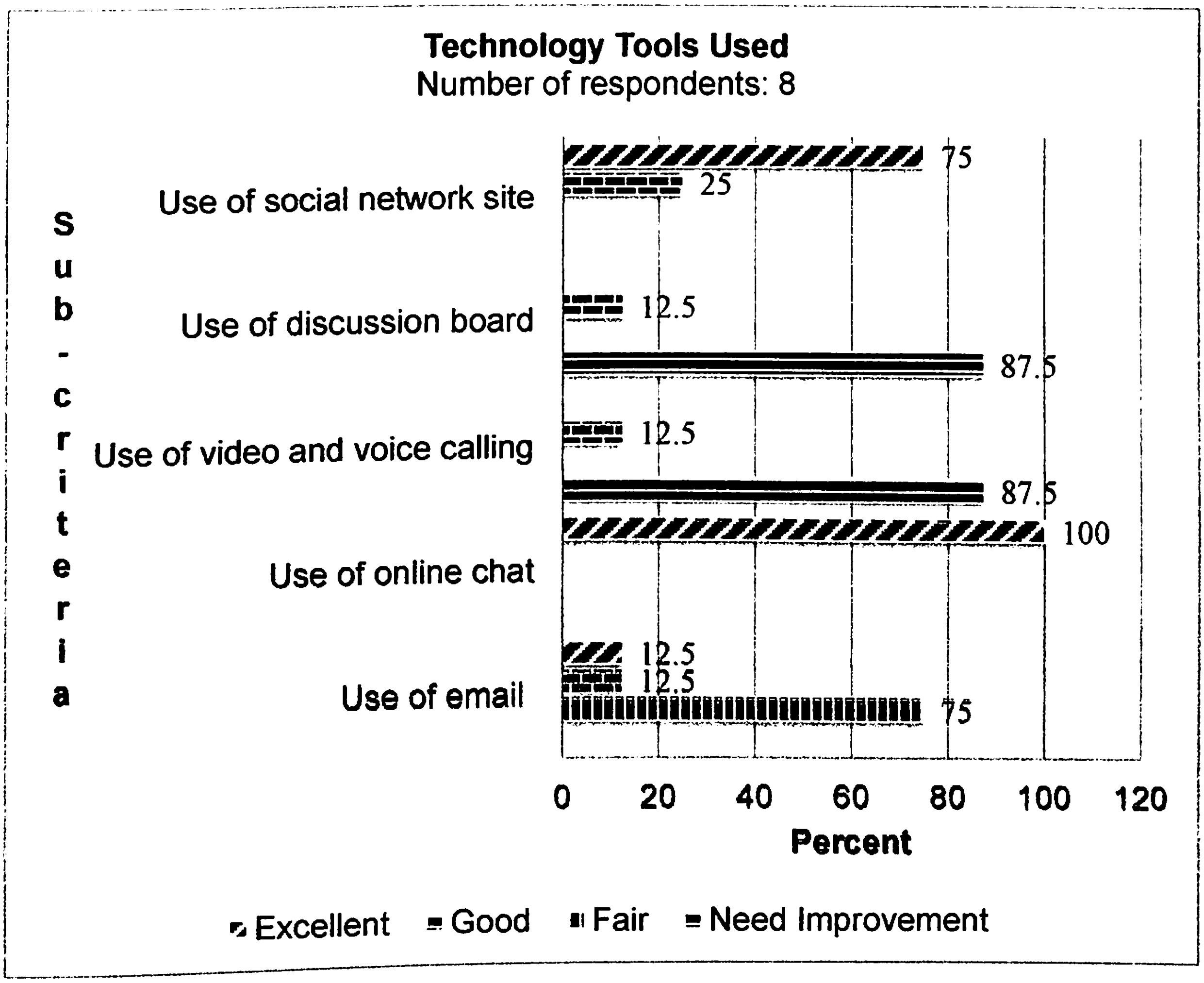


Figure 14. First iteration participants' perception of the technology tools used in learning practical mathematics.

The participants, as observed by the class observer and the researcher, enjoyed the ease and convenience of using Facebook because the site provided them tools of instant messaging and file sharing in discussing and performing a problem-based task at hand. As noted by Gross (2004), students also used social network sites for online learning and more meaningful and serious deliberations. The very positive perception of the participants on Facebook supported the study of Villiers and Pretorius (2013) who found Facebook to be a conducive learning environment that has supported, among others, effective peer learning and a successful social negotiation. Also, it affirmed another study that showed a social network site like Microsoft Share Point 2007although not Facebook this time but still is a social network—as an enabler of group learning and collaborative work (Mora-Soto, Sanchez-Segura, Medina-Dominguez & Amescua, 2015).

Examining the downside of this cluster, 87.5 percent of the participants found video or voice calling as a technology tools that need improvement. Based on the interview of the selected participants, they could not use these technology tools to communicate or discuss a lesson because of the weak connection issue encountered in the various Internet cafes that they visited. This poor Internet connection was also highly evident in the course of observation by the researcher and class observer. The participants' inability to use these tools also would underscore the ongoing problem of slow Internet connection in the Philippines which suffers from having the slowest but very expensive Internet speed in Southeast Asia and one of the slowest in Asia (Venus, 2016). Also, the same percentage found the use of discussion board for whole class discussion as another area that needs improvement, which was also in accordance with the observation of the researcher and class observer. Such student perception indicates that nobody used the discussion board to see a shared output and discuss it class-wide. This could be tied up to what this study would view as the preference of the participants for a small group discussion with the facilitator over a class-wide discussion involving twelve participants. Still on the downside, 87.5 percent rated the use of email to be fair which indicates that it was least used by the participants during the online study. This also emerged as a theme from the interview responses on the use of email by the student interviewees. Although email can be a good tool for asynchronous discussion, its functionalities, uploading and downloading, are well-assumed by Facebook, the groups' chosen social network site. Facebook has made available to the participants much faster and more convenient services that include instant messaging, uploading and downloading of files, pictures, video and audio calling. These were very important tools for sharing information in collaborative learning.

On the technology tools used in the study, the following themes emerged from the coded responses of the student interviewees. They were comfortable using the technology tools in studying practical mathematics online. They were unanimous on online group chat as often used during group discussions while email, video calling, and audio calling were tools not used or least used by the groups. Moreover, all agreed that the technology tools they used were adequate to support and appropriate to the learning activities of the module. Such total agreement of the participants on the support and appropriateness of technology to the learning activities of the module only affirmed the study of Wang (2013) who designed an online learning environment that used internet-based tools to support learners' collaboration on course group assignments at the National Institute of Education in Singapore. After completing his two-stage design research, he concluded, among others, that the effective strategy for collaborative learning on course assignments was the use of asynchronous and synchronous tools, both Internet-based tools . On the difficulties encountered in the use of technology tools, all pointed out to the issue of the weak Internet connection in the Philippines. Because of the connection issue encountered by the participants in the Internet cafés that they visited, they could not use video and audio calling as a tool to communicate with their facilitator.

As observed by the researcher and class observer, the participants' use of email, audio and video calling to communicate or discuss a lesson was not evident. Facebook has functionalities that make email unnecessary and inconvenient in the course of the online study. Through Facebook, the participants were able to send files or pictured written works to their group account much faster than sending the same through email. Because of the issue of weak or slow Internet connection, the participants were not able to use the synchronous technology tools like video and audio calling. Also not evident was the use of discussion board as a platform to view and discuss the shared output of a volunteer group. But the use of online group chat and Facebook were highly evident in the online discussion of the problem-based tasks in the seven learning modules in practical mathematics.

Presentation of the Online Learning Modules. Figure 15 shows the participants' perception on the presentation of the online learning modules of the study. In this last cluster of evaluation, 75 percent of the participants found the use of multimedia to be good which indicates that a lot of the video materials and written helpful notes from the video have helped the participants learn the lessons in the modules. The class observer and researcher had also noted as evident the usefulness of the multimedia presentation on online learning modules.

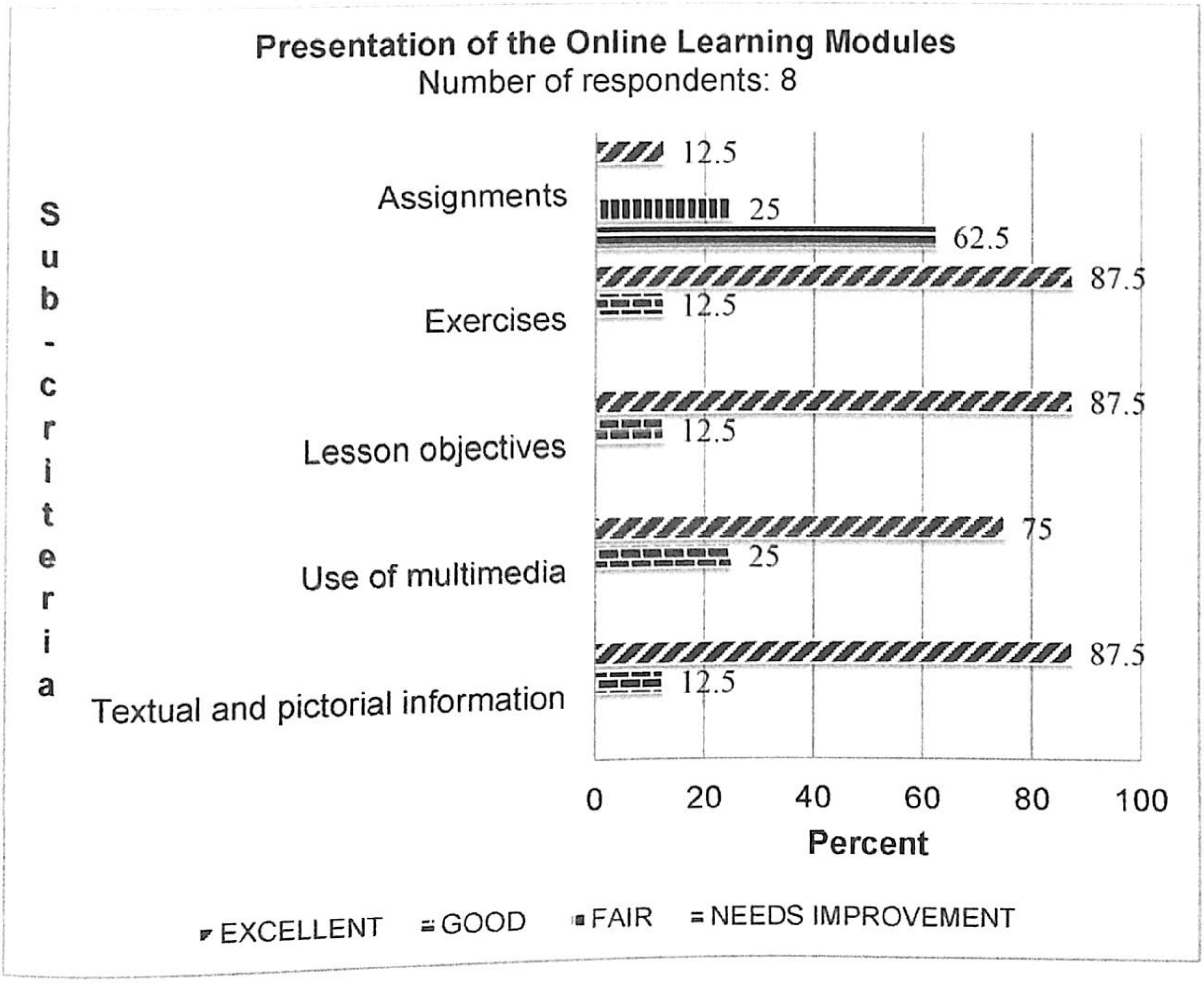


Figure 15. First iteration participants' perceptions of the presentation of technology-mediated learning modules in practical mathematics.

Moreover, the themes that emerged from the coded interview responses on the tutorials in video format and on helpful notes were positive and encouraging. To use the words of the two student interviewees, the video tutorials were "good especially to those who lacked knowledge on the lesson", "clear and effective", and did enhance the social presence of the facilitator. The students' positive description of the video tutorials may add to the growing literature on the positive effects of streaming video on student achievement and attitudes (Keefe, 2003; Boster, et. al, 2006; Lampert & Ball, 1990). This would also support the study of DeVaney (2009) that showed the positive perceptions of his participants on the impact of video tutorials in an online educational statistics course and the participants' suggestions that the video tutorials be an essential part of the online course. DeVaney (2009) further suggested that the video presentations used as supplemental materials may provide a good tool to create online courses as effective as the campus-based courses. On the other hand, the helpful notes, in the words of the other interviewees "were very helpful", "provided a good concept so that we won't forget the important inputs coming from the video tutorials", and "helped us develop our skills and understanding of the lesson." Such overall positive response on the multimedia presentation validated the cognitive theory of Mayer (2001) which essentially states that " people learn deeply from words and pictures than from words alone." Also, it is similar to the study outcome of Neo and Neo (2003) which showed that the multimedia presentation of the lesson is very helpful in student construction of knowledge and in enhancing a constructivist learning environment.

The textual and pictorial information in the modules, rated excellent by 87.5 percent of the participants, must have appealed to "how human brain works", a further condition of Mayer (2001), because, in a lesson, the participants found the instructions clear, words used very well-understood, and pictures highly motivating and interesting. Again, the same percentage of participants, 87.5 percent, found the lesson objectives and exercises to be excellent. This indicates that the lesson objectives were perceived by these participants to be clear, measurable, and achievable in most modules. When the student interviewees were asked to comment on the words used and the instructions in the learning modules, a typical response was ease of understanding the text of the modules because these modules used "simple words". Furthermore, all agreed that the lesson objectives were well-arranged and doable. The exercises with answers, moreover, have always helped them understand most of the lessons in the learning modules. The exercises with answer keys were helpful in reinforcing the participants' skills and knowledge. Most of them though did not answer the assignments, being the last activity of a lesson. This was so because they already had enough of the earlier lesson activities (i.e. problem-based task, watching video tutorials and helpful notes, individual exercises with answer keys and group chats) to help them perform the various problem-based tasks. As best expressed by one interviewee: "I found no need of the assignment and that is why I did not answer them." When asked on the sources of learning they had on knowledge and skills in practical mathematics, they answered that almost all of the learning acquired came from the online study of the learning modules in practical mathematics.

At the downside of this cluster, 62.5 percent assigned the lowest rating, described as needs improvement, to the assignments in the learning modules. In an interview of selected participants, one interviewee made a comment on the assignment: "I found no need of the assignment and that is why I did not answer them." The comment could be explained in the light of the cognitive load theory of Sweller and Chandler (1991). The assignment, presented in textual form, puts up an extraneous load which might not help the limited cognitive resource to process the intrinsic load (i.e.

the inherent difficulty in the assignment) and the germane load (i.e. processing, construction and automation of schema). This makes an assignment an unattractive task to engage in after performing all lesson activities which included the problem-based task. Besides, an assignment in a lesson was not part of the submissions to the online teacher.

Student Evaluation of the Technology-mediated Learning Modules in Practical Mathematics

This study used mean scores to rate the design principles of the study, grouped into four clusters: online learning approach, online roles of teaching, technology tools used, and presentation of the online learning modules. Various ranges with corresponding descriptive ratings were created for the mean scores (see Appendix W). These mean scores were obtained from the sub-criteria of the four clusters in the evaluation rubric. An overall mean score was obtained in order to describe the general perception of the student participants on the technology-mediated learning modules in practical mathematics.

Online Learning Approach. In the first cluster, the sub-criteria of the online learning approach consisted of the following: a) collaborative learning through posting of ideas; b) a group discussion size of four participants; c) problem-based task; and d) whole class discussion. Obtaining a mean score of 2.8 out of four from these sub-criteria, the online approach of the study was perceived by the student participants to be a good learning approach. This favorable student perception is similar to the students' perception of the e-learning environment in the study of Chang, et al. (2009). In the present study, 75 percent of the student participants, after trying out the online modules for two months, assigned good ratings on collaborative learning through posting of ideas and on the problem-based tasks. They were able to learn well in collaboration with each other as they communicated well their ideas through posting, tracked and understood others' posted ideas, and learned from others' ideas in the posts. Still a majority of them, at 75 percent, found the problem-based task to be manageable, had enough time to perform the task and were sure of their solutions. Similarly, Chang et al. (2009) have reported a higher level of preferences for peer learning, critical thinking, and problem-based task among the participants of his study after one semester of online learning on a Flemish course.

As they tried to solve a problem in the present study, 75 percent of the participants reported that they interacted well in a small group rather than in a whole class discussion. This is what the advocates of small size of discussion groups have argued that a small group size enhances group work and discussion, and is best conducive for collaborative learning (Barkley, Cross & Major, 2005; Du, Durrington & Mathews, 2007; Fernandez, 2007).

Online Roles of Teaching. With a mean score of 3.8 out of four, this cluster garnered an excellent rating from the student participants, the highest one among the clusters. In this student perception of an excellent online teaching, the assumed role of a facilitator got the highest mark. This excellent perception of being a facilitator is in support of some research outcomes showing that facilitation is a scaffold for processing of greater complexity of information (Morie-Dershire, 1996), a factor that significantly contributes to the effectiveness of learning and teaching in an online environment (Bischoff, 2000), and is being perceived as taking the primacy role of online teaching in this virtual learning environment (Liu, Bonk, Magjuha, Seung-hee Lee,& Su, 2005). Also, this excellent cluster lends support to Berge's proposed roles of online teaching categorized as pedagogical, social, and managerial roles. Among others, Berg (1996) viewed an online teacher as assuming the roles of a facilitator, feedback provider, social presence, manager, and a course designer in which these roles are the evaluative items of the this cluster. In this study, all student participants perceived that they were well-guided in the learning process, fully engaged with the task on hand, and always received feedbacks on their submissions. Moreover, 88 percent of the student participants perceived that they were afforded the opportunity of self-introduction and the teacher's introduction. They also perceived their online teacher not only as an instructor but also a friend as well. Still a majority of the student participants, 88 percent, also reported high satisfaction with the well-thought out and well-organized activities in the learning modules, the course orientation, and the teacher's responsiveness to their needs and concerns.

Technology Tools Used. In this cluster, this study allowed the following technology tools for use of the student participants including: a) emails for asynchronous discussions; b) group chat, voice and video calling for synchronous discussions; c) discussion boards; and d) the use of a social network site. With a mean score of 2.8 out of four, the cluster of technology tools used received a good rating from the student participants. This array of technology tools may find support in the validated design principles of Wang (2013) who designed the use of Internet-based tools to support online learners' collaboration on course group assignment. In his design research, he found out that the use of authentic tasks, choice of a social network site, and use of asynchronous and synchronous tools to support group interaction are good principles to design a collaborative, Internet-based online learning environment. Similarly, in the present study, the participants were given a choice of their social network site, and could use the synchronous and asynchronous tools as they engaged in learning collaboratively in small groups. All participants perceived online chat as an excellent tool to communicate ideas and discuss lessons, and Facebook as most conducive for online learning of the modules. Considering the participants' excellent perception on the use of online chat and Facebook, the Internet-based tools which they often used in the study, this finding also affirms some research studies which reported that social network sites were also used by students for online learning and more meaningful and serious deliberations (Gross, 2004), and that Facebook supports effective peer learning, successful social negotiation, group learning and collaborative work (Villiers & Pretorius, 2013; Mora-Soto, Sanchez-Segura, Medina-Dominguez & Amescua; 2015).

Presentation of the Online Learning Modules. With a mean score of 3.3 out of four, this cluster received a good rating from the student participants. Such mean score came from the following evaluative items that include: a) textual and pictorial information; b) use of multimedia; c) lesson objectives; d) exercises; and e) assignment. Supporting Mayer's theory (2001) that " people learn deeply from words and pictures than from words alone", 87.5 percent of the participants in the present study perceived the multimedia presentation of the modules (i.e., in video, words, and pictures) as helpful in learning the lessons in practical mathematics. With collaborative learning as the learning approach of the study, this perception can be compared to some study outcomes which showed that the multimedia presentation of the lesson is very helpful in fostering greater student engagement, student construction of knowledge, and in enhancing a constructivist learning environment (Neo & Neo, 2003; diSessa, 2001). Worth noting also in the present study is the positive perception of the video tutorial as part of the online module that finds agreement with DeVaney (2009) who reported the participants' positive perceptions of the video tutorials in online learning and their suggestions that video tutorials are an essential part of the online course. A majority of the participants, 87.5 percent, found the instructions of the modules were clear, words used well-understood, and the pictures were highly motivating and interesting (Mayer, 2001). They furthered that the exercises with answer keys reinforced their understanding of the lessons of the modules and that the lesson objectives were clear, measurable, and achievable in most modules.

Table 2 shows the overall mean score which was obtained from the scores of the 19 items of the evaluation rubric on the effectiveness of the online learning modules. Found at the higher end of the range 2.5 – 3.4 with a descriptive rating of good, the overall mean score of 3.2 suggests that the participants of the study perceived the technology-mediated learning modules to be good learning modules in learning the concepts of practical mathematics.

Improvements Done on the First Iteration Learning Modules

Using the findings of the first iteration based on the feedback of the student participants, class observer, and the researcher, this study has taken some actions for improvement of the technology-mediated learning modules in practical mathematics.

Table 2

First Iteration Student Perceptions of the Technology-Mediated Learning Modules in Practical Mathematics by Cluster

Cluster	Mean Scores	Descriptive Ratings
Online learning approach	2.8	Good
Online roles of teaching	3.8	Excellent
Technology tools used	2.8	Good
Presentation of the online learning modules	3.3	Good
Overall mean score	3.2	Good
Number of respondents	8	

These include:

1. Encourage asynchronous discussion on identified areas of difficulty in the various problem-based tasks for longer and deeper reflection. These would include:
    a) Designing the ground of a park in lesson 1.1;
    b) Devising strategies to calculate the perimeter and areas of the desired figures in lesson 1.1 and 1.2;

c) Understanding the concept of a variable as a measure of dimensions of the carton box and finding the dimensions of the carton box in lesson 1.5.

Make some changes in the problem-based tasks of the following modules:

a) In the lesson 1.1, the illustrated floor plan is replaced by another illustration that will be a good guide because it is simpler and less complicated in designing the ground of a park.

b) In lesson 1.2, the last three questions involving the lateral area and water volume of the park's fountain, and the fountain's specifications, the bases of the last three questions, are removed from the above module.

c) In lesson 1.3, the following changes are made:

    c.1) Delete one food item, Asian Adobo, from the menu.

    c.2) Delete a redundant sub-item in the first question of the problem-based task involving conversion of mg.

    c.3) Change calculation of selected ingredients from weekly amounts to daily amounts.

    c.4) Delete the last question asking for reasons in case there is a supply problem of the selected ingredients.

d) In lesson 1.4, shorten the list of appliances, which will consequently reduce the load of calculating task in order to focus more on the conversion between metric units, from nine appliances to seven appliances.

e) Delete the two questions that involved the lateral areas of the carton box from lesson 1.5.

f) Revise the questions in the problem-based task of lesson 1.7 to limit calculations of distance, fuel, and time to a one-way trip so that more attention is given to the application of ratio and direct proportion in the problem.

2. Focus on the use of online chat as the technology tool in discussing and performing the problem-based task in a learning module.
3. Two lesson activities, sharing out and discussion, and making the assignments, are removed from the first iteration learning modules in practical mathematics.

The Second Iteration

The results and discussions were presented for each of the four problems of the study which now included the question: how beneficial was the design research approach in the development of technology-mediated learning modules in practical mathematics compared to the traditional curriculum development approach used in schools?

Characterizing the Second Iteration Technology-Mediated Learning Modules

In order to characterize the student context and second iteration technology-mediated learning modules in practical mathematics, this study used and analyzed student feedbacks from another group of student participants, interviews of six selected participants from the new group, and observations of the researcher. Data collected from the evaluation rubric of the participants were measured on the Likert scale where measure of distance between response categories is not possible. Of the 19 items in the evaluation rubric used during the first iteration, four items were taken out from the rubric which was used to evaluate the second iteration modules. One removed item dealt with the use of video or voice calling, which cannot be used due to weak Internet connection. The other items dealt with discussion boards, emails and assignments which were no longer part of the second iteration learning modules. For a meaningful analysis of this kind of data, this study used the percentage scores, based on the frequency counts from the response categories in each of the 12 items of the evaluation rubric, and bar graphs for the presentation of this data. Also, qualitative analysis was conducted on the interview responses of the selected student participants.

Student Context. As all specialized in manual arc welding course, these 12 participants rated good or excellent, better ratings relative to those of the first iteration group, the problem-based tasks of the second iteration modules. This indicates again that the participants found the mathematical tasks and level of difficulty as manageable. A characteristic reply of those students interviewed (see Appendix X) revealed that "a problem-based task was not difficult and simple enough to be understood. " With a mean age of 17 years, these participants could again be described as digital natives, being borne into the 21st century. They rated excellent Facebook and online group chat as technology tools used in the study. Interview outcomes of selected participants showed unanimous agreement about the comfortable use of the Internet-based tools, adequacy of these tools to support learning needs, and appropriateness to their learning activities.

The problem-based tasks of the second iteration modules, simplified and improved by the feedback of the first iteration, had enhanced mathematical interest among student participants. A majority of these participants, 67 percent, liked to study practical mathematics, while only 37 percent remained indifferent to such study. The variety of the vocational contexts of the problem-based tasks were maintained in the second iteration modules. These could provide again relevant and helpful learning experiences to the majority of the participants, 50 percent, who planned to find work after graduation from senior high school. The provision of Internet allowance had been maintained and extended to these participants who did not have the financial resource to gain Internet access for this study. Their family breadwinners were either farmers, laborers, or drivers (see Appendix Y).

Online Learning Approach. Figure 16 shows the data on the perception of the 12 participants about the effectiveness of the technology-mediated learning modules in terms of the online learning approach in practical mathematics. In the first cluster on learning approach, 50 percent of the second iteration participants found collaborative learning through posting of ideas on group chats to be excellent, which was a significant improvement relative to the majority perception of the first iteration participants. By comparison, only 25 percent of the first iteration participants rated the same sub-criterion as excellent. Moreover, a theme from the interview responses, all six of those interviewed, showed that collaborative learning through synchronous discussion motivated the participants to perform a problem-based task because, in the words of one participant that echoed the opinions of the majority, "we could communicate well and respond easily to one another." Added another participant: "synchronous communication really helped us a lot." As noted by the researcher, asynchronous discussion was then encouraged by the online teacher to provide ample time for the participants to reflect on the park designs and the strategies on how to obtain those difficult dimensions and areas of the park. It was also used in analyzing the problem-based tasks in lessons 1.5 and 1.6.

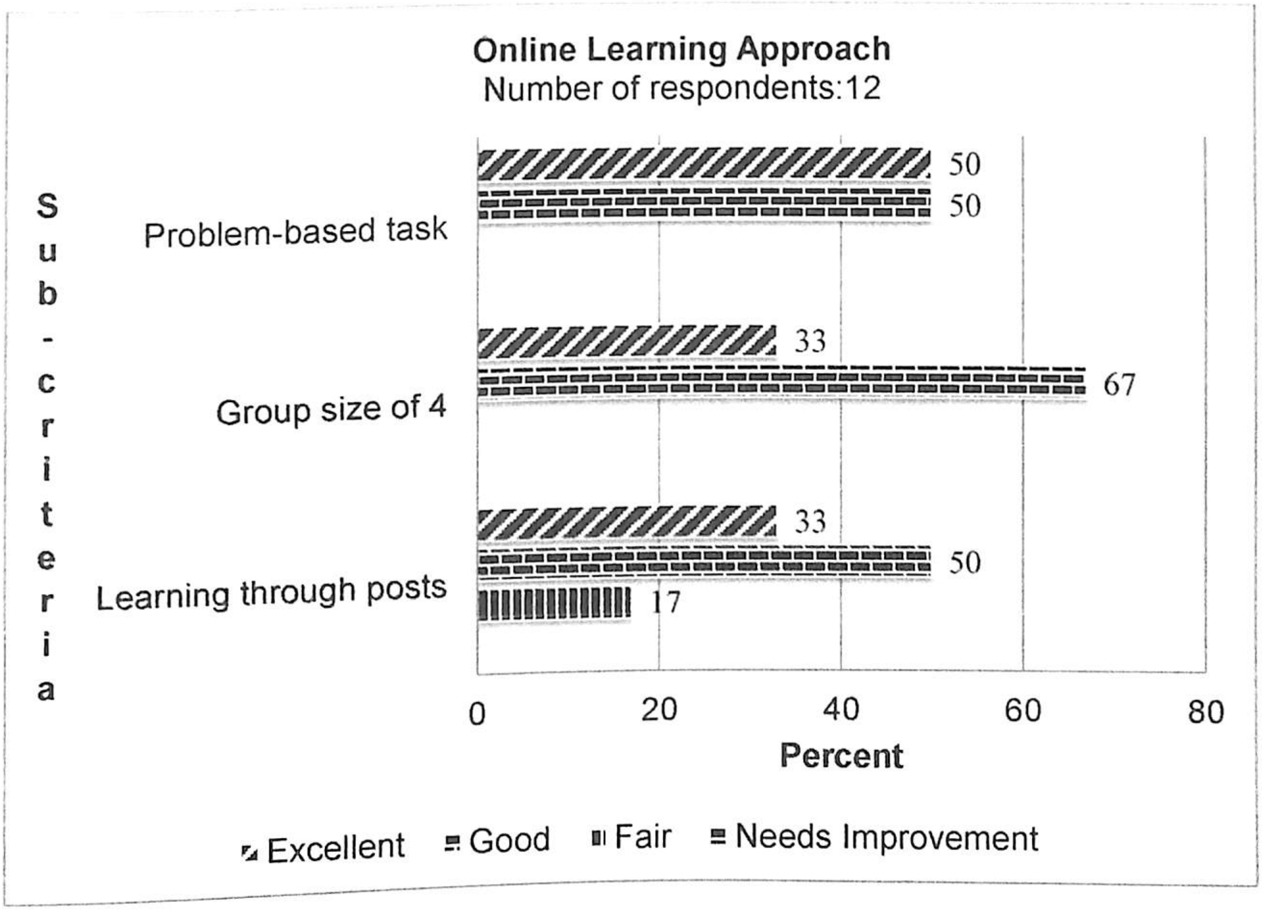


Figure 16. Second iteration participants' perception of the online learning approach in practical mathematics.

On the size of the discussion group, 67 percent of the second iteration participants reported it to be good, indicating that only three out of four members were interacting to perform the lesson tasks. By comparison, also a majority of the first iteration participants, at 75 percent, rated the size of discussion group as good. It was also observed by the researcher that interaction in online discussions of each group consisted mostly of three active members. While Du, Durrington and Mathews (2007) reported students' preference of four to six members to constitute well a discussion group, Fernandez (2007), on the other hand, proved that a group size of three learners is an effective group size for discussion. In both iterations of the study, the average number of active members in an online discussion would conform to the finding of Fernandez (2007).

On the problem-based task, 50 percent of the second iteration participants perceived it to be good, indicating that the task was manageable such that they were 75 percent sure of their solutions, and found enough time to perform the task and submit it on or before the schedule. The other 50 percent stated that they were 100 percent sure of their answer and found plenty of time to solve a problem and submit its solution on or before the schedule. Based on the interview responses of the participants, they unanimously stated that the problem-based task of a module was generally enough and not so difficult (see Appendix Y). A characteristic reply of these participants revealed that "the problem-based task was not difficult but simple enough to be understood." When compared to the perception of the first iteration participants on the problem-based task, the perception of the second iteration participants was a better one as it showed a relatively higher 50 percent of them rating the problem-based task as excellent. It should be noted here that the problem-based tasks in the second iteration learning modules were already modified or adjusted based on the findings and improvements done on the first iteration learning modules.

Online Roles of Teaching. In the second cluster, the perceptions of the second iteration participants on the five sub-criteria were all excellent. All participants gave excellent ratings to the online teacher as a facilitator and a feedback giver (see Figure

17). This was followed by a large 92 percent of the participants rating the management skills of the online teacher to be excellent. Next was 82 percent who rated the teacher's social presence to be excellent. Last, sixty-five percent found him to be an excellent course designer. By comparison, the ratings of the second iteration participants on the various sub-criteria of online teaching were relatively similar to the ratings of the first iteration participants. These similar findings might well imply that online teachers must have the skills required to effectively assume the online roles of teaching.

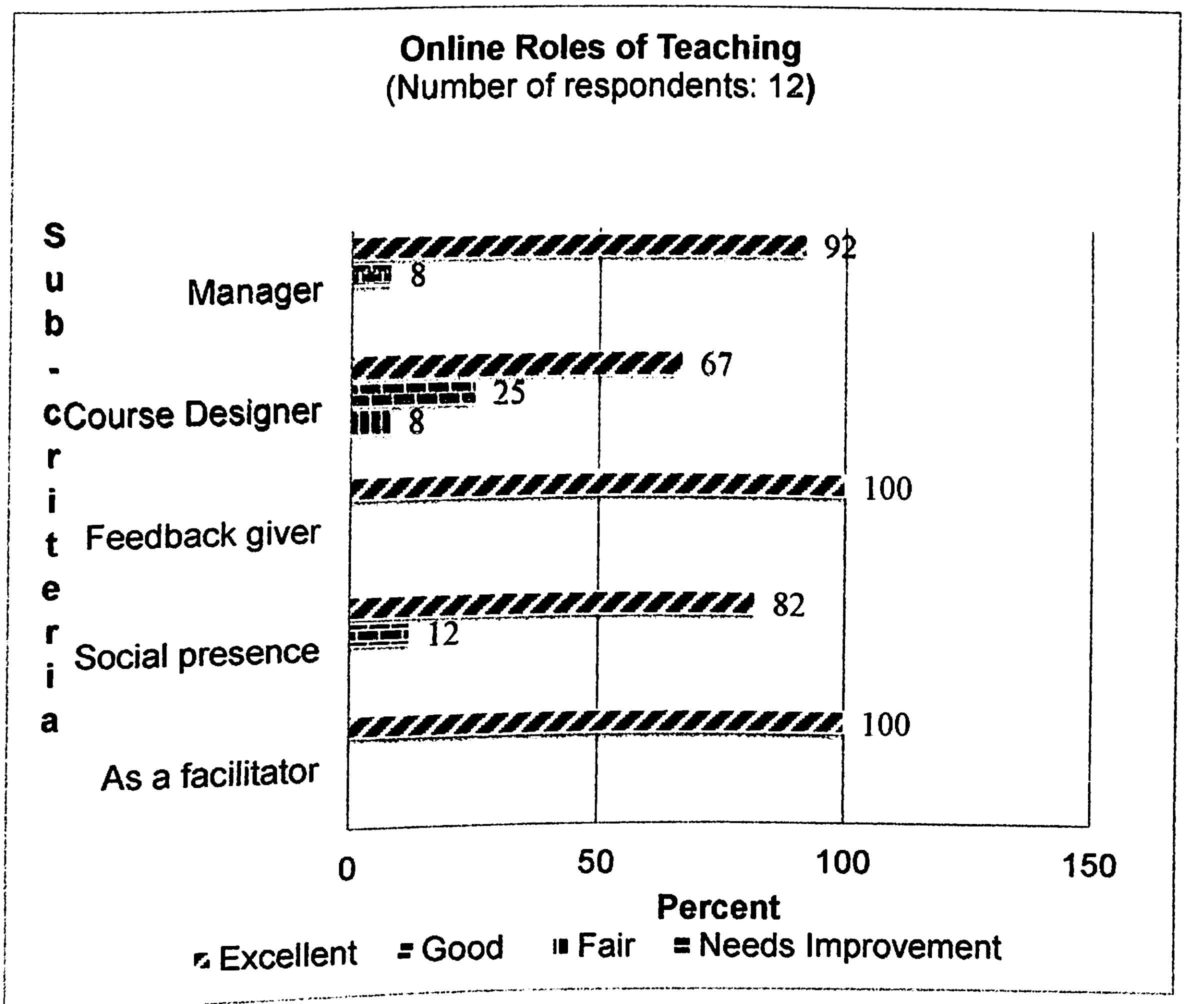


Figure 17. Second iteration participants' perception of online roles of teaching practical mathematics

The themes that emerged from the coded responses of the six interviewed students on the assumption of roles of online teaching were similar to the themes identified in the first iteration. In the second iteration, the participants manifested that the online teacher was responsive to their learning needs. As a facilitator, he was described by the participants as "easy to approach online and always finding ways to make us understand better especially on what we need to know." He provided us very good feedback which we can readily understand. The interviewed students furthered that the online teacher's management skills were very satisfactory because, in a typical response of one participant, "he laid out clear schedules of activities and guided the participants in the performance of these activities." When asked whether the online teacher did get to know them well, majority replied in the negative or could not make an answer. It can be noted here that the online teacher was given a general information on all participants of the study, consisting of names, class and the chosen senior high school track.

Technology Tools Used. In the third cluster, a large 92 percent of the second iteration participants found the chosen social network site, Facebook, to be excellent or most conducive for online learning of this course (see Figure 18). This was a relatively larger percentage of participants rating Facebook as excellent compared to 75 percent of the first iteration participants. On the use of online chat, 67 percent of the second iteration participants stated it to be excellent which means that all members in the group used online chat to communicate ideas or discuss the lesson. The interviewed participants of the second iteration all reported that online group chat was often used by their groups because such tool had no interruptions, was easy to use, and could send pictures and files. According to one participant, group chat offered real-time and simultaneous communication, very much similar to phone texting. Furthermore, they unanimously reported the following:

a. They were comfortable using the technology tools in studying practical mathematics online.

b. The technology tools were adequate in supporting their learning needs.

c. The technology tools were appropriate to their learning activities.

d. Other technology tools were not used due to weak Internet connection for video and audio calling, and the waiting time that can lead to asynchronous discussion for email.

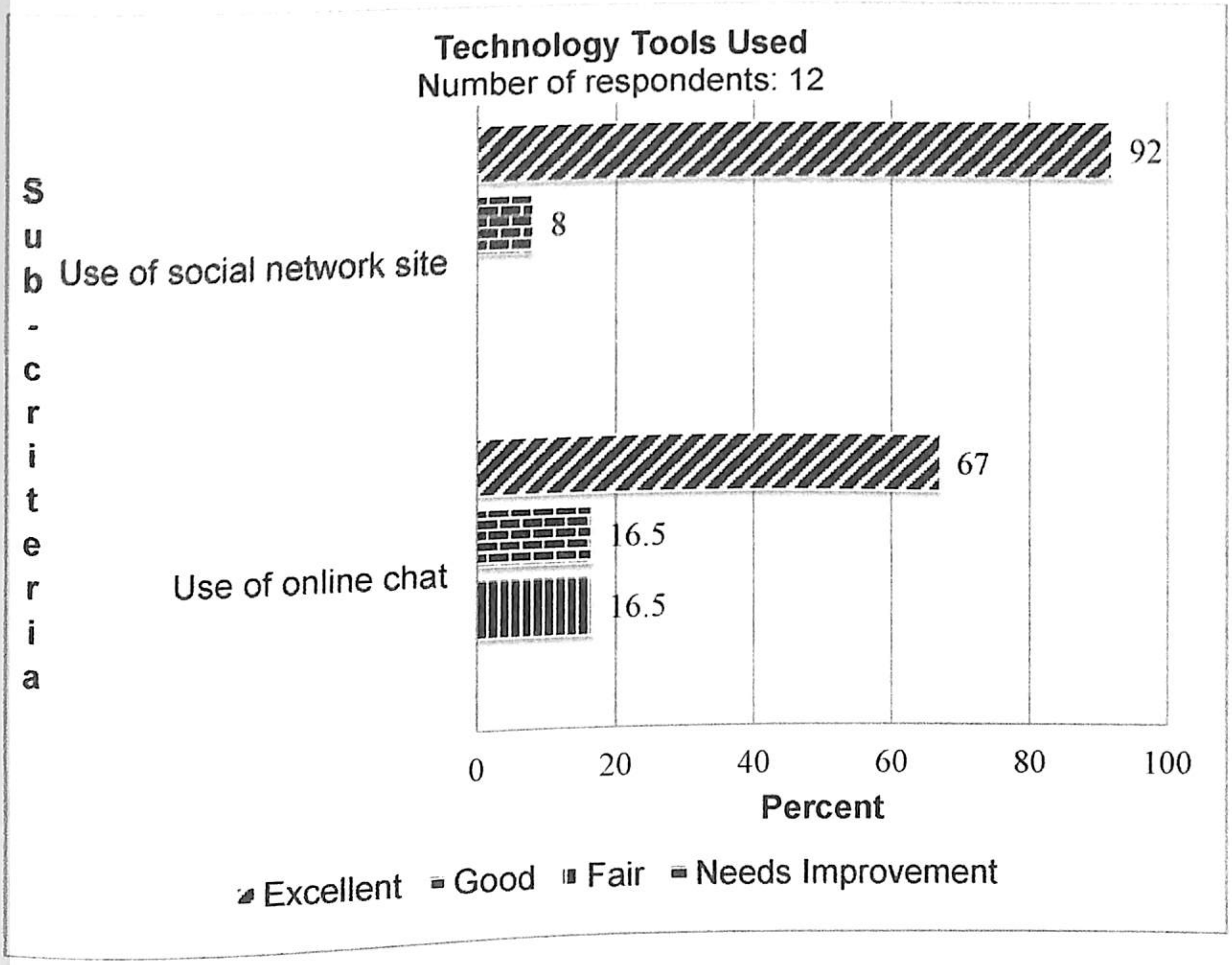


Figure 18. Second iteration participants' perception of the technology tools used.

When asked about any difficulty on the use of technology tools, they agreed to put the blame on the slow Internet connection that prevented them from using audio and video calling for synchronous discussion with the facilitator and from viewing the video tutorials.

As observed by the researcher, there was also the issue of weak Internet connection that spilled over to the second iteration. All three groups pointed to this issue as the cause of not viewing well the video tutorials or inability to view some videos. Because of this situation, these groups had to settle for the helpful notes that provided textual information on what they need to know. Such issue must have accounted for a decline in the proportion of participants who rated the use of multimedia to be excellent from a high 75 percent in the first iteration to 50 percent in the second iteration.

Presentation of the Online Learning Modules. Fifty percent of the second iteration participants rated both sub-criteria of the fourth cluster, textual and pictorial information and the use of multimedia, to be excellent (see Figure 18). By comparison, 87.5 percent of the first iteration participants rated textual and pictorial information as excellent and 75 percent of them had the same excellent rating for the use of multimedia. The slow Internet connection must have accounted for a decline in the proportions of participants who rated both sub-criteria as excellent from more than 50 percent in the first iteration to 50 percent in the second iteration. For instance, when interviewed students of the second iteration were asked about the tutorials in video format, some commented that the video tutorials helped them understand the lesson well but others were not able to view the video tutorials because of the weak Internet connection. Thus, they had to content themselves with the helpful notes to learn what they needed to know. On lesson objectives and individual exercises, 75 percent of the second iteration participants rated them to be excellent, which perceptions were similar to those of the majority of the first iteration participants.

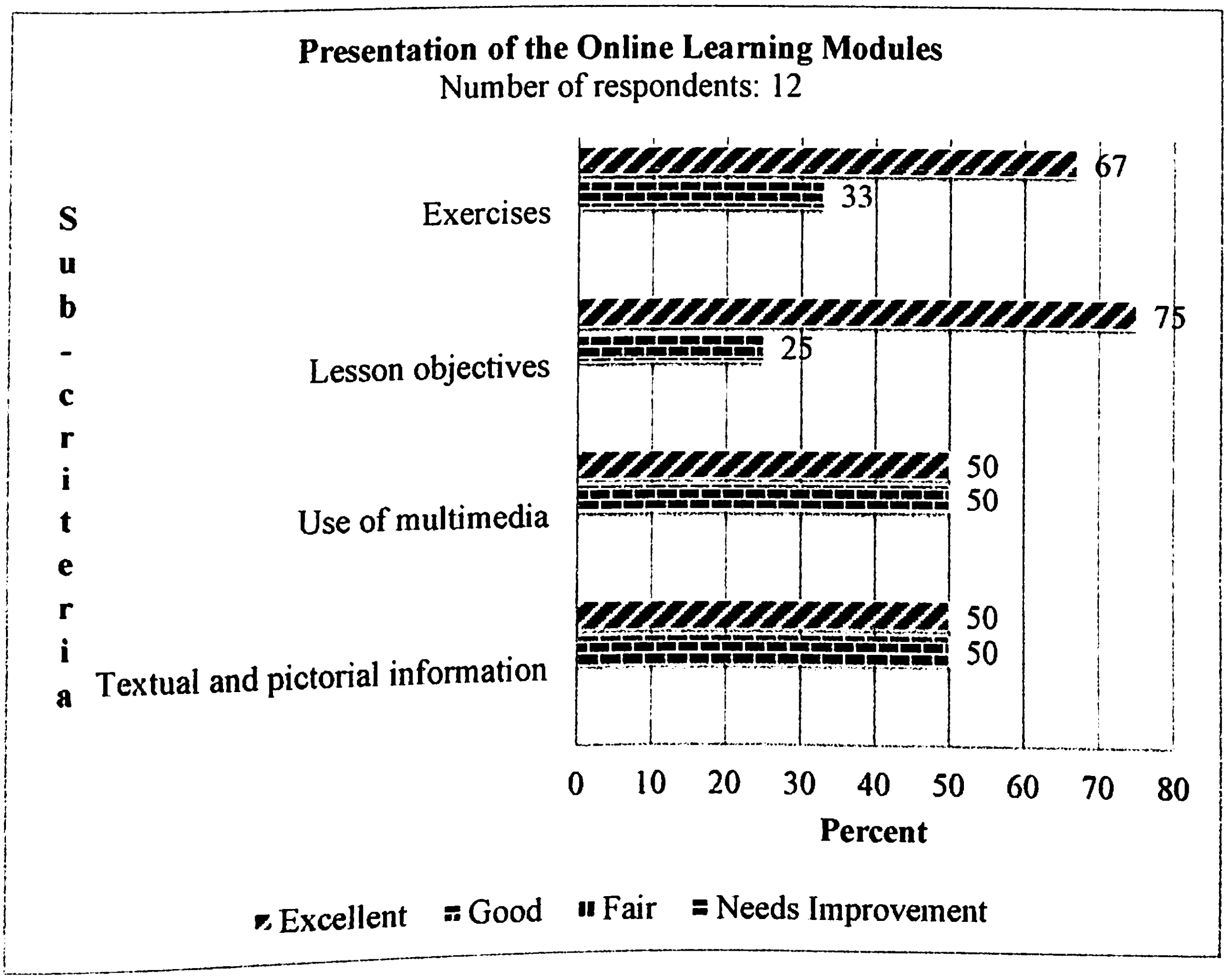


Figure 19. Second iteration participants' perception of the presentation on online learning modules in practical mathematics.

The themes that emerged from the coded responses of the interviewed students on online learning modules would show the following:

a. Words used and the instructions in the learning modules were clear and understandable.

b. The lesson objectives were clear, measurable, and achievable.

c. The lesson activities were well-arranged and doable.

d. On helpful notes, majority agreed that these were well-arranged, very clear, and useful. The exercises with the answer keys were also helpful in reinforcing skills and knowledge of a particular lesson. All interviewed participants attributed what they learned in practical mathematics from studying the online learning modules.

Based on the observation of the researcher on lesson 1.1, the new illustration on the design of a ground park provided a clear sample on how to design the ground of a park and what dimensions of the park to measure. In the second iteration, there were relatively less questions asked on how to make such design during the group chats on the problem-based task of the lesson. The average online discussion time particularly on the problem-based tasks of lessons 1.3 and 1.4, where some items had been deleted, was reduced. Calculations done in solving the problems of these lessons were less laborious than those in the first iteration. There was more focus now on the lesson objectives of conversions between metric measurement involving weight, mass, time, ampere, wattage, and volts.

Student Evaluation of the First and Second Iteration Groups on the Effectiveness of the Technology-Mediated Learning Modules

To get the overall student evaluation of the second iteration modules, mean scores were computed from the sub-criteria of the four clusters of the evaluation rubric and an overall mean score from the mean scores of the four clusters of the same rubric. With the use of the Mann-Whitney test, these second iteration mean scores were then compared to the first iteration mean scores in order to establish how well the technology-mediated modules facilitated the learning of the practical mathematics concepts.

Online Learning Approach and Online Roles of Teaching. Based on the mean scores obtained from the two clusters, perceptions of the second iteration participants did not vary from those of the first iteration participants. The online learning approach, with a mean score of 3.3, again got a good rating from the second iteration participants. The improvement in the mean score of this cluster, from its mean score of 2.8 in the first iteration, could be attributed to the removal of one design principle from this cluster, sharing-out and whole class discussion. This design principle got a lowest rating from the first iteration participants and showed no evidence of being used as observed by the researcher and the class observer. Similarly, Sasikumar (2014) reported that "students were not enthusiastic about the discussion boards and forums", which are activities inviting whole class participation. The other first iteration improvements on the online learning approach may also have contributed to the higher mean score of the cluster in the second iteration.

With a mean score of 3.9 obtained from the five sub-criteria of the second cluster in the second iteration, online roles of teaching garnered for the second time an excellent rating. It can be noted that the same roles of online teaching, assumed but applied to a different group in the second iteration, still obtained the same student outcomes as those in the first iteration.

Technology Tools Used and Presentation of the Online Learning Modules in Practical Mathematics. Based on the mean scores of these two clusters, student perceptions of the technology tools used and presentation of the online learning modules each further improved from a good rating in the first iteration to an excellent rating in the second iteration. With a mean score of 3.7, the technology tools used got an excellent rating from the second iteration participants. The improvement of rating on the technology tools used from fair in the first iteration to excellent in the second iteration can be accounted for by the modification made on this cluster which was the removal of the use of email. Such asynchronous tool was a least used technology tool in the first iteration.

The presentation of the online learning modules, with a mean score of 3.7 on the four sub-criteria of the cluster, was rated excellent by the second iteration participants. The improvement of rating on the presentation of the online learning modules from good in the first iteration to excellent in the second iteration can be accounted for by another modification made on this cluster which was the removal of the making of assignments from the first iteration modules.

Table 3 shows the second iteration mean scores of the four clusters of the evaluation rubric and an overall mean score which is the average of the scores on the 15 sub-criteria of the evaluation rubric. The overall mean score of 3.7 in the second iteration suggests that the participants perceived the second iteration learning modules as excellent modules in learning the concepts of practical mathematics.

Using the Mann-Whitney test, this study performed a two-tailed test to determine any significant difference in the mean scores of the evaluation rubric between the first iteration group and the second iteration group. Table 4 shows the test results at 0.05 significance level with $n_1=8$ and $n_2 = 12$. Since the computed U-value = 0 is less than the critical U = 22 at $p<0.05$, the null hypothesis is rejected in that the overall mean score of the second iteration group is significantly higher than the overall mean score of the first iteration group. This result shows that there is a significant improvement of the overall student evaluation from a good rating of the first iteration modules to an excellent rating of the second iteration modules. This further indicates that the technology-mediated learning modules facilitated the learning of practical mathematics concepts.

Table 3

Second Iteration Student Perceptions of the Improved Technology-Mediated Learning Modules in Practical Mathematics by Cluster

Cluster	Mean Scores	Descriptive Ratings
Online learning approach	3.3	Good
Online roles of teaching	3.9	Excellent
Technology tools used	3.7	Excellent
Presentation of the online learning modules	3.7	Excellent
Overall mean score	3.7	Excellent
Number of respondents	12	

Table 4

Mann-Whitney U Test on the Evaluation Mean Scores of the First and Second Iteration Groups

Statistics	Values
Sample size of first iteration group (n_1)	8
Sample size of first iteration group (n_2)	12
Computed U-value	0
Critical U at $p<0.05$	22
Z-value	3.6647
p-value	.00026
Mean rank of first iteration group	4.5
Mean rank of first iteration group	14.5

Test Scores of the Design Research Group and Comparison Group in Practical Mathematics

Table 5 shows the salient features that distinguish between the design research group and the comparison group. The design research group, on one hand, used collaborative learning through synchronous or asynchronous discussions as an approach to learning the practical mathematics concepts. Divided into three small groups, each small group collaborated to solve an authentic problem-based task. These discussions were facilitated by the online teacher who provided a scaffold to his/her students as they engaged in the construction of knowledge. Thus, students interacted with one another to explore the problem, share ideas, and to negotiate for the best possible outcome. Also, these students could interact with the teacher on what they need to know in performing the problem-based task. Each small group was assigned an online group chat in Facebook as a platform of discussion.

Table 5

Salient Features Distinguishing Between the Design Research Group and the Comparison Group

Clusters	**Design Research Group**	**Comparison Group**
a. **Learning Approach**	• Small-group collaborative learning through synchronous and asynchronous discussions • Authentic problem-based task	• Direct instruction
b. **Online Teacher**	• Facilitator/feedback giver/social presence/course designer/manager	• Lecturer
c. **Interaction**	• Teacher-student interaction • Student-student interaction	• Teacher-student interaction
d. **Technology Tools Used**	• Facebook • Group chat	• Facebook • Discussion board

On the other hand, the comparison group used direct instruction as an online approach in learning the practical mathematics concepts. This instruction was delivered to them by the online teacher through a video. As a lecturer in the video, the online teacher was the dispenser of knowledge to the group. As an individual learner, a member of the comparison group was expected to learn as much as he/she could knowledge from the teacher, viewed as the authority in this learning approach. Thus, the interaction was confined between the teacher and his/her students. Any member of the group, who had questions or clarifications on the subject matter, could post them on the discussion board, which was created in the Facebook.

Table 6

Mann-Whitney U Test on Pretest Scores of the Design Research Group and ComparisonGroup

Statistics	**Values**
Sample Size (N)	12
Computed U-value	42.5
Critical U at p<0.05	37
Z-value	-1.67432
p-value	0.09492
Mean rank of comparison group	10.04
Mean rank of design research group	14.96

The two groups, the design research group and comparison group, were randomly selected and independent, and the data on test scores is continuous. Thus, this study used the Mann-Whitney U test to address the following: a) the significant difference in the performance of the two groups in the pretest scores and b) the significant difference in the gain scores of the two groups.

Using the Mann-Whitney U test, the study performed a two-tailed test to determine any significant difference in the pretest scores of the two groups. Table 6 shows the results of performing a two-tailed test on the data at 0.05 significance level and n = 12. Since the computed U-value= 42.5 is greater than the critical U value= 37 at p<0.05, the null hypothesis is accepted in that there is no significant difference in pretest scores the of the design research group and comparison group. This indicates equality of the two groups in the level of base knowledge in practical mathematics before they tried out their assigned online learning modules.

Using the same nonparametric test, this study evaluated another null hypothesis stating that there is no significant difference in the gain scores in practical mathematics between the design research group and the comparison group. Table 7 shows the results of performing a two-tailed test on the data at 0.05 significance level and n = 12. Since the computed U value=48 is greater than the critical U value= 37 at p<0.05, the null hypothesis is accepted in that there is no significant difference in the test performances in practical mathematics between the two groups. Considering the mean rank statistics, the mean rank of the design research group is higher than that of the comparison group. This indicates that the test scores of the design research group are generally higher than those of the comparison group. However, the difference between the mean ranks does not reach the level of significance. The non-significant result supports the finding of Schlechter (1991) who conducted a narrative review of the twenty studies comparing two types of learning with computer technology: small group collaborative learning and individual learning. He found no collective evidence or consistent effects to show which type is more effective to achieve favorable student outcomes.

Table 7

Mann-Whitney U Test on Gain Scores of the Design Research Group and Comparison Group

Statistics	Values
Sample size (N)	12
Computed U-value	48
Critical U at $p<0.05$	37
Z-value	-1.35677
p-value	0.17384
Mean rank of comparison group	10.5
Mean rank of design research group	14.5

On the other hand, the finding of the study is in contrast to other research outcomes that, with the use of computer technology, small group learning, on the average, was significantly better than individual learning on student achievement and affective outcomes, and group task performance (Lou, Abrami & D'Apollonia, 2001; Johnson, Johnson & Stanne, 1985, 1986).

The contradiction of research results suggests that there could be other differential conditions which may mediate the effects of effective small group collaborative learning like technology, task designing or the use of group learning strategies (Lou, Abrami & D'Apollonia, 2001). Based on the observation of the researcher, this study might be in the use of a particular group learning strategy like more engagement in asynchronous discussion. As also observed, there was not enough evidence of the expected asynchronous discussion in the group chat among various small groups despite the facilitator's encouragement to use such discussion for better reflection and learning on solving a problem-based task. As reported by Jonassen and Kwon (2001), asynchronous discussions are more suited to solving ill-structured problems based on real-world situations which have multiple outcomes. However, considering the context of the study at that time, the academic demands and school activities may have limited the attention and time of the student participants to engage more in a longer and deeper reflection required of the problem-solving activity of a lesson.

Benefits of Using Design Research in Developing Technology-Mediated Learning Modules

In order to compare how beneficial the design research approach in the development of the technology-mediated modules in practical mathematics to the traditional development approach of a private sectarian college, this study used and analyzed the data from the focus group discussion, a review of the subject expert on the two types of modules, as well as delved into the nature of design research process.

Focus Group Discussion. After trying out the traditional learning modules, four student participants from the comparison group joined the focus group discussion—facilitated by the researcher through Facebook video calling. Before joining the focus group discussion, the participants were provided copies of the second iteration or design learning module in lesson 1.1 to read and compare it with the traditional learning modules they had used. The data gathered from the focus group discussion showed unanimity of preference of all four participants for the design research learning modules than the traditional learning modules in learning practical mathematics. Based on the themes that emerged from the focus group discussion, the student participants liked the group interaction and the collaborative problem-solving activity as provided in the design research modules but missed out in the traditional modules. A comment which characterized the responses on the first question of the FGD from one participant was articulated as: " I like to have a small group discussion where ideas to solve a task-based problem are shared and discussed." When asked what improvements to suggest on the traditional modules that they used, all of them responded small group discussions and problem-solving activities be added to the modules. A copy of the FGD outcomes is found in Appendix Z. As pointed out in these research studies, students have positive attitudes in online team activities and reported that social learning or learning as part of the group was one of the perceived benefits in an online collaborative learning (Chiong & Jovanovich, 2012; Lee et al, 2006). That comment was also overwhelmingly shared by the design research group when they perceived the online learning approach of the second iteration learning modules as a good learning approach in practical mathematics. Such approach was characterized as learning collaboratively in small groups and problem-based. Other ideas shared in the focus group discussion revealed positive comments on the problem-solving activity of the design research learning module because it provided "concrete pictures and designs" and gave an opportunity to "make actual measurements" in solving a problem. Moreover, the problem-solving activity "has encouraged us to think", "to use prior knowledge", and "to create a unique solution which cannot be copied." When asked about suggestions to improve the traditional learning modules, FGD participants suggested small group discussions and real-world problem solving activity be provided in the traditional modules that they tried out.

Review of the Subject Expert on the Two Types of Modules. The subject expert, guided by a prepared set of questions, was asked to review the design research learning modules and the traditional learning modules (see Appendix AA). On the learning approach, he found the learning modules, used by the comparison group, to be traditional, teacher-centered, and limited in interaction. Only appealing to the cognitive side of a learner, these modules, he furthered, do not provide enough motivation for learning the application of topics in real life. On the other hand, he found the design research learning modules as learner-centered ones which make use of prior knowledge and promote collaborative learning among students. He qualified the problem sets as based on real-world situations, manageable, and appropriate to the difficulty level of the senior high school students. He affirmed the discussion size of a group (from three to four members) as a convenient size to share ideas and elicit group cooperation.

In both types of the modules, he found the use of technology tools as adequate to facilitate online learning of practical mathematics. However, he stressed the need for a strong Internet connection and smartphones for users of these modules. On the presentation of both types of modules, he described both to have used language which is very precise, understandable, and appropriate to the level of senior high school students. In concluding his review, the subject expert has recommended using the design research learning modules in an online study of practical mathematics.

Nature of the Design Research Process. The outcomes from the FGD and the expert's review have indeed reinforced the excellent student perceptions of the second iteration learning modules. This is to be expected because these design research learning modules are a product of the two iteration processes where, among others, student feedback were used to validate and refine the design principles that made up the technology-mediated learning modules. Thus, this process created a product with greater student involvement—that is a set of learning modules shaped by how students would want to learn practical mathematics. This student input is missing in the making of the traditional learning modules in as much as these modules are a product of a teacher's revision based on the curriculum standard of a private sectarian college. Reflecting more on the nature of process can elicit another argument for the design research approach. The design research process has integrated most of the trends and characteristics of recent design and development approaches in the field of education and training. From the research study of van den Akker (1999), these characteristics, integrated in the design research process of the study, are: pragmatism, professional development, and successive approximation. In this study, the design research is found to be pragmatic as it was carried out in a real-world setting and used feedbacks from the student participants and observations of the research team to improve the online learning modules. Also, its final output—the set of design research learning modules—is pragmatic because it is ready and available for use by those who want to learn those selected topics in practical mathematics. Second, it caters to professional development because the process has engaged the researcher of the study to perform research work (i.e. from the review of related literature, gathering of data and analysis of feedbacks, and to writing the research report) and to practice the skills of online teaching during the implementation of the modules with the student participants. As part of the researcher's professional sharing, he is able to contribute with the set of validated design principles—the theoretical output of his study-- to the body of existing knowledge on the research topic of the study. In a traditional curriculum development standard, a template, specifying what and how to construct a module, is provided to a teacher, whose creativity is limited to just filling in the template with details, not really anchored on research work. Third, the design research is a process of successive approximation. In this study, its two-iteration process, a rigorous one, kept on validating the set of tentative design principles until it achieved the best approximation of effective and usable online learning modules in practical mathematics. On the other hand, the revision of the traditional learning modules was a one-time process and any further revisions were done mainly by the teacher based on his observation.

Further Improvements Done on the Second iteration, Technology-Mediated Learning Modules

Since the findings of second iteration, based on feedback of student participants and the researcher, validated the improvements made on the first iteration learning modules, this study has maintained the second-iteration technology-mediated learning modules with a minor change. This includes:

1. Reducing the discussion group size from four to three to allow for an active online synchronous discussion. Although synchronous discussion was the preferred mode, an asynchronous discussion should be maintained and conducted especially in analyzing previously identified areas of difficulty in some problem-based tasks.

Re-Conceptualized Framework

A number of changes, consisting of a major one and other minor ones, were introduced in the conceptual framework, resulting to the reconceptualized framework of the study.

As the major difference between the two frameworks, the cluster of design principles for presentation of learning modules has been reassigned from being an independent variable in the conceptual framework to a moderator variable in the reconceptualized framework. Based on observation and feedback in the first and second iteration implementation, this cluster of design principles served more as a moderator variable. In the study, the multimedia approach of the lesson (i.e. video tutorial and helpful notes), individual exercises with answer keys, the use of behavioral objectives, and choosing plain and simple language were perceived helpful in understanding the lessons and acquiring the necessary skills. As a minor difference between the two frameworks, one lesson activity in the conceptual framework, which is the assignment, was taken out from the cluster for presentation of learning modules of the re-conceptualized framework. The last lesson activity had to be discarded from the cluster since participants found the earlier lesson activities enough to help meet the objectives of the lesson.

Although the cluster of design principles for online learning approach is maintained as an independent variable, some minor changes from this cluster, however, have been made part of the reconceptualized framework. These minor ones, further differentiating between the two frameworks, include: a) more emphasis on the use of asynchronous discussions; b) simplification of the authentic problem-based task; and c) reduction of discussion group size from four to three members. Although results of the final iteration of the study showed participants' preference for collaborative learning through synchronous discussions, such mode of learning should be balanced by the use of asynchronous discussion. With the insignificant test results of comparing the gain scores of the design research group and the comparison group, this study would like to encourage more asynchronous discussions especially on identified areas of the problem-based tasks that require longer and deeper reflection. Another minor change, included in the re-conceptualized framework, was part of the improvements made on the first iteration learning modules. Such was the simplification of these authentic problem-based tasks by replacing a difficult illustration with a simple one, removing unnecessary questions and redundant items, shortening some problem sets, and others. These were made in order to make the problem-based tasks simpler, clearer, and more relevant to the lesson objectives. Another change in the design principles of online learning approach was the size of the discussion group which was reduced from the proposed four members in the conceptual framework to three members in the re-conceptualized framework. Based on the feedback of the participants, class observer, and the researcher, three members, on the average, were found actively interacting during group discussions. This finding affirmed the study of Kim (2013) that small-group online discussion forums elicited higher level of student interactivity and his conclusion that a high quality participation in a large online class could be realized through sub-grouping. Also, this finding supported the study of Fernandez (2007) who proved that an effective discussion group was composed of three learners. This group size of three may explain why participants did not bother to perform a lesson activity under the learning approach, the sharing-out and whole class discussion, since this activity would entail a larger discussion group.

Student context is still maintained as an independent variable in the re-conceptualized framework. The personal characteristics and background of the first iteration group—in terms of job skills specialization, student motivation and interest in mathematics, familiarity with ICT, and socio-economic status—were similar to those of the second iteration group. There is, however, one exception that provides a distinction between the two frameworks. A student participant in the re-conceptualized framework has greater interest in the study of practical mathematics relative to that of a student participant in the conceptual framework.

In terms of technology tools used in the study, its cluster of design principles is still maintained as the mediator variable, making possible the relationship between the two independent variables and the dependent variable of the study. These technology tools were so designed to enable student participants to gain access to the online environment and to support the collaborative learning through asynchronous and synchronous discussions in practical mathematics. The use of these tools made possible the online learning of practical mathematics. Moreover, In the re-conceptualized framework, some changes were introduced to the technology tools to be used in support of the learning needs of the participants. These included removal of emails and discussion boards from the cluster of design principles because the participants did not use them and found these tools no longer necessary to support collaborative learning through synchronous and asynchronous discussions. The functionalities of these tools were conveniently replaced by the facilities of Facebook like group chat, sending and downloading of files and pictures, and taking of photos, among others. This has caused the student participants to choose Facebook as a conducive site for the study of practical mathematics. Other changes though did occur in the mediator variable due to a factor extraneous to this study, which was the weak Internet connection. Because of this limitation, other synchronous tools like video and audio calling were not available for use in the study and had to be removed from the available tools in the reconceptualized framework.

Another cluster of design principles, the online roles of teaching, has moderated the relationship between the online learning approach and test performance. As perceived by the participants, class observer, and the researcher, the excellent roles of teaching facilitated the online learning process and has thus strengthened such relationship. Among others, the facilitator's feedback was direct and immediate which sustained and motivated collaborative learning through synchronous and asynchronous discussions. In the aspect of facilitation, the online teacher had to motivate each group to engage in asynchronous discussions especially on problem-based tasks that required longer reflection. Hence, in the re-conceptualized framework, the assumption of online roles of teaching is still maintained as a moderator variable. Figure 30 shows the re-conceptualized framework with the indicated relationships and the final design principles of the study.

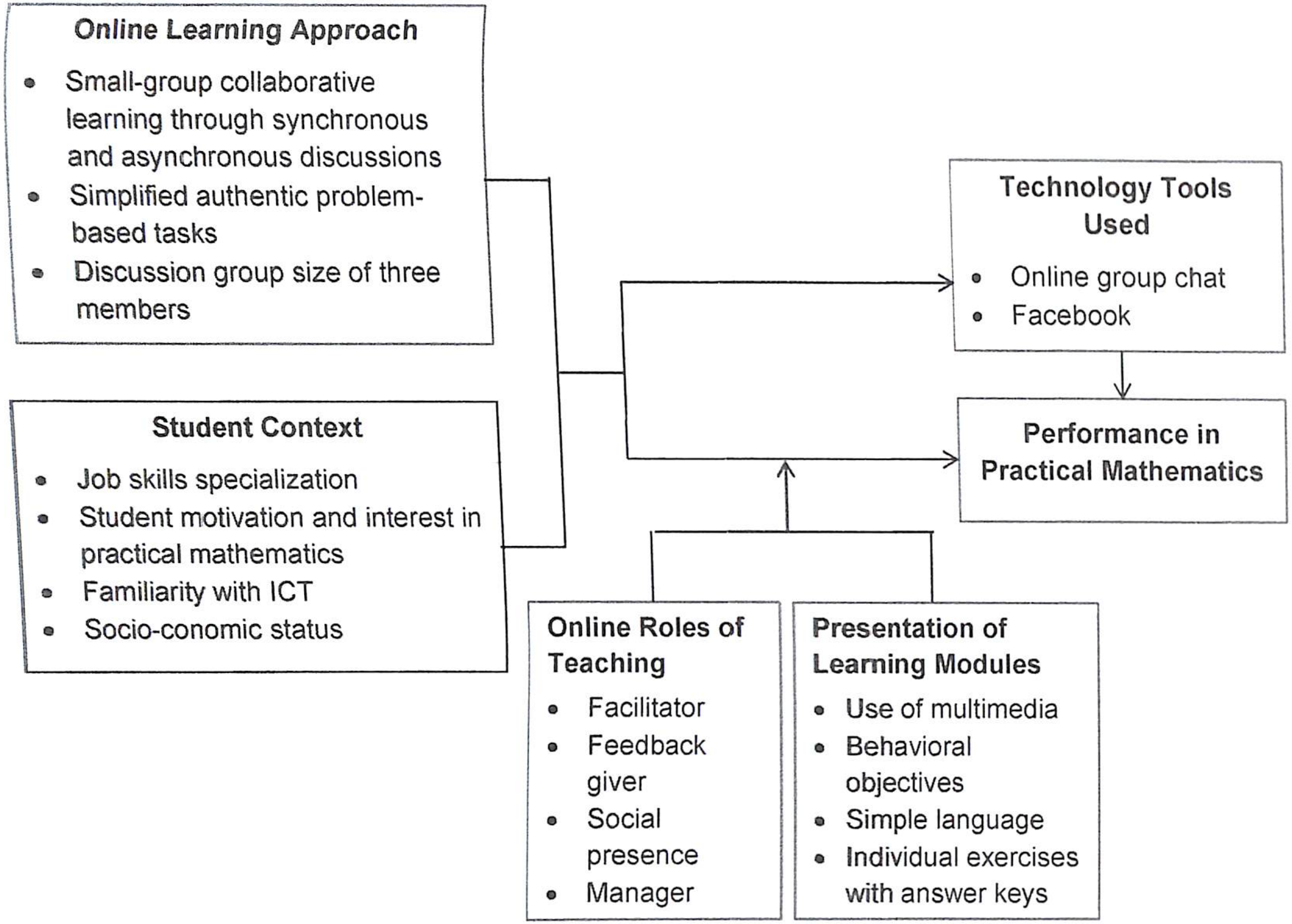


Figure 20. The re-conceptualized framework of developing technology-mediated learning modules in practical mathematics using design research.

Chapter 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This chapter presents the summary, conclusions, and recommendations of the study.

Summary

This study was undertaken to develop the technology-mediated learning modules in practical mathematics using the design research approach for the technical vocational track of the K to 12 curriculum. Design research is a research approach, characterized as interventionist, iterative, process-oriented, utility-oriented, and theory-oriented (Kelly, 2003). With this approach, this study was able to produce a twofold yield: the research-based intervention and a validation of the design principles that served as bases in developing the technology-mediated learning modules. The first yield was a product of two iterations. It consisted of three technology-mediated learning modules with seven lessons developed to facilitate online learning of practical mathematics in the technical vocational track of the K to 12 curriculum. The second yield consisted of a validated set of design principles of the study, categorized as follows: online learning approach, online roles of teaching, technology tools used, and the presentation of the online learning modules. The latter yield aimed at strengthening the educational practices of teaching and learning practical mathematics in an online setting and contributing to the body of knowledge of developing technology-mediated learning modules in the technical vocational education.

The design research model of Mckenney and Reeves (2013) was used in designing and in developing the technology-mediated learning modules. This way, research was embedded in the development process. The model, also called an iteration model, includes three phases: the analysis and exploration phase, design and construction phase, and the evaluation and reflection phase. As an innovation to this model, this study introduced the traditional curriculum development process, simultaneously implemented with the design research process. In the first of the two-iteration approach of the study, the first iteration learning modules were tried out by a group of eight participants, either enrolled in the technical vocational track of senior high school or the technical vocational school of private sectarian college in the southern part of the country. These modules also include the following materials: video tutorials, helpful notes, individual exercises with answer keys, and solutions to the assignments. The implementation period lasted for a total of almost ten weeks. The results of the first iteration were used to improve the first iteration learning modules with the improved version described as the second iteration learning modules in practical mathematics. Simultaneously in the first iteration, the same set of the first iteration learning modules was revised using the traditional curriculum development approach. The researcher revised the same online learning modules based on the TESDA format. The revised online learning modules, described as traditional learning modules, were then critiqued by two subject experts of a private sectarian college.

The second iteration of the study produced the final version of the design research, technology-mediated learning modules in practical mathematics and a validated set of the design principles. In this iteration, another group of participants was randomly selected as the design research group, This group was composed of twelve students in Grade 11 of the technical vocational track of same senior high school.

Divided into three small groups, the participants tried out the second iteration learning modules. The second iteration results were used to further improve the second iteration learning modules which became the final version of the design research learning modules. Simultaneously done with the second iteration implementation was the implementation of another set of technology-mediated learning modules—revised according to the traditional curriculum development standard of a private sectarian college. Described as the traditional learning modules, these were tried out by another group of 12 students who came from the same grade level, track, and senior high school. This group was randomly selected as the comparison group of the study. At the end of both implementations which went for a total of ten weeks, the two groups took the posttest and gain scores were compared to determine which of the two types of learning modules—design research learning modules and traditional learning modules—was more effective in learning practical mathematics.

This study used six researcher-made instruments to gather data from the participants, class observer, and the facilitator. These instruments included the following: the pretest and posttest, the evaluation rubric, the observation guide, the semi-structured interview, guide questions for focus group discussion, and a guide for review of the subject area expert. A panel of two subject experts examined and established the content validity of the four instruments. Also, a sample, similar in characteristics to the actual participants, was selected to pilot test three of these instruments for reliability. Of the 12 participants in the first iteration, eight completed the online course and answered the evaluation rubric immediately after the implementation of the last learning module. Of the eight completers, five were randomly selected for the interview.

On the side of the facilitator and class observer, they noted their observations through the use of the observation guide. In the second iteration, all 24 participants, from the design research group and the comparison group, took the pretest prior to the start of the online class. The three small subgroups of the design research group answered the evaluation rubric immediately after completing their online studies. Of the 12 participants in the design research group, six were randomly selected for the interview. Four participants of the comparison group joined the focus group discussion and compared the modules they tried out and the design research modules tried out by the other group. Also, a subject expert reviewed the two types of learning modules and concluded his review with a recommendation to use the design research learning modules in practical mathematics. Right after the implementation period, the participants from the design research group and the comparison group took the posttest of the study.

Findings of the study were based on the evaluation of the students of the online learning modules, themes identified from the interview responses and focus group discussions, review of the subject expert, results of a nonparametric test, and common observations of the researcher and the class observer. Percentage scores and ratings were used to describe the evaluation of the modules by the students. The Mann-Whitney U test, a nonparametric test, was used to determine any significant difference in the test performances of the design research group and the comparison group. Qualitative analysis was conducted on the focus group discussions of the comparative group and the review of the subject expert on comparing the private sectarian modules and the design research modules.

In this study, the following findings were derived:

1. **Student context.** A typical participant, enrolled in shielded manual arc welding course with basic mathematics requirement, found the mathematical task and level of difficulty of a lesson's problem-based task to be manageable. Borne into the 21st century, a participant was found to be proficient and comfortable with the technology tools used in the study The vocational contexts of the problem-based task were relevant to a participant's plan to work after graduation from senior high school and had interested him to study practical mathematics. Belonging to a low-income group, a participant needed financial resource to have access to Internet for online study in practical mathematics.
2. **Online Learning Approach.** In the first iteration, collaborative learning through synchronous discussion was the preferred mode of online learning in practical mathematics. Three members were actively engaged in a small group discussion. The problem-based tasks were perceived to be good and manageable or not so difficult. For greater clarity and simplification, some modifications were made in the problem-based tasks of lessons 1.1, 1.2, 1.3, 1.4, 1.5, and 1.7. The sharing-out and class-wide discussion, a lesson activity in a learning module, was not useful in learning practical mathematics. The second iteration findings, which constituted the final design of online learning approach, validated all the first iteration findings and included two further

improvements. These improvements were the use of asynchronous discussion in analyzing areas of difficulty in some problem-based tasks and the excellent student perception of the problem-based tasks.

3. **Online Roles of Teaching.** In the first iteration, the assumed online roles of teaching like giving of feedback, facilitating, class management, and social presence were all perceived by the student participants to be excellent and highly evident by the class observer. The other role which is related to designing of the online course by the teacher, received a good rating from the student participants. As the final design of online roles of teaching, the second iteration findings consisted of a large majority describing all assumed roles of the online teacher as excellent. These assumed roles were those of a facilitator, social presence, feedback giver, course designer, and manager. Themes from the interview responses also showed a most positive perception of all the assumed roles of online teaching that facilitated very well small group discussions, provided immediate and complete feedback, fostered great social presence, organized and managed very well the lesson activities of the learning modules.
4. **Technology Tools Used.** In the first iteration, online chat was the most usable technology tool in the discussion of problem-based tasks while other tools like video and audio calling and emails were either least used or not used at all. Facebook was the preferred platform of the participants. The discussion board, created in the Facebook for class-wide discussion, was not used as a platform to post and discuss ideas and answers. As the final design

of the technology tools used, the second iteration findings validated all the first iteration findings and showed an improvement of student perception on the technology tools used to an excellent rating from a first iteration rating of fair.

5. **Presentation of the Online Learning Modules.** In the first iteration, the online learning modules were perceived to be excellent by the student participants in terms of the pictorial and textual information, exercises, and objectives but good in terms of the use of multimedia. A majority of 87.5 percent assigned the lowest rating to the assignments of the learning modules. Interview responses revealed that student participants did not bother to make the assignments. One interviewee made a characteristic comment on the assignment: "I found no need of the assignment and that is why I did not answer them." As the final design of the presentation of the online learning modules, the second iteration findings validated the first iteration findings and showed an improvement of student perception of the presentation of the modified technology-mediated learning modules from a good rating to an excellent one.

6. **Student Evaluation of the Learning Modules.** The result of Mann-Whitney U test shows that the overall student evaluation of the second iteration modules is significantly higher than that of the first iteration modules. In the first iteration, the overall student evaluation of the technology-mediated learning modules in practical mathematics was good. All clusters of the design principles but one cluster received good ratings from the participants.

Only the design principle of online roles of teaching was rated excellent. The second iteration finding showed a further improvement in the overall student evaluation of the technology-mediated learning modules in practical mathematics, modified according to the first iteration improvements, to an excellent rating. This time, all clusters of design principles but one cluster received excellent ratings from the participants. Only the design principle of online learning approach was rated good. Furthermore, the comparison group and the subject expert had chosen the use of the design research learning modules over the traditional learning modules in learning the practical mathematics concepts. Based on the focus group discussion of the comparison group, the student participants liked the group interaction and the collaborative problem-solving activity as provided in the learning modules developed using the design research approach. These two features were not present in the learning modules developed using the traditional curriculum development of private sectarian college. In addition, feedback from the subject expert included that the learning modules developed using the design research approach were relevant to real-world settings, learner-centered, and promoted collaborative learning.

6. **Students' Scores In Practical Mathematics Test.** Results of Mann-Whitney U test show the following: a) there is no significant difference of the design research group and the comparison group in the pretest scores; and b) there is no significant difference of the test performances in practical mathematics between the design research group and comparison group. In the second test

result, the mean rank of the design research group is greater than the mean rank of the comparison group but such difference was not significant at 0.05 confidence level.

Conclusions

Based on the findings of the study, the following conclusions are made:

1. The technology-mediated learning modules in practical mathematics, developed using the design research approach, have facilitated well the learning of practical mathematics concepts. A typical student participant, enrolled in shielded manual arc welding course, is interested in the study of practical mathematics and finds the mathematical tasks and level of difficulty of these modules manageable. The problem-based tasks with vocational contexts are relevant to his plan to find work after graduation from senior high school. A combination of the final design principles of the modules has been rated excellent by the student participants. The technology tools used like Facebook and open chat have well-supported the participants' preferred mode of learning—collaborative learning through synchronous or asynchronous discussions. As a perception of the majority, the student participants communicate well their ideas in the open chat, track and understand others' posted ideas, and learn from others' posted ideas. Also, they find the problem-based tasks of the modules manageable, are confident of their solutions, and able to submit their group outputs on time. As pointed out by Jennings (2006) , online collaboration, based on a problem-based scenario, would maximize interaction, fully engage participants on the task of

problem-solving, and would visibly contribute new knowledge. From the constructivist perspective, authentic problem-based tasks, one design principle of the study, facilitate the transfer of skills and knowledge. Also validating the study of Fernandez (2007), the discussion group size of three is conducive for online collaboration as the size elicits active discussion from all the group members of the present study. The assumed roles of facilitating and giving feedback guide very well each small group discussion, keep the participants fully engaged on the problem-based tasks, and provide complete feedback on the exercises and group outputs. The other assumed roles—having a social presence, course designing, and management—highly satisfy the participants' learning needs and non-academic concerns, organize very well the activities of the modules, and create a community of learners among student participants. The multimedia presentation of the modules help participants understand more deeply the lessons of the modules, as anticipated by Mayer (2001) in his multimedia theory. Words used are simple and easy to understand while the set of exercises helps the participants master the practical mathematics concepts.

2. The design research approach in the development of technology-mediated learning modules in practical mathematics is more beneficial than the traditional curriculum development approach used in a private sectarian college. The implementation of the final design principles embedded in the design research modules, as rated excellent by the student participants, was also found to be evident or highly evident in the course of observation by the

researcher and class observer. Other findings of the study have lent more arguments in favor of a greater benefit of using the design research approach in developing online learning modules in practical mathematics relative to the traditional curriculum development of a private sectarian college. There are the unanimous preferences of the design research learning modules by the FGD participants—after trying out the traditional learning modules and subsequently comparing them with the design research learning modules—and the subject expert's recommended use of the design research learning modules. The outcomes from the FGD and the expert's review have indeed reinforced the positive perceptions of students of the design research learning modules. Thus, this process creates a product with greater involvement of the end users of the learning modules, that is, a set of learning modules shaped by how students want to learn practical mathematics. As one benefit of the design research approach, such student involvement is missing in the making of the traditional learning modules in as much as these modules were a product of a teacher's design and revision based on the curriculum standard of the college and review of the subject experts.

3. Using design research is pragmatic and rigorous in developing technology-mediated learning modules in practical mathematics. First, the study is carried out in a real-world setting and used feedback—coming from the student participants, the class observer, and the facilitator—to improve the online learning modules. Also, the practical output of the study, the final version of the set of online learning modules, is ready and available for use by those

who want to learn those selected topics in practical mathematics. Second, the design research approach is a rigorous process of successive approximation. In this study, its iteration process keeps on validating the set of tentative design principles until it achieved the best approximation of effective and usable online learning modules in practical mathematics. Adding greater rigor is the innovation made by the study to the design research model, an introduction of a comparing the design research online modules with the traditional learning module

4. The design research group and comparison group are equal in base knowledge of practical mathematics. The test performance of the design research group in practical mathematics is the same as the test performance of the comparison group.

Recommendations

Based on the findings of the study, the following recommendations are made:

1. Course designers who want to develop online learning modules for the mathematics curriculum of the technical vocational track of K to 12 program must use design research approach. The present study can provide designers a walkthrough of the design research process which is cyclical, iterative, pragmatic, interventionist, and based on natural settings. The practical and theoretical outputs of the study may serve as inputs in the construction of the tentative online learning modules.
2. For a more rigorous conduct of the design research approach in developing learning modules, the following modifications should be done:

a) In the second iteration implementation, there should still be a comparison group who will try out online learning modules developed by the traditional curriculum development standard of a private sectarian college. After trying out these modules, the comparison group is given an opportunity to try out two or three online learning modules developed by the design research approach. The same holds true for the experimental group who, after trying out the design research online learning modules, should also try out two or three learning modules based on the traditional curriculum development standard.

b) Aside from the data gathered from various stakeholders of the present study, the comparison group, with the use of the evaluation rubric, should also rate the online modules based on the traditional curriculum development standard. With such additional data, there can be additional quantitative analysis by comparing student perceptions of the online learning modules used between the experimental group and the comparison group. Moreover, the focus group discussion can expand to include randomly selected participants from both the experimental and comparison groups. Since these FGD participants will have tried out the two sets of modules, they will be able to provide meaningful and reliable responses on comparing the two sets of modules. Thus, themes developed from the FGD discussion will be more informative and experiential.

3. As a product of the best possible approximation of an ideal set of online learning modules, the practical yield of the study is recommended for use as an online learning and teaching on the seven lessons of practical mathematics. Some findings of the study, however, may have implications on the online learning and teaching of practical mathematics using the modules developed using the design research approach. These include:
   a) Students must be equipped with the necessary skills and values for collaborative learning through synchronous or asynchronous discussions, and must have access to strong Internet connection. These collaborative skills include active listening, respect for other's ideas, open-mindedness, positive attitude, self-reflection, critical thinking, communication, and negotiation for meaning or solution. Without these skills, students cannot be expected to engage in a successful collaborative endeavor of learning. Thus, part of a school curriculum should focus on the explicit teaching and modeling of these collaborative skills to prepare those enrolled in online course for an effective and successful collaborative work.
   b) Teachers who want to teach online practical mathematics or any other subjects should have a solid preparation on how to assume effectively the online roles of teaching. Thus, the teacher education curriculum in the schools should offer training courses on online teaching. In-service trainings with teaching manuals can be offered to teachers especially those who want to teach online. The final design principles on the roles of online teaching, which include facilitating, social presence, feedbacking,

managing, and course designing, can be made a basis for creating or enriching a teaching manual or a training course on how to teach an online course especially mathematics in the technical vocational track of K to 12 program. These validated design principles of the study can provide fresh approaches and insights to pre-service and in-service teachers on how to deliver effectively the knowledge and skills in mathematics in an online environment.

c) To conduct design research study on developing online learning modules based on their teaching specialization is also recommended as a practicum for pre-service teachers or a research work for in-service teachers. Such design research study will involve them in its three phases—analysis of the problem and review of literature, design and construction of tentative learning modules, and evaluation and reflection.

d) In the implementation aspect, using the final design principles of the study enables them to practice the online roles of a facilitator, feedback giver, social presence, course designer, and classroom manager. The conduct of such study provides pre-service teachers opportunities to practice research skills and online teaching skills, and caters to the professional development of the in-service teachers.

e) A school institution, especially the distance learning institution, can use or continue to use the social media sites like Facebook as viable optional sites for online academic discussions between teachers and students.

4. For further research, another design research study on developing technology-mediated learning modules in Geometry and Trigonometry may be conducted. Developing modules on these topics will further improve the practical yield—increasing the number of research-based and technology-mediated learning modules in practical mathematics. Using the same design research process, future studies should consider the following:

   a) Increase the number of student participants. A sample size, randomly chosen, should increase to sixteen participants or greater but not more than 20 participants. A bigger sample size will increase the validity of results of the study.

   b) Provide the participants continued access to strong Internet connection. A strong Internet connection will enable the participants to use technology tools like video and audio calling, which were not effectively used in the present design research study because of the weak Internet connection. These Internet tools, though, were perceived to enhance synchronous discussion and social presence in a virtual learning environment.

   c) Use a classroom-based comparison group. Since the present study has used an online-based comparison, using a classroom-based comparison group will address a dearth of literature on the comparison between an online study based on collaborative learning using the synchronous and asynchronous discussion, and a classroom-based study using the traditional learning method. The theoretical yield of this recommended study will enrich the body of knowledge that compares the effectiveness between online collaborative learning through synchronous and asynchronous discussion and the classroom-based, traditional way of learning mathematics.

5. A school institution that plans to offer online courses in mathematics to technical vocational students should provide technical vocational students free access to Internet in consideration of their economic status. The rationale of offering online courses should not only consider time-bound or place-bound students but also “finance-bound” students. In both iterations of the study and research literature, technical vocational students belong to the low-income group. In this light, one can understand, as affirmed in this study and research literature, that finding work after graduation from senior high school or technical vocational institute is the main motivation of students taking up technical vocational courses.

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APPENDICES

Appendix A

Mathematical Requirement of Shielded Metal Arc Welding (SMAW) NC II

UNIT OF COMPETENCY: PERFORM INDUSTRY CALCULATIONS

UNIT CODE: MEE721203

UNIT DESCRIPTOR: This unit covers the competencies required to perform basic calculations using the four fundamental operation.

ELEMENTS	**PERFORMANCE CRITERIA** ***Italicized*** terms are elaborated in the Range of Variables
1. Perform four fundamental operations.	1.1 Simple calculations involving whole numbers, mixed numbers, fraction and decimal are performed using *four fundamental operations.*
2. Perform conversion of units	2.1 Units are converted to the required figure using the given formulae. 2.2 *English measurements are converted to metric* measurements according to procedure
3. Perform calculations on algebraic expressions	3.1 Simple calculations are performed on algebraic expressions using the four fundamental operations 3.2 Simple transposition of formulae are carried out to isolate the variable required, involving the four fundamental operations. 3.3 Where appropriate, formulae are constructed to enable problems to be solved 3.4 Equations involving one unknown are solved correctly.
4. Compute percentage and ratio	4.1 Percentages are computed using appropriate formula. 4.2 Ratio and proportion are computed using appropriate formula.

COR JESU COLLEGE, INC.
Sacred Heart Avenue, Digos City, Province of Davao del Sur, Philippines
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Appendix B

Letter Comments on Four Insruments

November 10, 2016

Dear Mr. Benedicto Norberto V. Aves,

In regard to your letter-request dated October 16, 2016, it is our pleasure to comment on the validity of the following instruments of your study:

- Pretest and Posttest
- Evaluation Rubric
- Observation Guide
- Semi-structured Interview Protocol

Attached to this letter, please find our comments and wish you all the best in your present undertaking.

Appendix B (continued)

OUR COMMENTS ON PRETEST AND POSTTEST

Overall, the 26-item test has covered well the lesson objectives of the 3 main topics of the subject. Some comments, however, can be made for greater clarity and appropriateness of the test, as follows:

1. Use some good illustrations to better understand those test items on ratio and direct proportion, and polynomials.
2. Need to use word problems on simple equations which degree of difficulty is appropriate to the level of Grade 11 students, belonging to Tech-Voc Track.

OUR COMMENTS ON THE EVALUATION RUBRIC

The evaluation rubric is comprehensive and sufficient to measure what it wants to measure in each of the 4 major clusters of the rubric. For better differentiation though between the ratings scale of the rubric, consider the following comments:

1. There should be a more distinctive qualitative description to show a clearer differentiation between the ratings scale. Use levels and degrees to show variation in your qualitative description about a particular design principle.
2. Use always, most of the time, sometimes, and never to describe the frequency of a facilitator's inputs in the learning process.

3. Use number of answer keys to show variation of feedbacks of a facilitator.

OUR COMMENTS ON THE OBSERVATION GUIDE

We find the 28-item guide, like the evaluation rubric, a comprehensive one to conduct an observation on the four major areas of the study. But here are some comments to consider:

1. These suggested measures like highly evident, evident, not so evident, and not observed would better describe what has been observed on each item in the observation guide.
2. Reserve a space after each of the clusters for comments of the observer to capture observations which may not be included in the various items of the observation guide.
3. In the learning approach, include item 1 or 2 items on the manageability and appropriateness of the problem-based task.

OUR COMMENTS ON THE SEMI-STRUCTURED INTERVIEW PROTOCOL

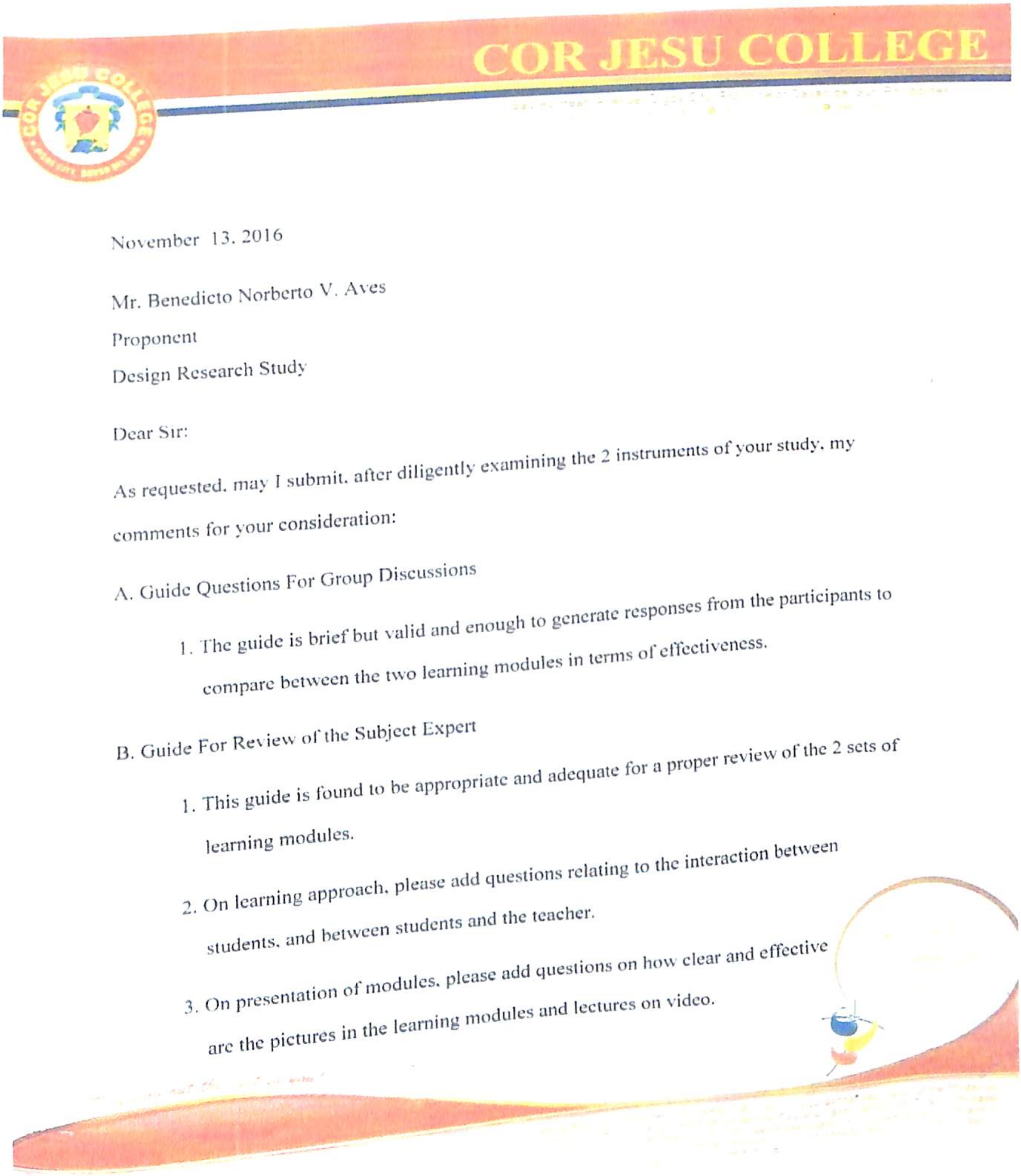
1. Uncommon words like asynchronous and synchronous discussions should be defined and explained well to the interviewees to help them understand what is asked of them.

Appendix B (continued)

2. Suggest to use some open-ended questions starting with “how” or “can you comment on” to give interviewees some elbow room to respond to the questions.

Appendix C

Letter Comments on Guide Questions For FGD and Subject Expert



COR JESU COLLEGE

November 13, 2016

Mr. Benedicto Norberto V. Aves
Proponent
Design Research Study

Dear Sir:

As requested, may I submit, after diligently examining the 2 instruments of your study, my comments for your consideration:

A. Guide Questions For Group Discussions

1. The guide is brief but valid and enough to generate responses from the participants to compare between the two learning modules in terms of effectiveness.

B. Guide For Review of the Subject Expert

1. This guide is found to be appropriate and adequate for a proper review of the 2 sets of learning modules.
2. On learning approach, please add questions relating to the interaction between students, and between students and the teacher.
3. On presentation of modules, please add questions on how clear and effective are the pictures in the learning modules and lectures on video.

Appendix C (Continued)

I hope you find the above comments in order and helpful.

Sincerely yours,

Mr. Jun Mark Panlaan
Math Teacher
Senior High School

Appendix D

Practical Mathematics Pretest

Name____________________ Grade level______________

INSTRUCTION: ***Encircle the letter that corresponds to your answer for each item.***

I. Find a map below with a scale of 1 cm = 52 km. The straight-line distance on the map between Kansas City and Saint Louis is 6.5 cm.

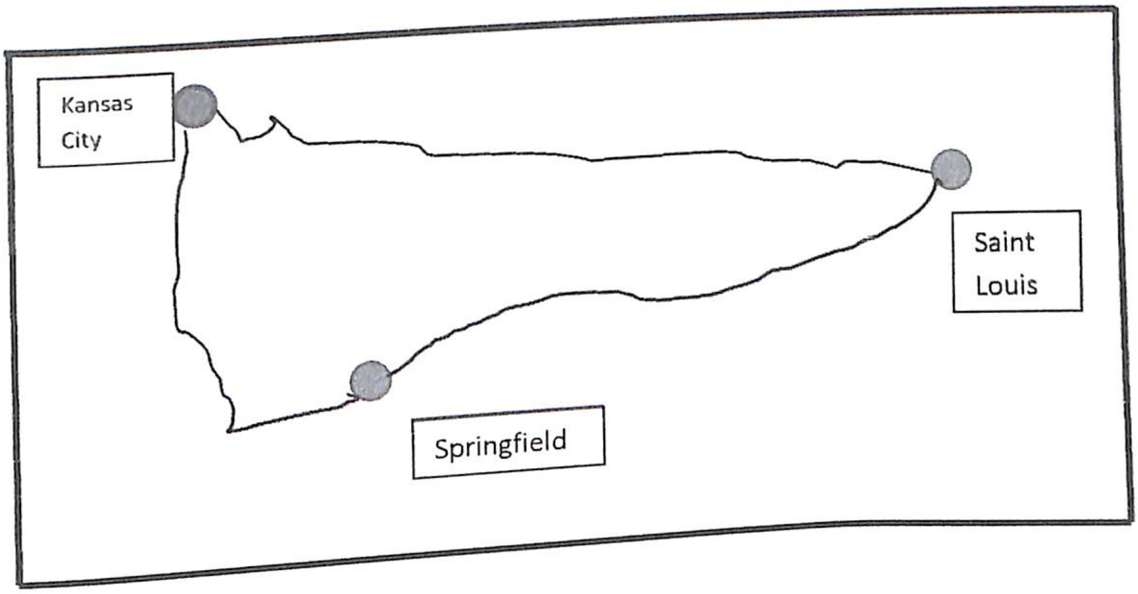


Figure 1

(Items 1, 2, and 3 are based on Figure 1)

1. Write the ratio of the map scale and that of map distance between the 2 cities to its actual distance (x).
2. Using direct proportion, what is the actual distance between the 2 cities?
3. With your usual car speed of 118 kilometers in 2 $\frac{1}{4}$hr, you plan to drive from Kansas City to Saint Louis. How long will it take you to reach Saint Louis?

A copy of the entire test may be requested through email to the researcher at goodnorberto@gmail.com.

Appendix E

Practical Mathematics Posttest

Grade

Name______________________________
level____________________

INSTRUCTION. Encircle the letter that corresponds to your answer for each item.

1. Find the product of $-3xy$ and $(x^2y - xy^2 + 4xy)$.
   a. $-3x^2y^2 + 3x^2y^3 - 12x^2y^2$
   b. $-3x^2y^2 - 3x^2y^3 - 12x^2y^2$
   c. $-3x^2y^2 - 3x^2y^2 - 12x^2y^2$
   d. $-12x^2y^3 + 3x^2y^3 - 3x^2y^2$

Table 1. Power consumption of selected appliances

Appliance	Power Use/unit	No. of units	No. of use hour/unit each day
TV	10 daw	2	2 hours
Air	100,000 cw	2	7 hours
Desktop computer	0.50 hw	2	3 hours

(Items 2 and 3 are based on table 1)

2. Compute the total amount of wattage (w) used by all appliances in a day.
   a. 7,350 w
   b. 2,300 w
   c. 14,000 w
   d. 14, 700 w

3. Using 30 days per month, what is the total amount of power consumption per month in kwh?
   a. 420 kwh
   b. 441 kwh
   c. 220.5 kwh
   d. 69 kwh
   a. 300 w
   b. 320 w
   c. 400 w
   d. 420 w

**A copy of the entire test may be requested through email to the researcher at goodnorberto@gmail.com .*

Appendix F

Evaluation Rubric

NOTE TO THE PARTICIPANT

Please note that your responses below will be treated with utmost confidentiality. Your honest evaluation will certainly help determine and validate those effective design principles of the study. So that you can *freely* make an evaluation, you are not required to write your name. Please score all the items at the rightmost column (except the box marked with *N/A*). Then, email or send it to your group leader and use a secret code as the file name of your filled-up evaluation form. The scoring system is presented below:

- 4 points = excellent
- 3 points = good
- 2 points = fair
- 1 point = needs improvement

I- Socio-Economic Profile. *Fill in the blank.*

a. Do you like to study practical mathematics (Yes, No or Neutral)?__________

b. Do you plan to find work after finishing senior high school or technical vocational course (Yes No, or Neutral)?______

c. What is the work of the breadwinner of the family?___________

Appendix F (continued)

II-Evaluation Rubric. Please type each score in the rightmost box corresponding to its numbered item.

MAIN CLUSTERS		NEEDS IMPROVEMENT	FAIR	GOOD	EXCELLENT
Learning Approach	Learning together through emails, chats, or discussion boards	• I have difficulty communicating my ideas through posting. • I get lost understanding others' ideas in the posts. • I do not learn well from the posts of other members of the group.	• Sometimes, I have difficulty communicating my ideas through posting. • Sometimes, I get lost understanding others' ideas in the posts. • Sometimes, I learn from others' ideas in the posts.	• I can communicate well my ideas through posting. • Oftentimes, I am able to track and understand others' ideas in the posts. • I learn from others' ideas in the posts.	• I can communicate very well my ideas through posting. • At all times, I am able to track and understand very well others' ideas in the posts. • I learn very well from others' ideas in the posts.
Online Roles Of Teaching	Social presence	• The instructor did not introduce himself to us. • Nobody, among us, was given the opportunity of self-introduction. • We did not consider our online instructor as a friend.	• The instructor did introduce himself only to some of us. • Some of us were given time for self-introduction while others were not. • Sometimes, we considered our online instructor as a friend.	• The instructor introduced himself well to all of us. • We were all given time for self-introduction. • We also considered our online instructor as a friend.	• The instructor introduced himself very well to all of us. • We were all given plenty of time for self-introduction. • We always considered our instructor not only as an online teacher but as a good friend as well.

Appendix F (continued)

MAIN CLUSTERS		NEEDS IMPROVEMENT	FAIR	GOOD	EXCELLENT
Technology tools	The use of emails or discussion boards	• Nobody used emails or discussion boards to communicate ideas or discuss the lesson.	• Only 1 to 2 members of our group used emails or discussion boards to communicate ideas or discuss the lesson.	• 3 members of our group used emails or discussion boards to communicate ideas or discuss the lesson.	• All of us used emails or discussion boards to communicate ideas or discuss the lesson.
Online Learning Modules	Presentation of the online modules	• The presentation of the modules was timely and logical in none to 1 module.	• The presentations of the modules were timely and logical in a few modules	• The presentations of the modules were timely and logical in many modules.	• The presentations of the modules were timely and logical in most modules.

---

[*] A copy of the entire evaluation rubric may be requested through email to the researcher at goodnorberto@gmail.com.

Appendix G

Observation Guide

Instructor's name__________________________ Period of observation___________

Observed group___________________________ Lesson/s____________________

Observer's name___________________

Please check the box that best describes how you see each of the items below. See the description of each of the column heading numbers, as follows:

1 = Not observed

2 = Not so evident

3 = Evident

4 = Highly evident

LEARNING APPROACH	1	2	3	4
1. The group learns together through chats.				
2. The group learns together through emails.				
3.The group learns together through video calling or voice calling.				
4. Group members interact to help each other perform the given lesson tasks.				
5. There is enough time for the group to solve the problem-based task and submit it on or before the schedule.				

6. The group is engaged on solving the problem-based tasks.				
7. The group has managed to solve the problem-based task.				
8. The shared output—posted on the discussion board--and its ensuing class discussion has enlightened the group or validated their work.				
Write any comments here.				

ONLINE ROLES OF TEACHING	**1**	**2**	**3**	**4**
9. Instructor facilitates group discussion towards the attainment of the lesson objectives.				
10. He uses strategies to keep the group fully engaged on the task at hand.				
11. The instructor introduces himself well to the group.				
12. Group members are given time for self-introduction.				
Write any comments here.				

A copy of the entire observation guide may be requested through email to the researcher at goodnorberto@gmail.com .

Appendix H

Interview Protocol

The following are guide questions in the conduct of a semi-structured interview. These questions are grouped into 4 clusters—each cluster probing on the usability of a set of design principles of the study.

For learning approach

1. How do you find the problem-based task of a module?
2. Were you motivated to join the asynchronous discussion (i.e. messages exchanged over an extended period of time) or synchronous discussion (i.e. messages are exchanged back and forth simultaneously) as your group performed a problem-based task?
3. How do you find the workload in a module—studying 2 lessons each week?
4. Do you like grouping based on your choices? Why?
5. Is group size of 4 conducive for asynchronous discussion (i.e. messages exchanged over an extended period of time)? Why?
6. Can you comment on the weekly submission of group and individual outputs?
7. Were you able to discuss well with the other members of the group the solution to the problem?

[*] A copy of the entire observation guide may be requested through email to the researcher at goodnorberto@gmail.com.

Appendix I

Guide Questions for Focus Group Discussion

Answer as best as you can the following questions for focus group discussion:

1. Of the two types of modules at hand (one that you used and the other type you did not use), which one would you choose should you want to learn more topics in Practical Mathematics?

2. Why would you choose such module?

3. Can you suggest, if any, some improvements on the modules that you did not choose?

Appendix J

Guide for Review of Subject Expert

	Design Research Learning Modules	Traditional Learning Modules
LEARNING APPROACH	1. Is the approach, which is problem-based and collaborative, a learner-centered or teacher-centered one? 2. Will this approach motivate and interest online students to study Practical Math? To what extent or degree will the learning activities (i.e., first trying to solve the problem as a group by using prior knowledge, then watching video for tutorial on the need-to-knows to completely solve the problem, and individual exercises) engage our students? 3. Are the problems in the modules based on real-world situations, manageable, and appropriate to the difficulty level of the users? 4. What can you say about the	1. Is the approach a learner-centered or teacher-centered one ? 2. Will this approach motivate and interest online students to study Practical Math? To what extent or degree will the learning activities (first watching lecture on video, solving exercises, asking questions, if any, from the teacher, and making an assignment)? 3. What can you say about the whole class discussion (during Q & A with the teacher)? 4. Would you recommend this approach other than the one in an online study of Practical Math? 5. What can you say about the interaction which is limited

	size of a discussion group (three members) in regard to how well it enhances discussion and student engagement? 5. Can students in senior high school handle and engage well in an asynchronous discussion (which allows time for reflection on what is asked of the problem before a participant contributes something to the group discussion)? 6. What can you say about the level of interaction which allows student-to-student interaction during collaboration time and student-to-teacher interaction for guidance? 7. Would you recommend this approach other than the one in an online study of Practical Math?	only to teacher-student interaction? 6. Would you recommend this approach other than the one in an online study of Practical Math?

[*] *A copy of the entire review guide may be requested through email to the researcher at goodnorberto@gmail.com.*

Appendix K

Problem Title : Phase 1 of Ground Design of a Park

Lesson 1.1 : Length

The Problem

Dear Contractor,

I want you to make the ground design of a people's park with appropriate length measurements in the metric system. Please make your design based on the specifications that I set below:

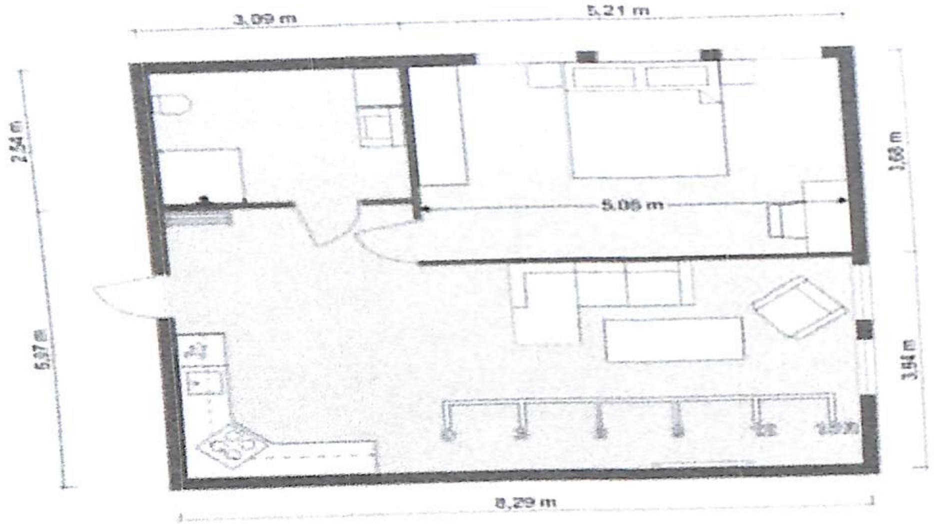
- The shape of your park will be your choice.
- The perimeter of the park should range from 9 to 10 times the length of a basketball court.
- Your park must have a concrete border where runners and walkers can freely move around it. The width of the border should not be more than 3,000 mm but not less than 2,500 mm. Its concrete thickness should range from 0.005 dam to 0.01 dam.
- Within the concrete border is a ground covered with bermuda grass where you will put no more than 20 marble benches—each bench could comfortably sit 3 persons. The height of each bench is 380,000 μm from the ground.

[City of Alliance Central Park Fountain] (2010). Retrieved from https://en.wikipedia.org/wiki/City_of_Alliance_Central_Park_Fountain

Appendix *K* (continued)

- In the middle of the ground covered with bermuda grass is a fountain that jets water as high as no more than 0.12 hm.
- There should be 3 entrances/exits to the park and each could pass 5 persons simultaneously.

Make the ground design as simple as you can. Draw the sketch of the ground design of your park—an illustration of which is shown—and, most importantly, indicate its appropriate metric measurements.



A Floor Plan. Retrieved from https://www.roomsketcher.com/blog/how-to-create-perfect-measurements-with-roomsketcher/

Best regards,
Public Park Commission

Appendix K (continued)

Now, based on the specifications above, you will answer with solutions the following questions:

(Your answers are values of measurements appropriate to the dimensions being asked)

1. What is the perimeter of your park?
2. What is the width of the concrete border? its concrete thickness?
3. What is the perimeter of the ground covered with bermuda grass?
4. What is the height of the marble bench?
5. What is the height of the water jet of the fountain?

Objectives (*what are the essential knowledge and skills you should learn?)*
i. Identify an appropriate metric measurement for a particular length dimension. ii. Identify the prefixes for metric unit of length and SI abbreviations of these prefixes iii. Convert from one unit to another within metric system involving length.
Student Prior Knowledge
All students should know the following: • perimeter of polygons

Problem Roll-Out

- Take time with your group to discuss what you know about the problem like the group's freedom to choose the ground design, the park's specifications, and the structures (i.e. fountain, bench, etc).
- Then, discuss what you need to know to solve the problem-based task like the symbols and values of the specifications and conversions between metric units involving length.
- Agree with your group on the design of your park.

Work Time

- Start drawing the selected design of a park.
- When you now come to your need to know, please proceed to workshop.

Workshop

Please click on "*Video tutorials*" and watch the video presentation on the following:

a. Identify an appropriate metric measurement for a particular length dimension.

b. Identify the prefixes for metric unit of length and SI abbreviations of these prefixes.

c. Convert from one unit to another within metric system involving length.

- You can watch the video for as long as you need it.

Prefix	Multiple or submultiple*	Power of 10	Prefix symbol
tera	1,000,000,000,000	10^{12}	T
giga	1,000,000,000	10^{9}	G
mega	1,000,000	10^{6}	M
kilo	1,000	10^{3}	k
hecto	100	10^{2}	h
deka	10	10^{1}	da
deci	0.1	10^{-1}	d
centi	0.01	10^{-2}	c
milli	0.001	10^{-3}	m
micro	0.0000001	10^{-6}	μ
nano	0.000000001	10^{-9}	n
pico	0.000000000001	10^{-12}	p

** Factor by which a metric unit is multiplied*

Appendix K (continued)

- Now, answer individually the exercises 1.1 below and check your answers by clicking on "*Answer key*".

A. Write the metric prefix for each of the values below. Two items may have the same metric prefix.

1. 10^9 = ____________

2. 0.000000001 = ____________

3. 10^{-1} = ____________

4. 10^6 = ____________

B. Provide the SI symbols for each of the following prefixes:

5. milli = ____________

6. micro = ____________

7. kilo = ____________

C. Write the SI abbreviation for each of the following quantities:

8. 61 centimeters = ____________

9. 100 kilometer = ____________

D. Write the SI unit for each of the following abbreviations:

10. 2 mm = ____________

11. 50 hm = __________

E. Supply the missing item with the most appropriate unit (km, m, cm, or mm).

12. The standard metric size for plywood is 1200______wide and 2400______long.

13. The size of John's waistline is 93_______.

14. The width dimension of a classroom is 7______.

15. An airplane generally cruises at an altitude of about 8 to 9 ______high.

16. The steering wheel of his car is 36_______ in diameter.

C. Convert the following:

17. 765m = ________km

18. 546 cm =________m

19. 5.7 m = ________mm

20. 1.3 m =__________um

Appendix K (continued)

Sharing out and Discussion

- One group will share their park design on the discussion board. Click on "Discussion board" and, if it is already there, take time to examine it. You are welcome to ask questions or comments on the shared output.

Work Time

- Go back to your work. Your group may watch again the video, do some revisions, or completely write your solutions.

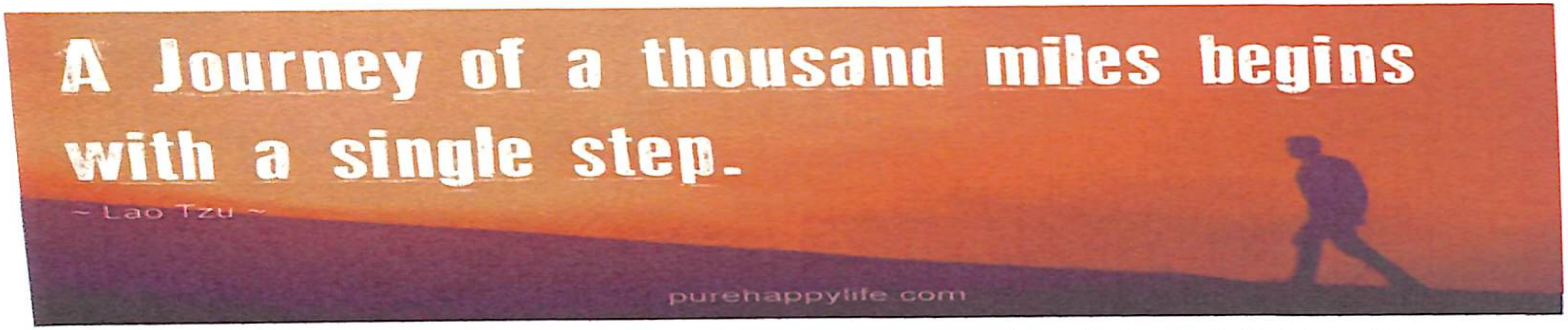
Final Action on the Problem

- Send a soft copy of your group report to your teacher containing the ground design of your park and solutions to the questions of the problem-based task. Keep one copy as reference for the next lesson.

Assignment 1.1

- Try to solve the assignment below and click on *"Solutions"* to self-check solutions to your assignment.

Your park is a two-hours' run straight to a beach resort. What is the distance between the park and the beach resort given the average runner's speed of 4000 m per 40 minutes?



Purehappylife.com [A Journey of a thousand miles begins with a single step]. Retrieved from https://purehappylife.com/life_quotes_love_quotes/inspirational-quotes-a-journey-of-a-thousand-miles-begins-with-a-single-step-html

You have now taken that single step!

Appendix K (continued)

Problem Title: Phase 2 of the Park Design

Lesson 1.2 : Areas and Volumes

The Problem

Dear Contractor,
This is now the second and last phase of the ground design of your park. For your convenience, I will rewrite below the first set of specifications from your phase 1 of ground design. What follows is the second set of specifications which you need to consider in doing the last phase of your park design.

A. First Set

- The shape of your park will be your choice.
- The perimeter of the park should range from 9 to 10 times the length of a basketball court.
- Your park must have a concrete border where runners and walkers can freely move around it. The width of the border should not be more than 3,000 mm but not less than 2,500 mm. Its concrete thickness should range from 0.005 dam to 0.01 dam.
- Within the concrete border is a ground covered with bermuda grass where you will put no more than 20 marble benches—each bench could comfortably sit 3 persons. The height of each bench is 380,000 µm from the ground.
- In the middle of the ground covered with bermuda grass is a fountain that jets water as high as no more than 0.12 hm.

Appendix K (continued)

- There should be 3 entrances to the park and each could pass 5 persons simultaneously.

B. Second Set

- The length and width dimensions of the top of a marble bench are 11.4 dm and 3.8 dm respectively.
- The fountain may take the shape of an open concrete circular box, a rectangular box, or an open, concrete square box. Pick your choice. The height of the vertical side of the fountain ranges from 0.060 dam to 0.066 dam. Its thickness is 0.0015 hm.

Best regards,

Public Park Commission

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* 1stdibs.com [Marble Bench]. Retrieved from https://www.1stdibs.com/furniture/building-garden/garden-ornaments/marble-bench roman-carved-bases-blue-cheese-marble-top/...

**[Circular Fountain]. Retrieved from https://longwoodgardwns.org/components/highlight-item/50105

***[Rectangular Fountains]. Retrieved from www.aquafountainpool.com/product/recangular-fountain/

Now, based on the above specifications, compute the areas and volumes (in appropriate metric measurements) of the following:

1. What is the total area of the concrete border?
2. What is the area of the top of a marble bench?
3. How much volume of concrete will be used for the border?
4. What is the area of the ground covered with bermuda grass?
5. Given that we need to beautify our fountain by tiling its outer and top sides, how many units of a square decorative tile with a side dimension of 140 mm will be used for that purpose?
6. Assuming that your fountain should be three-fourths full of water at any time, how much volume of water is placed in the fountain?

Objectives (what are the essential knowledge and skills that you should learn?)

1.2.1 Identify an appropriate metric unit for a particular area.
1.2.2 Convert from one unit to another within the metric system involving area.
1.2.3 Identify an appropriate metric unit for a particular volume.
1.2.4 Convert from one unit to another within the metric system involving volume.

Student Prior Knowledge

All students should know the following:

- Convert from one metric unit to another involving length
- Areas of polygons
- Volumes of some solids

Problem Roll-Out

- Just to refresh what you know but must have forgotten!

$A = L \times W$ (area of rectangle)

Area = s^2 (area of a square) where s = side of a square

$V = L \times W \times H$ (volume of rectangular box)

$V = s^3$ (volume of a cube)

$V = \text{Л}r^2 \times h$ (volume of a cylinder)

$L = 2\text{Л}r \times h$ (lateral area of a cylinder)

$L = 4(s^2)$ (lateral area of a square box or area of 4 sides of the box)

$L = 2(wh) + 2(wL)$ (lateral area of a rectangular box or area of 4 sides of a rectangular box)

Appendix K (Continued)

DON'T FORGET

Prefix	Multiple or submultiple*	Power of 10	Prefix symbol
tera	1,000,000,000,000	10^{12}	T
giga	1,000,000,000	10^{9}	G
mega	1,000,000	10^{6}	M
kilo	1,000	10^{3}	k
hecto	100	10^{2}	h
deka	10	10^{1}	da
deci	0.1	10^{-1}	d
centi	0.01	10^{-2}	c
milli	0.001	10^{-3}	m
micro	0.0000001	10^{-6}	µ
nano	0.000000001	10^{-9}	n
pico	0.000000000001	10^{-12}	p

** Factor by which a metric unit is multiplied*

en, discuss what you need to know.

Appendix K (continued)

Work Time

- Start calculating the areas and volume of the problem.
- When you now come to the need to know, proceed to workshop.

Workshop

- Please click on “*Video tutorials*” and watch the video presentation on the following:

  1. Identify an appropriate metric unit for a particular area.
  2. Convert from one unit to another within the metric system involving area.
  3. Identify an appropriate metric unit for a particular volume.
  4. Convert from one unit to another within the metric system involving volume.

- You can watch the video for as long as you need it.
- Now, answer individually Exercises 1.2 below and click on “Answer keys” to find the answer key to the said exercises.

Appendix K (continued)

Part A. Choose the most appropriate metric unit in area or volume (m^2, m^3, cm^2, L, mL, ha, km^2) to measure each of the following items:

1. Oil in your car's crankcase
2. Size of an industrial park
3. Eye drops
4. Floor space in a warehouse
5. Size of a rice farm
6. Page size of a book
7. Cargo space in a truck
8. Cross-sectional area of a piston
9. Gasoline in a car's gas tank
10. Can of Pepsi

Convert from one unit to another unit.

11. 2,300 mL = _____L

12. 820 L = _______m^3

13. $90\ cm^3 =$ ______ mL

14. $660\ mm^3 =$ ______ cm^3

15. $550\ dm^3 =$ ______ mm^3

16. $44\ m^2 =$ ________ cm^2

17. $400\ ha =$ ________ km^2

18. $30{,}400\ m^2 =$ _____ ha

19. How many hectares are there in a recreation park with the dimension of 75 m by 90 m?

20. How many hectares are there in a rectangular farm that measures ¼ kilometer by ½ kilometer?

Sharing out and Discussion

- As one saying goes, “two heads are better than one.” Click on “Discussion board” to take a look at a shared output on the discussion board. Your critical thinking is needed here!

Work Time

- Go back to your work. Your group may watch again the video, do some revisions, or completely write your solutions.

Final Action on the Problem

- Send a soft copy of the group report containing the solutions to the questions of the problem to your teacher.

Assignment 1.2

- Continue to challenge yourself with this extension of assignment 1.1 and click on *"Solutions"* for the solutions to the assignment.

1. Assume that the space between the park and the beach resort in assignment 1.1 is a large square of land applied to mixed use of residence and forest. What is the total area of the large square of land?
2. Given that the average daily demand of Coca-cola by park goers is 50 dm^3, answer the following:
   a. What is the average daily demand in liters?
   b. How many 330-mL cans of Coca-cola will you sell to satisfy the average daily demand?

GOOD
JOB ☺

**Copies of other learning modules may be requested through email to the researcher at goodnorberto@gmail.com.*

Appendix L

Screenshots of Video tutorials

Lesson 1.1 Length (video)

Lesson 1.2 Areas and volumes (video)

Lesson 1.3 Mass, weight and time (video)

Lesson 1.4
urrent, voltage
watts (video)

Lesson 1.5 Polynomials (video)

Lesson 1.6 Simple Equations (video)

Lesson 1.7 Ratio & direct proportion

**These video tutorials may be requested through email to the researcher at goodnorberto@gmail.com.*

Apendix L (continued)

Sample Content Description of Video Tutorials

Video tutorial 1.1. The video tutorial lasts for 12:54 minutes. In this video, the facilitator defines length and uses the side of a rectangle as an illustration on length. He shows a table containing metric prefixes with corresponding symbols and explains when to use them. Moreover, he has also expounded the following:

a. What metric unit is appropriate for a particular length;
b. The procedure on mental conversion and two applications;
c. The procedure on conversion facto and two applications;
d. Conversions involving very large units and very small units.

Video tutorial 1.2. *The video tutorial lasts for* 13:29 minutes. In the first part, the facilitator defines the area, cites the common metric units of the area, and uses the conversion factor to solve two problems involving conversions between metric units of an area. In the second part, the facilitator defines the volume, shows the appropriate metric units of large or small measurements, and solves two conversion problems involving volume by using the conversion factor.

**Content descriptions of the other video tutorials may be requested through email to the researcher at goodnorberto@gmail.com.*

Helpful Info

On Video 1.1

Appendix M

The table has a value 1/10 of that to its immediate left or a value 10 times that to its immediate right.

1,000m	100m	10m	1 m	0.1 m	0.01	0.001m
1 km	1 hm	1 dam	1 m	1dm	1cm	1 mm

Thus, moving one place in the table corresponds to moving one decimal place.

Example 1.Change 5.32 mm to cm.

1,000m	100m	10m	1 m	0.1 m	0.01	0.001m
1 km	1 hm	1 dam	1 m	1dm	1cm	1 mm

Notice that moving from 1 mm to 1 cm (converting from a small unit to a large unit) in the table entails moving one place to the left. This also means that we can move the decimal point of the unit being converted one place to the left. We now write the result with the new unit.

5.32 Consider the table below. Since the metric measurement is a base-10 system, each

place in the mm = 0 5.32

= 0.532 cm

Example 2. Change 2.5 hm to dam.

1,000m	100m	10m	1 m	0.1 m	0.01	0.001m
1 kg	1 hm	1 dam	1 m	1dm	1cm	1 mm

Notice again that moving 1 hm to 1 dam (converting from a large unit to a small unit) entails moving one place to the right. Thus, we can also move the decimal point of 2.5 hm one place to the right. The final answer is presented below.

1.5 hm = 2.5

= 25 dam

Copies of other helpful notes may be requested through email to the researcher at

goodnorberto@gm

Appendix N

Exercises 1.1

A. *Write the metric prefix for each of the values below.* Two items may have the same metric prefix.

1. 10^9 = **giga**

2. 0.000000001 = **nano**

3. 10^{-1} = **deci**

4. 10^6 = **mega**

B. Provide the SI symbols for each of the following prefixes:

5. milli = **m**

6. micro =**u**

7. kilo =**k**

C. Write the SI abbreviation for each of the following quantities:

8. 61 centimeters = **61cm**

9. 100 kilometer = **100 km**

D. Write the SI unit for each of the following abbreviations:

10. 2 mm = **2 millimeters**

11. 50 hm = **50 hectometers**

E. Supply the missing item with the most appropriate unit (km, m, cm, or mm).

12. The standard metric size for plywood is 1200 **mm** wide and 2400 **mm** long.

13. The size of John's waistline is 93 **cm**.

14. The width dimension of a classroom is 7 **m**.

Appendix N (continued)

15. An airplane generally cruises at an altitude of about 8 to 9 **km** high.

16. The steering wheel of his car is 36 **cm** in diameter.

F. Convert the following:

17. 765m = **0.765 km**

18. 546 cm = **5.46 m**

19. 5.7 m = **5,700 mm**

20. 1.3 m = **1,300,000 um**

**Copies of the other answer keys may be requested through email to the researcher at goodnorberto@gmail.com.*

Appendix N (continued)

Assignment 1.2

1. Assume that the space between the park and the beach resort in assignment 1.1 is a large square of land applied to mixed use of residence and forest. What is the total area of the large square of land?

Solution:

- Since the distance between the park and the resort (or one side of the land) is 12 km and the space in between is a large square of land, then we compute as follows:

  12 km x 12 km = 144 km^2

2. Given that the average daily demand of Coca-cola by park goers is 50 dm^3, answer the following:

a. What is the average daily demand in liters?

Solution:

Since 1 dm^3 = 1L, then 50 dm^3 = 50 L.

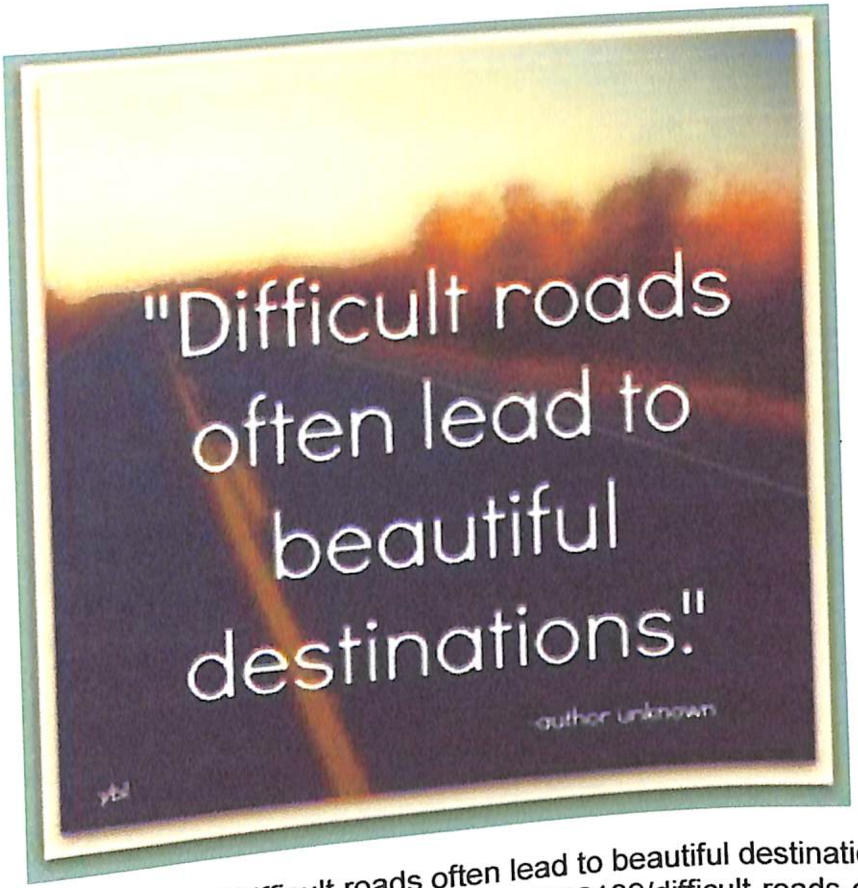
b. How many 330-mL cans of coca-cola will you sell to satisfy the average daily demand? (Round your answer to a whole number)

Solution:

In ml, the average daily demand is 50,000 mL. Divide this daily demand by 330

mL, the answer is 151.5 or rounded it off to 152.

Appendix N (continued)

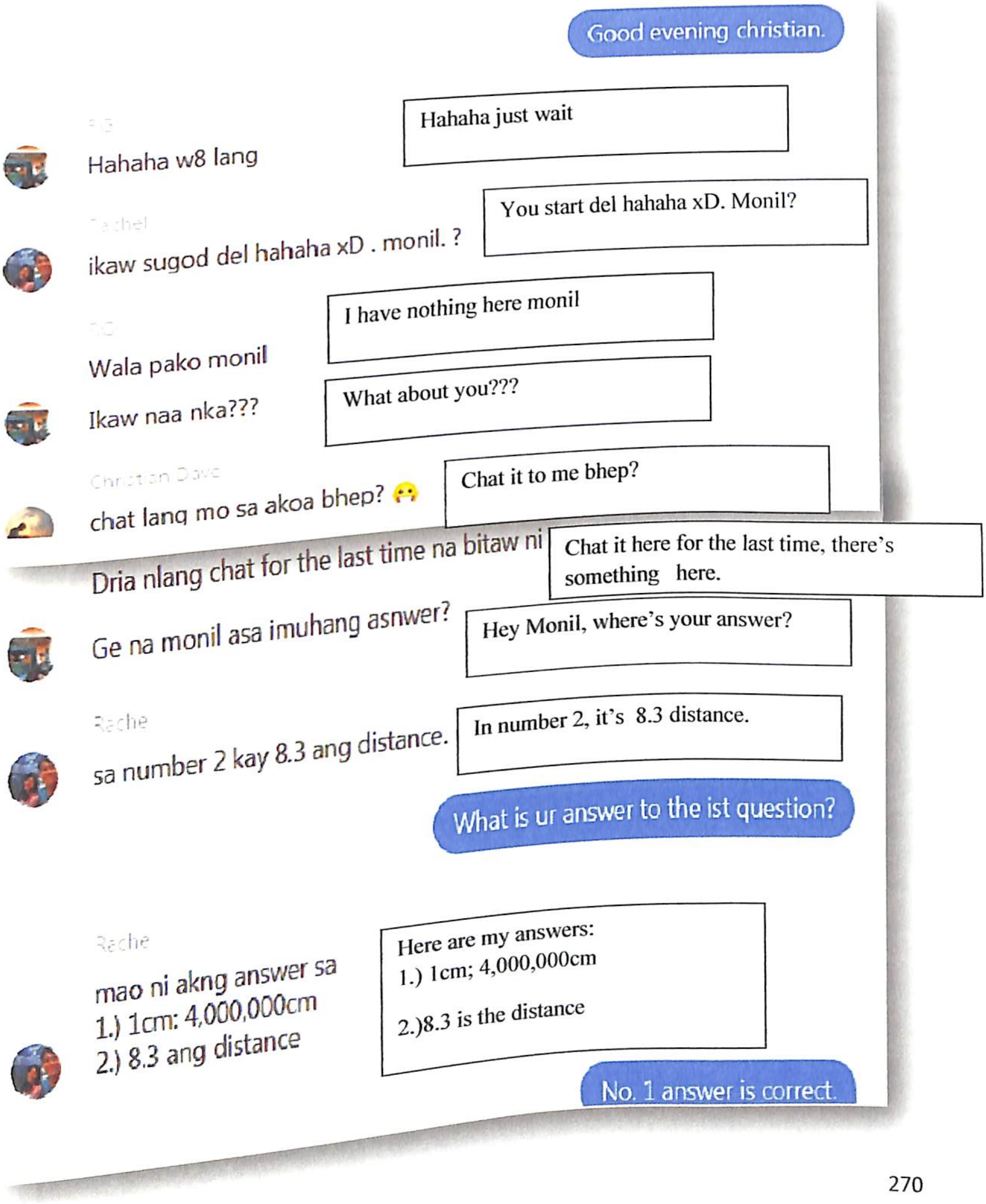


LoveThisPic [Difficult roads often lead to beautiful destinations]. Retrieved from www.lovethispic.com/image/190109/difficult-roads-often-lead-to-beautiful-destinations

Copies of the other solution keys may be requested through email to the researcher at goodnorberto@gmail.com.

Appendix O

An Excerpt of a Group Chat on Module 1.7



Good evening christian.

RG

Hahaha w8 lang

Hahaha just wait

Rachel

ikaw sugod del hahaha xD . monil. ?

You start del hahaha xD. Monil?

RG

Wala pako monil

I have nothing here monil

Ikaw naa nka???

What about you???

Christian Dave

chat lang mo sa akoa bhep? 😬

Chat it to me bhep?

Dria nlang chat for the last time na bitaw ni

Chat it here for the last time, there's something here.

Ge na monil asa imuhang asnwer?

Hey Monil, where's your answer?

Rache

sa number 2 kay 8.3 ang distance.

In number 2, it's 8.3 distance.

What is ur answer to the ist question?

Rache

mao ni akng answer sa
1.) 1cm: 4,000,000cm
2.) 8.3 ang distance

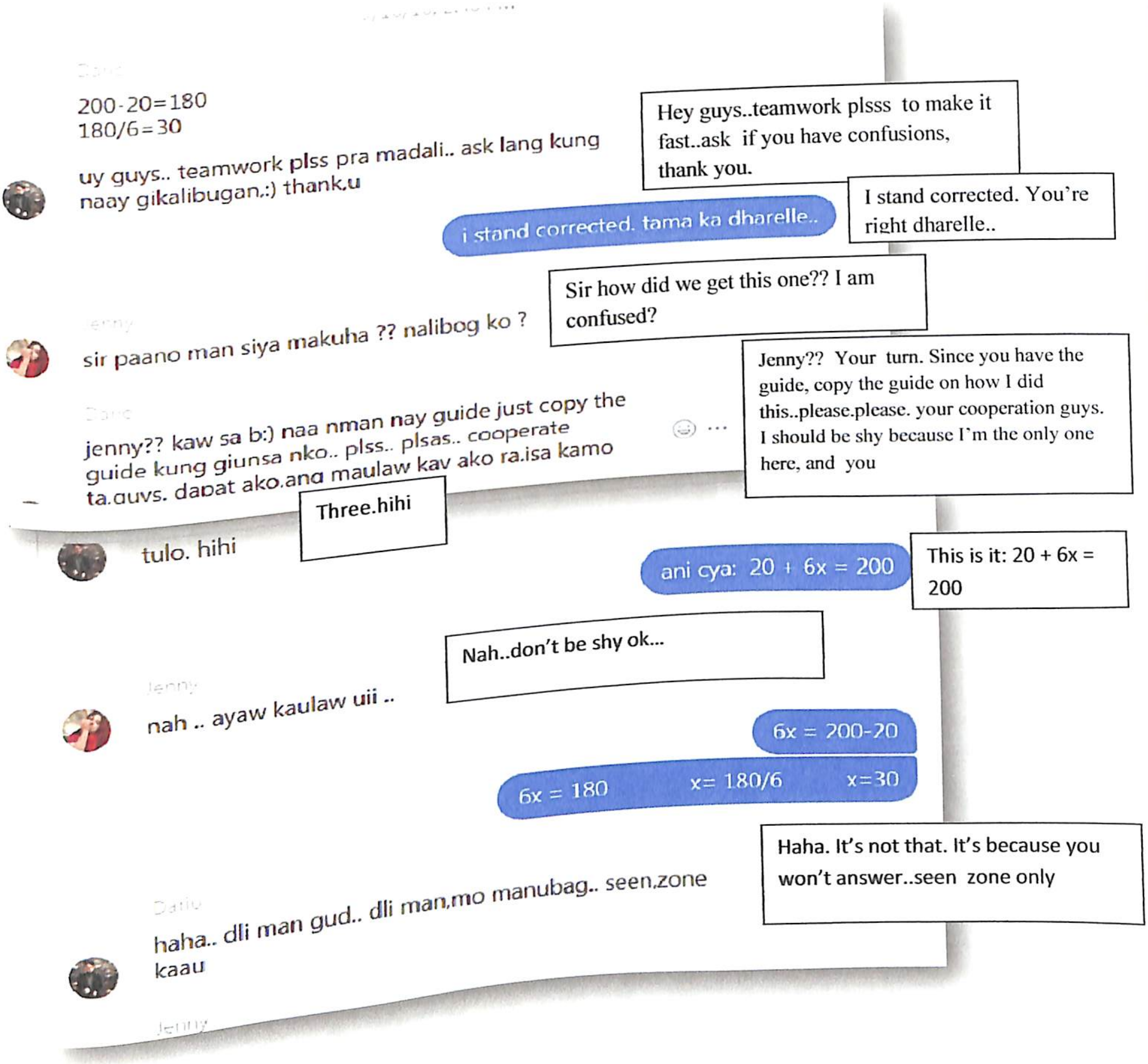
Here are my answers:
1.) 1cm; 4,000,000cm

2.)8.3 is the distance

No. 1 answer is correct.

Appendix O (continued)

An Excerpt of a Group Chat on Module 1.6



Dario

200-20=180
180/6=30

uy guys.. teamwork plss pra madali.. ask lang kung naay gikalibugan.:) thank.u

Hey guys..teamwork plsss to make it fast..ask if you have confusions, thank you.

i stand corrected. tama ka dharelle..

I stand corrected. You're right dharelle..

Jenny

sir paano man siya makuha ?? nalibog ko ?

Sir how did we get this one?? I am confused?

Dario

jenny?? kaw sa b:) naa nman nay guide just copy the guide kung giunsa nko.. plss.. plsas.. cooperate ta.guys. dapat ako.ang maulaw kay ako ra.isa kamo

Jenny?? Your turn. Since you have the guide, copy the guide on how I did this..please.please. your cooperation guys. I should be shy because I'm the only one here, and you

tulo. hihi

Three.hihi

ani cya: 20 + 6x = 200

This is it: 20 + 6x = 200

Jenny

nah .. ayaw kaulaw uii ..

Nah..don't be shy ok...

6x = 200-20

6x = 180 x= 180/6 x=30

Dario

haha.. dli man gud.. dli man,mo manubag.. seen,zone kaau

Haha. It's not that. It's because you won't answer..seen zone only

Jenny

Appendix P

Problem Title : Phase 1 of Ground Design of a Park
Lesson 1.1 : Length
The Problem

Dear Contractor,

I want you to make the ground design of a people's park with appropriate length measurements in the metric system.

Please make your design based on the specifications that I set below:

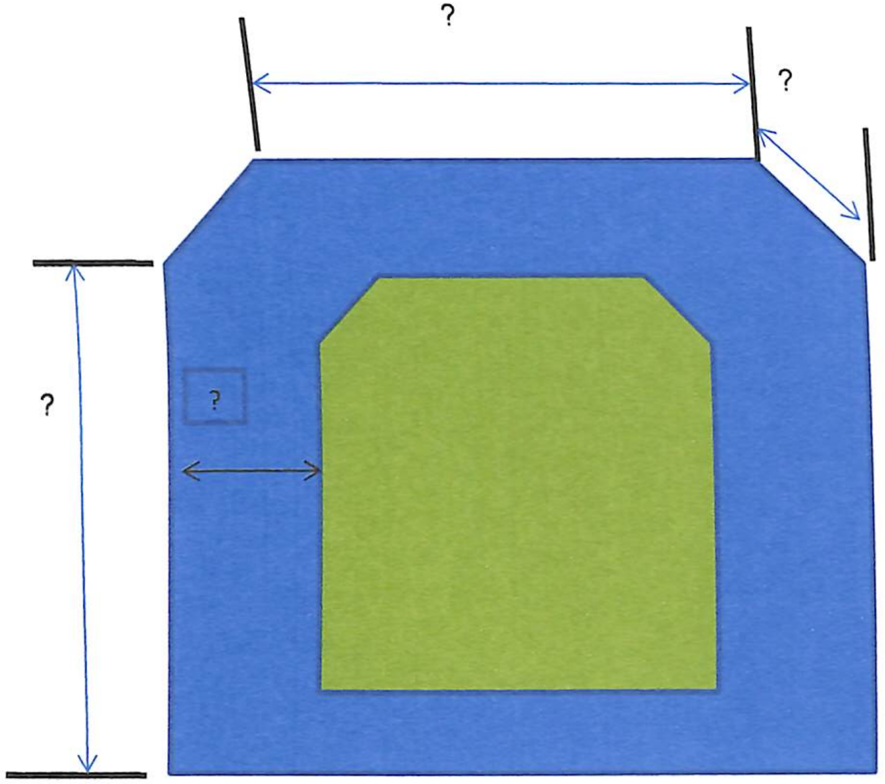
- The shape of your park will be your choice.
- The perimeter of the park should range from 9 to 10 times the length of a basketball court.
- Your park must have a concrete border where runners and walkers can freely move around it. The width of the border should not be more than 3,000 mm but not less than 2,500 mm. Its concrete thickness should range from 0.005 dam to 0.01 dam.
- Within the concrete border is a ground covered with bermuda grass where you will put no more than 20 marble benches—each bench could comfortably sit 3 persons. The height of each bench is 380,000 µm from the ground.

Appendix P (continued)

- In the middle of the ground covered with bermuda grass is a fountain that jets water as high as no more than 0.12 hm.

- [City of Alliance Central Park Fountain] (2010). Retrieved from https://en.wikipedia.org/wiki/City_of_Alliance_Central_Park_Fountain

Make the ground design as simple as you can. *Draw the sketch of the ground design of your park, an illustration of which is shown below*, and, most importantly, *indicate its appropriate metric measurements.*



Best regards,
Public Park Commission

Appendix P (continued)

Now, based on the specifications above, you will answer with solutions the following questions:

(Your answers are values of measurements appropriate to the dimensions being asked)

1. What is the perimeter of your park?
2. What is the width of the concrete border? its concrete thickness?
3. What is the perimeter of the ground covered with bermuda grass?
4. What is the height of the marble bench?
5. What is the height of the water jet of the fountain?

Objectives *(what are the essential knowledge and skills you should learn?)*

i. Identify an appropriate metric measurement for a particular length dimension.
ii. Identify the prefixes for metric unit of length and SI abbreviations of these prefixes
iii. Convert from one unit to another within metric system involving length.

Student Prior Knowledge

All students should know the following:

- perimeter of polygons

Problem Roll-Out

- Take time with your group to discuss what you know about the problem like the group's freedom to choose the ground design, the park's specifications, and the structures (i.e. fountain, bench, etc).
- Then, discuss what you need to know to solve the problem-based task like the symbols and values of the specifications and conversions between metric units involving length.
- Agree with your group on the design of your park.

Work Time

- Start drawing the selected design of a park.
- When you now come to your need to know, please proceed to workshop.

Workshop

- Please click on "*Video Tutorials*" with helpful notes and watch the video presentation on the following:

a. Identify an appropriate metric measurement for a particular length dimension.

Appendix P (continued)

b. Identify the prefixes for metric unit of length and SI abbreviations of these prefixes.

c. Convert from one unit to another within metric system involving length.

➢ You can watch the video for as long as you need it.

Prefix	Multiple or submultiple*	Power of 10	Prefix symbol
tera	1,000,000,000,000	10^{12}	T
giga	1,000,000,000	10^{9}	G
mega	1,000,000	10^{6}	M
kilo	1,000	10^{3}	k
hecto	100	10^{2}	h
deka	10	10^{1}	da
deci	0.1	10^{-1}	d
centi	0.01	10^{-2}	c
milli	0.001	10^{-3}	m
micro	0.0000001	10^{-6}	μ
nano	0.000000001	10^{-9}	n
pico	0.000000000001	10^{-12}	p

** Factor by which a metric unit is multiplied*

Appendix P (continued)

- Now, answer individually the Exercises 1.1 below and check your answers by clicking on "Answer Key."

A. Write the metric prefix for each of the values below. Two items may have the same metric prefix.

1. 10^9 = __________
2. 0.000000001 = __________
3. 10^{-1} = __________
4. 10^6 = __________

B. Provide the SI symbols for each of the following prefixes:

5. milli = __________
6. micro = __________
7. kilo = __________

C. Write the SI abbreviation for each of the following quantities:

8. 61 centimeters = __________
9. 100 kilometer = __________

Appendix P (*continued*)

D. Write the SI unit for each of the following abbreviations:

10.2 mm =__________

11.50 hm =__________

E. Supply the missing item with the most appropriate unit (km, m, cm, or mm).

12. The standard metric size for plywood is 1200______wide and 2400______long.

13. The size of John's waistline is 93_______.

14. The width dimension of a classroom is 7______.

15. An airplane generally cruises at an altitude of about 8 to 9 ______high.

16. The steering wheel of his car is 36_______ in diameter.

C. Convert the following:

17. 765m = ________km

18. 546 cm =________m

19. 5.7 m = _________mm

20. 1.3 m =_________um

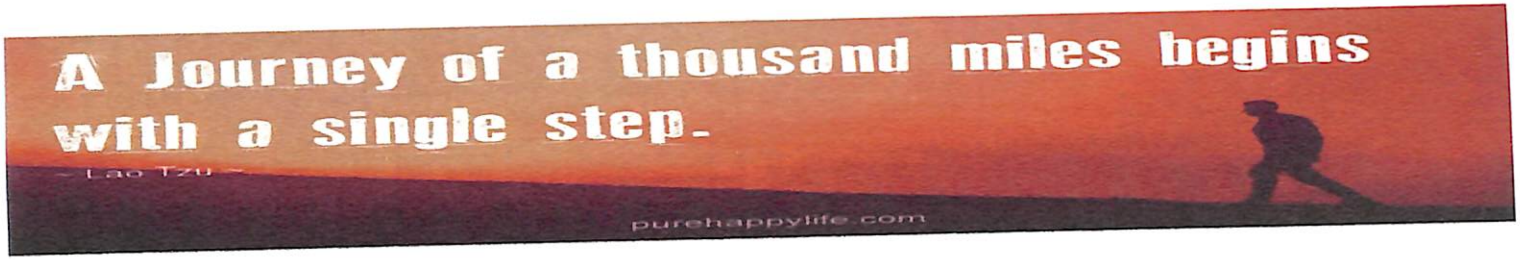
Appendix P (continued)

Work Time

- Go back to your work. Your group may watch again the video, do some revisions, or completely write your solutions.

Final Action on the Problem

- Send a soft copy of your group report to your teacher containing the ground design of your park and solutions to the questions of the problem-based task. Keep one copy as reference for the next lesson.



Purehappylife.com [A Journey of a thousand miles begins with a single step]. Retrieved from https://purehappylife.com/life_quotes_love_quotes/inspirational-quotes-a-journey-of-a-thousand-miles-begins-with-a-single-step-html

You have now taken that single step!

Appendix P (continued)

Problem Title: Phase 2 of the Park Design

Lesson 1.2: Areas and Volumes

The Problem

Dear Contractor,

This is now the second and last phase of the ground design of your park. For your convenience, I will rewrite below the first set of specifications from your phase 1 of ground design. What follows is the second set of specifications which you need to consider in doing the last phase of your park design.

A. First Set

- The shape of your park will be your choice.
- The perimeter of the park should range from 9 to 10 times the length of a basketball court.
- Your park must have a concrete border where runners and walkers can freely move around it. The width of the border should not be more than 3,000 mm but not less than 2,500 mm. Its concrete thickness should range from 0.005 dam to 0.01 dam.

Appendix P (continued)

- Within the concrete border is a ground covered with bermuda grass where you will put no more than 20 marble benches—each bench can comfortably sit 3 persons. The height of each bench is 380,000 µm from the ground.
- In the middle of the ground covered with bermuda grass is a fountain that jets water as high as no more than 0.12 hm.

B. Second Set

- The length and width dimensions of the top of a marble bench are 11.4 dm and 3.8 dm, respectively.

1stdibs.com [Marble Bench]. Retrieved from https://www.1stdibs.com/furniture/building-garden/garden-ornaments/marble-bench roman-carved-bases-blue-cheese-marble-top/...

Best regards,

Public Park Commission

Now, based on the above specifications, compute the areas and volumes (in appropriate metric measurements) of the following:

1. What is the total area of the concrete border?
2. What is the area of the top of a marble bench?
3. How much volume of concrete will be used for the border?
4. What is the area of the ground covered with Bermuda grass?

Appendix P (continued)

Objectives (what are the essential knowledge and skills that you should learn?)
1.2.1 Identify an appropriate metric unit for a particular area. 1.2.2 Convert from one unit to another within the metric system involving area. 1.2.3 Identify an appropriate metric unit for a particular volume. 1.2.4 Convert from one unit to another within the metric system involving volume.
Student Prior Knowledge
All students should know the following: • Convert from one metric unit to another involving length • Areas of polygons • Volumes of some solids

Problem Roll-Out

- Just to refresh what you know but have forgotten!
- Then, discuss what you need to know

$A = L$ x W (area of rectangle)

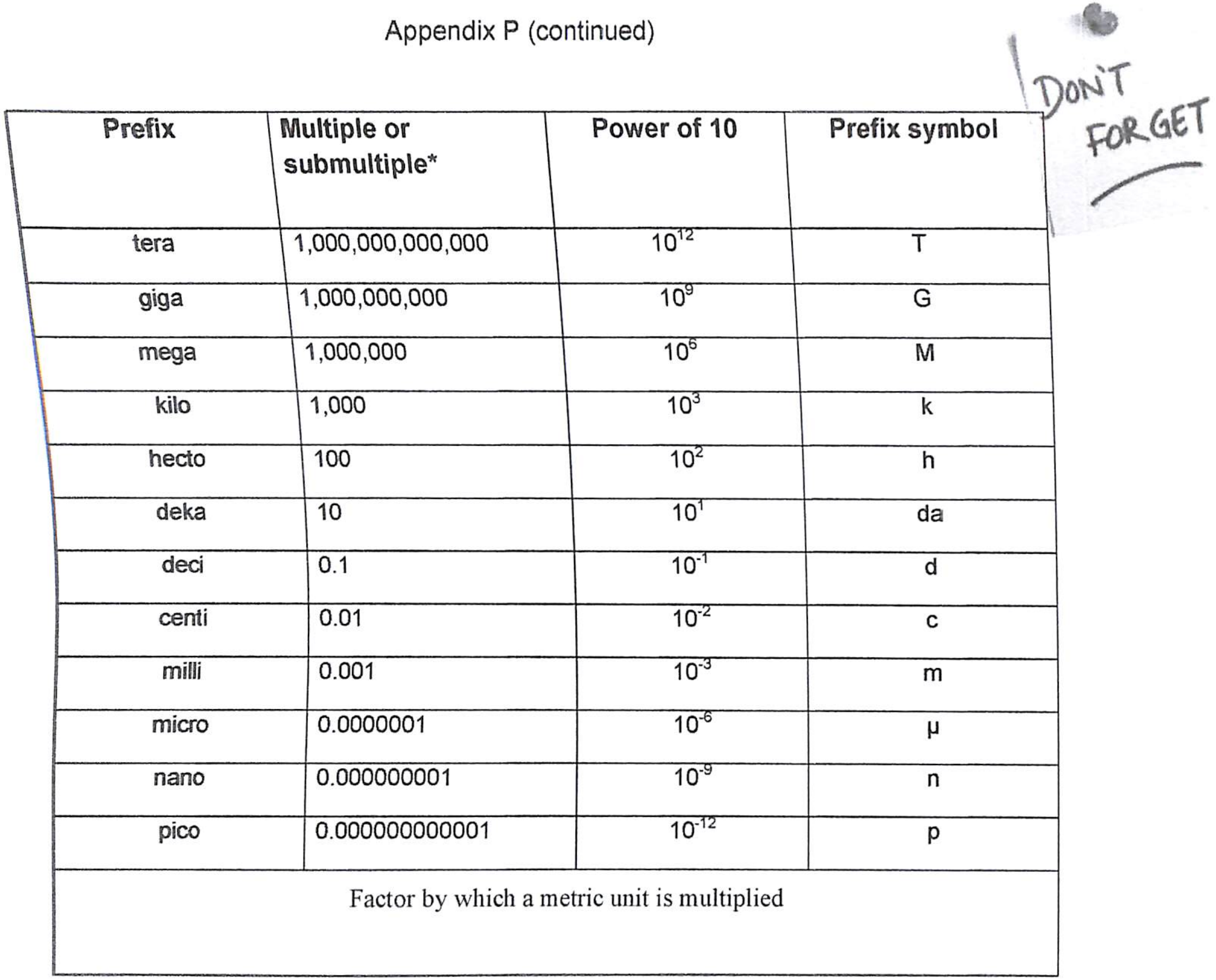
Area $= s^2$ (area of a square) where s = side

$V = L$ x W x H (volume of rectangular box)

$V = s^3$ (volume of a cube)

$V = JIr^2$ x h (volume of a cylinder)

Appendix P (continued)



Prefix	Multiple or submultiple*	Power of 10	Prefix symbol
tera	1,000,000,000,000	10^{12}	T
giga	1,000,000,000	10^{9}	G
mega	1,000,000	10^{6}	M
kilo	1,000	10^{3}	k
hecto	100	10^{2}	h
deka	10	10^{1}	da
deci	0.1	10^{-1}	d
centi	0.01	10^{-2}	c
milli	0.001	10^{-3}	m
micro	0.0000001	10^{-6}	µ
nano	0.000000001	10^{-9}	n
pico	0.000000000001	10^{-12}	p

Factor by which a metric unit is multiplied

Work Time

- ➢ Start calculating the areas and volume in the problem.
- ➢ When you now come to the need to know, proceed to workshop.

Workshop

- ➢ Please click on *“Video Tutorials”* and watch the video presentation on the following:

  1. Identify an appropriate metric unit for a particular area.
  2. Convert from one unit to another within the metric system involving area.
  3. Identify an appropriate metric unit for a particular volume.
  4. Convert from one unit to another within the metric system involving volume.

- ➢ You can watch the video for as long as you need it.

Appendix P (continued)

- Now, answer individually the Exercises 1.2 below and click on *“Answer Keys”* to find the answer key to the said exercises.

Choose the most appropriate metric unit in area or volume (m^2, m^3, cm^2, L, mL, ha, km^2) to measure each of the following items:

1. Oil in your car’s crankcase
2. Size of an industrial park
3. Eye drops
4. Floor space in a warehouse
5. Size of a rice farm
6. Page size of a book
7. Cargo space in a truck
8. Cross-sectional area of a piston
9. Gasoline in a car’s gas tank
10. Can of Pepsi

Appendix P (continued)

Convert from one unit to another unit.

11. 2,300 mL = _____L

12. 820 L = _______m^3

13. 90 cm^3 = ______mL

14. 660 mm^3 =_____cm^3

15. 550 dm^3 =______ mm^3

16. 44 m^2 =________cm^2

17. 400 ha =________km^2

18. 30,400 m^2 = _____ha

19. How many hectares are there in a recreation park with the dimension of 75 m by 90 m?

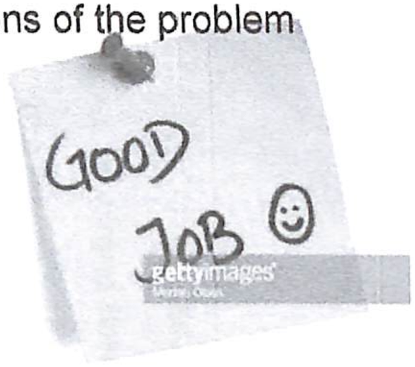
20. How many hectares are there in a rectangular farm that measures ¼ kilometer by ½ kilometer?

Work Time

Go back to your work. Your group may watch again the video, do some revisions, or completely write your solutions.

Final Action on the Problem

- Send a soft copy of the group report containing the solutions to the questions of the problem to your teacher.



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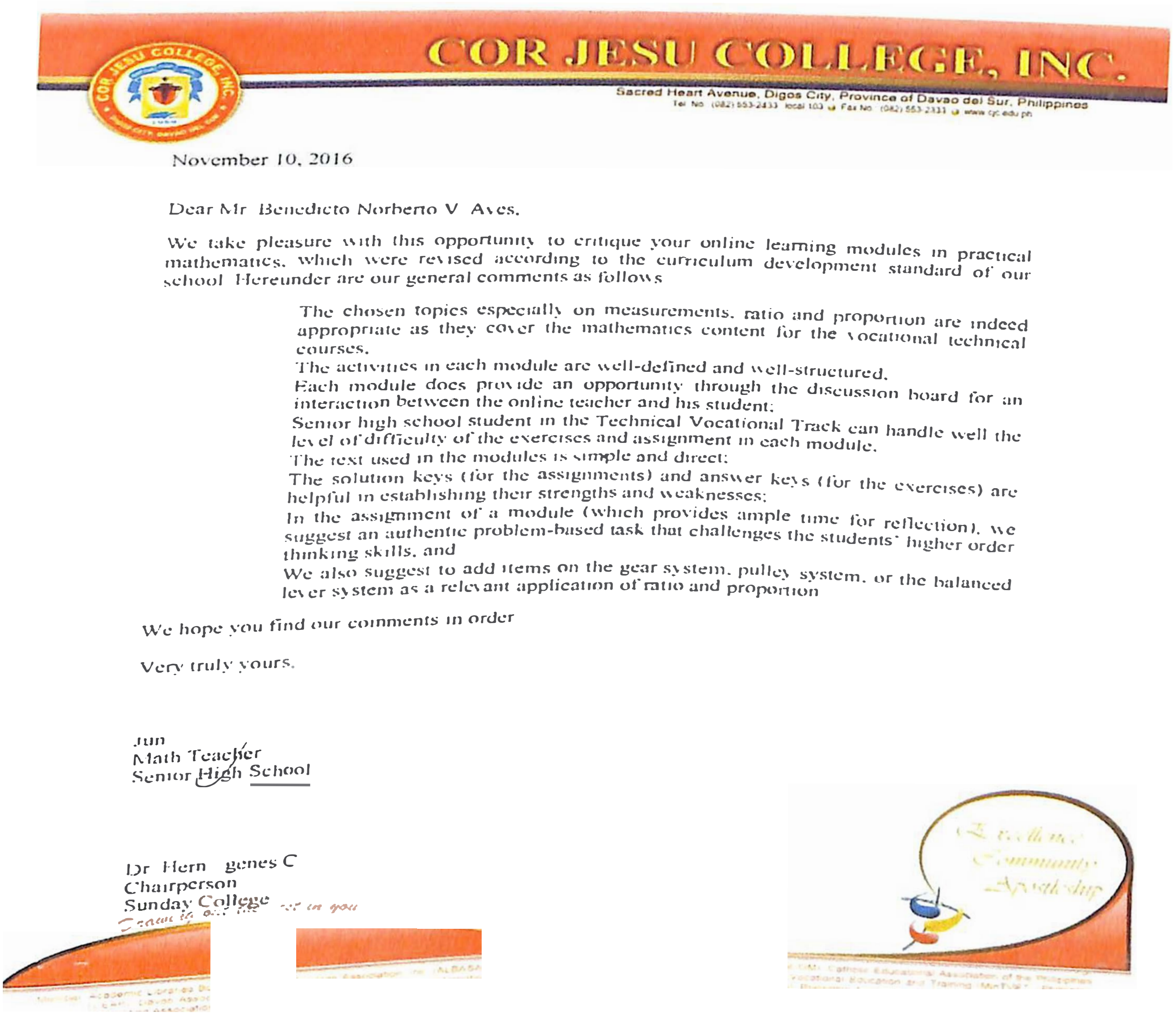
[*] Copies of other modified online learning modules may be requested through email to the researcher at

goodnorberto@gmail.com

Appendix Q

Letter Critique on the Modules Developed Based on a Traditional Curriculum Standard of a Private Sectarian College



COR JESU COLLEGE, INC.
Sacred Heart Avenue, Digos City, Province of Davao del Sur, Philippines
Tel No (082) 553-2433 local 103 Fax No (082) 553-2331 www.cjc.edu.ph

November 10, 2016

Dear Mr Benedicto Norberto V Aves,

We take pleasure with this opportunity to critique your online learning modules in practical mathematics, which were revised according to the curriculum development standard of our school Hereunder are our general comments as follows

The chosen topics especially on measurements, ratio and proportion are indeed appropriate as they cover the mathematics content for the vocational technical courses.

The activities in each module are well-defined and well-structured.

Each module does provide an opportunity through the discussion board for an interaction between the online teacher and his student;

Senior high school student in the Technical Vocational Track can handle well the level of difficulty of the exercises and assignment in each module.

The text used in the modules is simple and direct;

The solution keys (for the assignments) and answer keys (for the exercises) are helpful in establishing their strengths and weaknesses;

In the assignment of a module (which provides ample time for reflection), we suggest an authentic problem-based task that challenges the students' higher order thinking skills, and

We also suggest to add items on the gear system, pulley system, or the balanced lever system as a relevant application of ratio and proportion

We hope you find our comments in order

Very truly yours,

Jun
Math Teacher
Senior High School

Dr Hern genes C
Chairperson
Sunday College

Appendix R

TESDA FORMAT

Learning Outcome Summary

LEARNING OUTCOME 2: **PERFORM CONVERSION UNIT**

CONTENTS:

1. Units
   - Fractions

   - Mixed numbers

   - Decimal
2. Conversion of English to metric (vice versa)

ASSESSMENT CRITERIA:

1. Units are converted to the required figure using the given formulae.
2. English measurements are converted to metric measurements according to procedure.

CONDITIONS:

The students/ trainee should be provided with:

1. Equipment/ accessories
   - Calculators
2. Supplies/materials
   - Pencil/paper
   - Reference books

- Learning materials/module
- OHP/transparencies
- Video/multi-media materials

ASSESSMENT METHODS:

1. Written/oral
2. Direct observation
3. Interview
4. Demonstration

Information Sheet 3.2-1

ENGLISH TO METRIC CONVERSIONS

Most jobs require that you work in either English units or Metric units, but not both. It is necessary, however, to occasionally convert units from one system to another.

The **English System** of measurement grew out of the creative way that people measured for themselves. Familiar objects and parts of the body were used as measuring devices. For example, people measured shorter distances on the ground with their feet.

Appendix R (Continued)

They measured longer distances by their paces (a "mile" was a thousand paces). They measured capacities with common household items such as cups, pails, and baskets. The word *gallon* comes from an old name for pail.

Unfortunately, these creative measuring devices allowed different measurements to be obtained when different people measured the same items. Eventually, a standard was set so that all measurements represented the same amount for everyone.

The **metric system** is less complicated. All metric units are **related by factors of 10.** Nearly the entire world (95%), except the United States, now uses the metric system.

Because the metric system uses units related by factors of ten and the types of units (distance, area, volume, mass) are simply related, performing calculations with the metric system is much **easier**. Mathematical manipulations using the metric system lead to fewer mistakes and increase the chance that industrial principles and concepts can be understood.

Simple Conversion Operations in the English and Metric Systems

1. Units of Distance

ENGLISH SYSTEM	METRIC SYSTEM
12 in = 1 ft	10 mm = 1 cm
3 ft = 1 yd	
1760 yds = 1 mi	100 cm = 1 m

** A complete copy of the module may be requested through email to the researcher at goodnorberto@gmail.com.*

Appendix S

Revised Online Module 1.1 Based on the Traditional Curriculum Development Standard of a Private Sectarian College

Lesson 1.1 Length

Objectives

a. Identify an appropriate metric measurement for a particular length dimension.

b. Identify the prefixes for metric unit of length and SI abbreviations of these prefixes

c. Convert from one unit to another within metric system involving length.

Materials

- calculator, pencil and paper

Assessment Methods

- scores from exercises and assignments

Lecture on Video

Watch the video lecture with helpful notes on the topics below by clicking on "Video lecture 1.1."

Exercises 1.1

With the table below, answer individually the Exercises 1.1 and check your answers by clicking on the "*Answer key.*"

Write the metric prefix for each of the values below. Two items may have the same metric prefix.

1. 10^9 = ___________

2. 0.000000001 = ___________

3. 10^{-1} = ___________

Appendix S (continued)

Prefix	**Multiple or submultiple***	**Power of 10**	**Prefix symbol**
tera	1,000,000,000,000	10^{12}	T
giga	1,000,000,000	10^{9}	G
mega	1,000,000	10^{6}	M
kilo	1,000	10^{3}	k
hecto	100	10^{2}	h
deka	10	10^{1}	da
deci	0.1	10^{-1}	d
centi	0.01	10^{-2}	c
milli	0.001	10^{-3}	m
micro	0.0000001	10^{-6}	µ
nano	0.000000001	10^{-9}	n
pico	0.000000000001	10^{-12}	p

** Factor by which a metric unit is multiplied*

Appendix S (continued)

4. 10^6 =___________

Provide the SI symbols for each of the following prefixes:

5. milli =___________

6. micro =___________

7. kilo =___________

Write the SI abbreviation for each of the following quantities:

8. 61 centimeters =___________

9. 100 kilometer =___________

Write the SI unit for each of the following abbreviations:

10. 2 mm =___________

11. 50 hm =___________

Supply the missing item with the most appropriate unit (km, m, cm, or mm).

12. The standard metric size for plywood is 1200______wide and 2400______long.

13. The size of John's waistline is 93_______.

Appendix S (contiued)

14. The width dimension of a classroom is 7______.

15. An airplane generally cruises at an altitude of about 8 to 9 ______high.

16. The steering wheel of his car is 36_______ in diameter.

C. Convert the following:

17. 765m = ________km

18. 546 cm =________m

19. 5.7 m = _________mm

20. 1.3 m =__________um

Q & A

Click on the "Discussion Board" for any questions or clarifications you may have on our present lesson.

Appendix S (contiued)

Assignment 1.1

Try to solve the assignment below and click on *“Solutions”* to self-check solutions to your assignment.

Your park is a two-hours’ run straight to a beach resort. What is the distance in km between the park and the beach resort given the average runner’s speed of 4000 m per 40 minutes?

**Copies of other private-sectarian school’s technology-mediated learning modules in practical mathematics may be requested through email to the researcher at goodnorberto@gmail.com.*

Appendix T

Thematic Analysis of Data from Interviews of Five Selected Participants of the First Iteration

The Learning Approach		
How did you find the problem-based task of a module?	**Coded Responses**	**Frequency**
	a. Enough and/or not so difficult	5
Which form of discussion did motivate you to perform a problem-based task: synchronous discussion (i.e. messages exchanged in real-time communication like discussion through group chat, video calling, or audio calling) or asynchronous discussion (i.e. messages exchanged over an extended period of time like discussion through email or discussion boards)? Why?	**Coded Responses**	**Frequency**
	a. Synchronous discussion	4
	b. No comment	1

Appendix T (continued)

	Coded Responses	Frequency
Is group size of 4 conducive for either asynchronous discussion or synchronous discussion? Why?	a. Discussion size of 4 for synchronous discussion	3
	b. Discussion size of 4 for asynchronous discussion for better reflection and understanding of the lesson	1
	c. Larger than 4 for more learning	1
Can you comment on the weekly submission of group outputs?	**Coded Responses**	**Frequency**
	a. Weekly submission is fine.	4
	b. Not fine because of our schoolwork	1

**A copy of the complete result may be requested through email to researcher at goodnorberto@gmail.com*

Appendix U

Personal Data of the First Iteration Group

Participant No.	Occupation of Family Breadwinner	Do you like to study practical math?	Do you plan to find work after completing senior high school/tech voc course?	Age
1	Packing crew	Yes	No.	16
2	Self-supporting	Neutral	Yes	17
3	Farmer	Yes	Yes	17
4	Tricycle driver	Yes	Yes	18
5	Farmer	Neutral	No	18
6	Driver	Neutral	Yes	18
7	Farmer	Neutral	Yes	16
8	Farmer	Neutral	Yes	17

Appendix V

Observation of Class Observer in the First Iteration

Instructor's name MR. BENEDICTO AVES Period of observation August 10 –13, 2019

Observed group Group A Lessons 1.1

Observer's name JUN MARK R. PANLAAN

Please check the box that best describes how you see each of the items below. See the description of each of the column heading numbers, as follows:

1 = Not observed
2 = Not so evident
3 = Evident
4 = Highly evident

LEARNING APPROACH	1	2	3	4
1. The group learns together through chats.			✓	
2. The group learns together through emails.	✓			
3.The group learns together through video calling or voice calling.	✓			
4. Group members interact to help each other perform the given lesson tasks.			✓	
5. There is enough time for the group to solve the problem-based task and submit it on or before the schedule.			✓	
6. The group is engaged on solving the problem-based tasks.			✓	

**A copy of the complete results may be requested through an email to the researcher at goodnorberto@gmail.com.*

Appendix W

Ranges of Mean Scores with Descriptive Ratings on the Evaluation of the First and Second Iteration Modules

Ranges of mean scores	Descriptive ratings
3.5—4.0	Excellent
2.5—3.4	Good
1.5—2.4	Fair
1.4 and below	Need Improvement

Appendix X

Thematic Analysis of Data from Interviews of Second Iteration Selected Participants

The Learning Approach		
How did you find the problem-based task of a module?	**Coded Responses**	**Frequency**
	a. Enough and/or not so difficult	6
Which form of discussion did motivate you to perform a problem-based task: synchronous discussion (i.e. messages exchanged in real-time communication like discussion through group chat, video calling, or audio calling) or asynchronous discussion (i.e. messages exchanged over an extended period of time like discussion through email or discussion boards)? Why?	**Coded Responses**	**Frequency**
	Synchronous communication because: • It helped us a lot. • We could communicate well • It was easy to contact our team.	6

	Coded Responses	Frequency
Is group size of 4 conducive for either asynchronous discussion or synchronous discussion? Why?	d. Discussion size of 4 for synchronous discussion	4
	e. Discussion size of 4 for asynchronous discussion to make sure of our answers, understand them very well and to review our output before submission.	2

**A copy of the complete results may be requested through an email to the researcher at* *goodnorberto@gmail.com*

Appendix Y

Personal Data of Design Research Group

Participant No.	Occupation of Family Breadwinner	Do you like to study math?	Do you plan to find work after completing senior high school/tech voc course?	Pretest Performance	Age
1	Sari-sari operator/poultry	Yes	No.	19	17
2	Driver/helper	Yes	Neutral	15.5	17
3	Tricycle driver	Neutral	No	8	17
4	Trading/lending	Neutral	No	8	17
5	Manager	Yes	No	5	17
6	Latero	Yes	Yes	5.75	17
7	Self-employed	Yes	Yes	8.25	18
8	Farmer	Neutral	Yes	1.75	18
9	Laborer	Yes	Yes	6.25	17
10	Pedicab driver	Neutral	Yes	3.5	17
11	Caterer	Yes	No	15	17
12	Laborer	Yes	Yes	6.25	16

Appendix Z

Thematic Analysis of Focus Group Discussion

1. Of the two types of modules at hand (one that you used and the other type you did not use), which one would you choose should you want to learn more topics in practical mathematics?	
a. Design research technology-mediated learning modules	4
b. Private sectarian technology-mediated learning modules	0
2. Why would you choose such modules?	
a. Group interaction/discussion	4
b. Collaborative problem-solving activity	4
c. Concrete pictures and designs	1
d. Make actual measurements.	1
e. Encourage us to think.	1
f. Use of prior knowledge	1
g. Solutions are unique and cannot be copied.	1
3. Can you suggest, if any, some improvements on the modules that you did not choose?	
a. Group discussion	4
b. Problem-solving activity	4

Appendix AA

Review of the Subject Expert

Traditional Learning Modules

The content of the approach is very traditional. It is teacher-centered. If the interaction is limited only on teacher-student interaction the art of communication cannot be developed properly, furthermore it limits the opportunity of the learners to expound their ideas in terms of sharing.

The module provides no concrete illustration. The content of the module is more on cognitive approach. Practically, the motivation of the module is not enough. The approach can provide learning but it is enough in order to let the student see the application of it in real-life.

An online teacher perform his roles in these modules by giving instructions, teaching the concept and checking the answers.

Messenger and video call are enough for this learning approach. However, it needs more time and strong signal/ internet connection.

The language being used is precise and clear for a senior high student.

Compare to Modified Learning Modules, I less recommend this module.

Design Research Learning Modules

The approach is learner-centered. It cultivates the prior knowledge of the learners. However, the instructions of the approach should be clarified by the teacher, then let the module guide the students what to do. The module is providing a gradual release of responsibility approach towards students. Thus, it gives activity that lead to collaborative learning which can be used for independent learning.

**A copy of the complete review may be requested through an email to the researcher at goodnorberto@gmail.com.*