DEVELOPMENT AND EFFECTIVENESS OF FACILITATED LEARNING MODULES IN INTRODUCTORY ANALYTICAL CHEMISTRY

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The dissertation attached hereto entitled **DEVELOPMENT AND EFFECTIVENESS OF FACILITATED LEARNING MODULES IN INTRODUCTORY ANALYTICAL CHEMISTRY** in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Education (major in Chemistry Education), is hereby accepted.

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DEDICATION

To my parents, Hadja Hidjarah and the late Hadji Omar,

To my brothers, sisters, nephews, and nieces,

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Abstract

MOCSIR, MARZOKIE M. University of the Philippines Open University, May, 2017. Development and Effectiveness of Facilitated Learning Modules in Introductory Analytical Chemistry.

Adviser: Marlene B. Ferido, Ph. D.

This study involved development and assessment of facilitated learning modules that emphasized mathematical and statistical tools in introductory analytical chemistry. These facilitated learning modules were deemed to address the need of medical technology students for supplementary learning materials that address students' difficulty in solving quantitative problems involved in introductory analytical chemistry.

The first phase of the study covered the development of seven facilitated learning modules on selected topics in introductory analytical chemistry which require mathematical and statistical tools. These topics were considered necessary because they involve mathematical and statistical treatments which students find difficult because of their insufficiency in mathematical and statistical background. The development of facilitated learning modules employed both qualitative and quantitative analyses. The qualitative aspect involved evaluation of the facilitated learning modules' face content and form by chemistry education experts. Relevant comments and suggestions incorporated into the modules' final forms characterized the essential features of the facilitated learning modules. The quantitative aspect focused on the evaluation of analytical chemistry instructors on the facilitated learning modules' objectives in terms of attainability, clarity, and relevance. It also included their evaluation of the modules' content in terms of appropriateness, appeal, innovativeness, and conformity to standards

using a questionnaire developed by Lumaque (2011). The instructors found the objectives of the learning modules to be highly attainable, very clear, and very relevant. They rated the modules' content to be very appropriate, very innovative, very appealing, and strongly conforming to standards. Part of the quantitative aspect was the determination of the facilitated learning modules' student's involvement index, grade level, and communication index. Using Romey's procedure (1965), student's involvement index of the modules was 1.34, which indicated that the modules could keep the interest of users while reading the modules. Fry's Readability Graph (1968) indicated Grade 11 as the grade level of the modules, which matched that of the intended users. Further, Talisayon's procedure (1983) indicated that communication index of the learning modules was acceptable at 0.009.

The second phase assessed the facilitated learning modules' effectiveness on improving student performance using the quasi-experimental method that utilized pretest-posttest nonequivalent groups design. In this study, the use of facilitated learning modules was the independent variable while the student performance was the dependent variable. The performance was measured using the posttest scores comprising knowledge of using mathematical and statistical tools in introductory analytical chemistry and the knowledge of introductory analytical chemistry. Before the treatment, a pretest on basic algebra and statistics was administered to find out if there was a significant difference between the mathematical and statistical aptitude and skills of the two intact classes. Results of the pretest showed that both groups are comparable in terms of mathematical and statistical aptitude and skills. Moreover, both the experimental and control groups adopted facilitated learning instructions such as peer mentoring, on-demand tutorial, and online group discussion and file sharing. However, only the experimental group used the facilitated learning modules to supplement facilitated learning instruction while the control group only used learning materials which were common to both groups. After the intervention, both groups were given a posttest. The one-way analysis of covariance results revealed that the use of facilitated learning modules had a statistically significant effect ($F(1,92) = 6.04$, $p = .016$) on the posttest scores of students with their pretest scores as the covariate. Results further showed that those who used the facilitated learning modules as supplementary learning materials had a higher mean score ($M = 69.20$) than those who did not ($M = 62.82$) suggesting that it may be beneficial to supplement facilitated learning instruction in introductory analytical chemistry with facilitated learning modules as this may improve the performance of students in introductory analytical chemistry. Further, *Pearson's correlation* test results showed that knowledge of the application of mathematical and statistical tools in introductory analytical chemistry was significantly correlated with the knowledge of introductory analytical chemistry with $r = .669$ suggesting that it would be good to strengthen students' knowledge in mathematics and statistics as results of this study have shown that students who did well in mathematics and statistics also did well in introductory analytical chemistry.

It is recommended that in the development of facilitated learning modules, the number of chemistry education experts and analytical chemistry instructors be increased in order to gather more inputs regarding the form and content as well the evaluation of the objectives and contents of the learning modules. The inputs of these experts are essential to the development of the facilitated learning modules. Curriculum writers may develop facilitated learning modules in analytical chemistry that employ varied instructional strategies such as virtual or face-to-face brainstorming sessions, group activities like games, and virtual classroom sessions on other topics in analytical chemistry such as various titrimetric methods of analysis such as acid-base, precipitation, and complexometric titration; and spectroscopic methods of analysis.

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Chapter 1
INTRODUCTION

Facilitated learning is a teaching strategy where students are encouraged to take more control of their learning process. The role of the teacher becomes that of a facilitator and organizer providing resources and support to students (Crocket and Foster, 2005). This strategy offers techniques and approaches that can be incorporated in the conventional teaching methods. Education experts believe that facilitated learning instruction can be supplemented by the use of facilitated learning modules which contain learning activities that students can perform in order to enhance the learning process. Lumaque (2011) emphasized that the use of facilitated learning modules is suitable for subjects that require higher-order thinking skills such as analytical chemistry. Facilitated learning activities together with the use of facilitated learning modules are deemed appropriate in analytical chemistry to help students understand difficult mathematical and statistical manipulations incorporated in the subject.

Background of the Study

The inseparability of mathematics and science cannot be underestimated by science education experts. Beavis and Baker (2013) reported that a strong background in mathematics is essential to the successful study of other science disciplines such as chemistry, physics and biology. Jackson, et al. (2014) also explained that experts recognize mathematical competence as fundamental for studying a wide range of science disciplines. In fact, experts consider mathematics the language of science. Urdouso (2011) particularly argued that proper understanding of chemical principles such as isotopes, formulas, equations, solubility, kinetics, molar ratios, radioactivity, pH and equilibrium requires a good working knowledge of basic mathematics.

However, different factors affect students' recognition of how important mathematics is in their study of chemistry. Loughlin, et al. (2015) reported in their study that students do not have a high-level of confidence in their mathematical skills although they recognize the importance of mathematical applications in chemistry lessons. Further, Loughlin, et al. (20115) also mentioned that there are a number of factors that influence students' lack of confidence in their mathematical skills. These are motivation, experience and a general outlook that mathematics and science are simply very difficult subjects.

Bardini and Pierce (2015) found in their study that the unfamiliarity and density of mathematical symbols caused students to lose confidence in mathematics which later lead them to select a course that requires less use of mathematics. Such perspective is impractical today. Countries need a high level of scientific literacy which can be addressed by having a large supply of science, technology, engineering and mathematics (STEM) professionals within their general population (Prescott 2014). To stimulate students' interest in science and engineering, they should be made to understand first the fundamental mathematical skills so that the abstract scientific ideas, concepts and principles would not be difficult to comprehend.

With the awareness of the importance of mathematics in understanding science, practitioners of the subject have made efforts to overcome the negative attitude in learning mathematics. Yuzi (2003) employed the use of the problem-based learning (PBL) in analytical chemistry, in which students must use their judgment to come to an acceptable conclusion. Aguilar, et al. (2012) on the hand used computer-based applications to address challenges in chemistry-related problem solving especially those involving mathematics. Such efforts helped address the need to make science more interesting.

The Bachelor of Science in Medical Technology offered in Notre Dame of Marbel University requires analytical chemistry as a pre-requisite subject for some of the program's professional subjects as shown in the prospectus. Students of the program take analytical chemistry immediately after passing general chemistry when students have only completed one basic algebra subject. Thus, these students encounter difficulty in dealing with mathematical and statistical techniques involved in analytical chemistry because they have not taken any statistics subject and they only have limited background in algebra. Teachers handling the subject noted poor performance of students in their various tests on the statistical treatment of data and on problem solving.

Previous records of medical technology students form Notre Dame of Marbel University who took analytical chemistry showed an average failure rate of 34.55% in the recent five years. Chemistry instructors of the same university considered this failure rate higher than the failure rate in general chemistry, which the students took as a prerequisite of analytical chemistry. They suggested that this high failure rate in analytical chemistry was due to students' difficulty in mathematical manipulations and statistical treatment involved in this area of chemistry. With this observation, there has been a strong clamor by analytical chemistry teachers of the university to provide supplementary learning materials other than textbooks and online reading materials to address these problems.

The development of learning modules is one of the many approaches that teachers may consider in helping students perform better in chemistry classes. The study conducted by Lumaque (2002) showed that engineering students using learning modules performed better in class than those students who were not using these learning modules. Taylor (2004) also noted that students studying general chemistry with the help of the learning modules developed positive attitude towards chemistry and performed well in class. These studies and the difficulty students encountered in analytical chemistry due to limited background in algebra and statistics prompted the researcher to develop learning modules on mathematical and statistical tools used in analytical chemistry. The researcher developed facilitated learning modules that students used while doing facilitated learning activities such as peer mentoring and tutorial sessions to help address these issues. These modules are deemed to help students gain deeper understanding of topics in analytical chemistry particularly the mathematical and statistical manipulations by performing the learning activities incorporated in the modules.

Statement of the Problem

The study aimed to develop seven facilitated learning modules in introductory analytical chemistry, which incorporate the required mathematical and statistical tools. It also aimed to assess the effectiveness of these facilitated learning modules in enhancing student performance.

Specifically, this study sought to answer the following questions:

1. What are the essential features of the facilitated learning modules' face content and forms as perceived by chemistry education experts?
2. How do analytical chemistry instructors describe the facilitated learning modules'

1.1. objectives in terms of

1.1.1. attainability?

1.1.2. clarity?

1.1.3. relevance?

1.2. content in terms of

1.2.1. appropriateness?

1.2.2. appeal?

1.2.3. innovativeness?

1.2.4. conformity with standards?

3. What are the student's involvement index, grade level and communication index of the facilitated learning modules?
4. Does the use of the facilitated learning modules influence student performance?
5. Does knowledge of using mathematical and statistical tools in introductory analytical chemistry correlate with the knowledge of introductory analytical chemistry?

Significance of the Study

The availability of learning modules for classroom instruction does not only benefit the students. These learning materials also serve the interest of the administrators and the teachers since they address the prevailing need for supplementary materials such as learning modules. The use of facilitated learning modules as supplementary learning materials for facilitated learning activities can be beneficial in enhancing students' understanding of the topics particularly those that involve mathematical manipulations. Subjects that incorporate mathematical skills require more effort from teachers to make students understand the topics better. This burden of teachers can be lessened by providing additional learning materials where students can perform activities by themselves with minimal teacher supervision. In addition, teachers can be assured that there would be more learning engagement because students have performed additional learning activities included in the facilitated learning modules.

These facilitated learning modules are designed in such a way that they can also serve as part of the curriculum plan for the subject. The sequence of topics included in the facilitated learning modules and the time frame allotted for each module are patterned from the syllabus of the subject. Also, the learning objectives of the facilitated learning modules are designed based on the learning competencies set by the Commission on Higher Education (CHED) for the subject. Thus, these learning modules are also expected to guide administrators in supervision and monitoring of classroom instruction in terms of attainment of the curriculum plan.

In developing the learning modules, the needs, characteristics and interests of students were taken into consideration. In addition, it was expected that these modules would guide students on the mathematical manipulations involved in solving problems in analytical chemistry as they read the modules. Thus, the materials would improve their mathematical skills in problem solving as well as in the statistical treatment of data. Also, the module writer expected students to involve themselves in facilitated learning activities. The facilitated learning activities of the modules also engaged students actively in the learning process.

The results of the study can serve as basis for curriculum writers to develop facilitated learning modules in other science subjects such as Physics and Mathematics. They can use facilitated learning instruction supplemented by the use of facilitated learning modules. Curriculum writers in other disciplines can also utilize other suitable facilitated learning activities together with the use of appropriate learning modules to supplement classroom instruction or as alternative teaching strategies.

The use of facilitated learning modules in conjunction with facilitated learning instruction is anchored on constructivism because it is a student–centered approach. In facilitated learning instruction, students take control of their leaning process with minimal supervision of the teacher as the facilitator. The study thereby contributes to constructivism as a body of knowledge and strengthens its claim as effective educational philosophy that science educators can consider to improve the teaching – learning process.

Scope and Delimitation of the Study

The study focused on the development of facilitated learning modules incorporating mathematical and statistical tools involved in analytical chemistry. It also assessed the effectiveness of these facilitated learning modules on student performance. The learning modules covered topics on statistical testing for treatment of data, ways of expressing concentrations, chemical equilibrium, acids and bases, other aqueous equilibria, and gravimetric methods of analysis. The existing syllabus designed by chemistry teachers who had handled the subject served as basis for the sequence of topics. Thus, the topics in the modules were similar to those covered in the syllabus.

Mathematical applications in measurements are also included in a number of modules, where they are relevant and applicable.

Each of the facilitated learning modules included the following parts: title, introduction, facilitated learning activity, objectives, time frame, check-up test, feedback on the check-up test, lesson proper, brief introduction of the involved chemical ideas, assignments, key answers, summary (what you learned), and references. The module also has a teacher's guide.

In developing the learning modules, the needs, characteristics, and interests of students were considered based only on the grades of all students who took analytical chemistry in the previous ten semesters. However, the particular need for the enhancement of mathematical and statistical skills was based on the chapter objectives and activities cited in the existing syllabus of Analytical Chemistry available in the department and on the feedback of instructors who had handled the subject in the previous semesters.

There were only three facilitated learning activities considered in the study. These were peer mentoring, on-demand tutorial, and online file sharing and group discussion. For peer mentoring, only the performances of the mentors and co-mentors in the pretest and their class standing were considered in selecting the mentors and co-mentors. The ability of the mentors and co-mentors to conduct mentoring was not considered in the study. Only two on-demand tutorial sessions were conducted for the study because of the limited tome availability of the instructor-tutor. Further, one Facebook account was created each for the experimental group and the control group where the students from each group posted their comments for online discussions on their assigned Facebook account. The use of the facilitated learning modules was allowed only to the experimental group during the conduct of these facilitated learning activities while the control groups only used textbooks and other learning materials used by both groups. The effectiveness of the conduct of the three facilitated learning activities was not assessed in the study.

The internet literacy of the students in using social media was not considered in the study. Moreover, the internet connectivity outside the school where students stayed while participating in the online group discussion was not considered in the study as well.

Development of the facilitated learning modules included the conception of topics in analytical chemistry that need to be covered in the facilitated learning modules. The developed modules were evaluated by chemistry education experts. The experts' assessment of the modules were limited to form and face content only. Further evaluation by analytical chemistry instructors were also included in the study.

The module writer assessed the effectiveness of the facilitated learning modules during the Second Semester of the school year 2015-2016. Students enrolled during this semester used these learning modules for ten (10) weeks to cover only the topics requiring difficult mathematical and statistical manipulations. Topics towards the end of the syllabus, such as instrumental techniques, which do not need complicated mathematical and statistical tools, were no longer included. Only two intact classes of medical technology students enrolled in analytical chemistry during that semester were used in the study to test the effectiveness of the modules.

Furthermore, in this study, correlation result on the knowledge of using mathematical and statistical tools in introductory analytical chemistry and knowledge of introductory analytical chemistry, only indicates a presence or absence of a relationship and not causation.

Considering that other instructors handled the laboratory part of the analytical chemistry subject, the study did not cover the use of the learning modules in laboratory classes anymore. Thus, the study did not assess the effectiveness of the facilitated learning modules for the laboratory part of the subject.

Chapter 2

REVIEW OF RELATED LITERATURE AND CONCEPTUAL FRAMEWORK

This chapter begins with a description of constructivism as a learning theory because use of the facilitated learning modules and the manner of instruction employed in the study are based on constructivism. It also describes the evaluation of the effectiveness of the facilitated learning materials. The last part of this chapter presents the conceptual framework of the study.

The Learning Theory of Constructivism

Most educational philosophies have designed suitable strategies to achieve a significant teaching-learning experience in the classroom (Murphy, 1997). One of the most influential educational philosophies in recent years is the view that students build or construct new knowledge on their previous knowledge. Educational theorists call this constructivism. So far, there have been a great number of researches published about constructivism (SSTA Research Centre Report, 1997).

The constructivist's view of learning recognizes the students' active participation in problem-solving and the critical thinking used in a learning activity that they find relevant and engaging. This allows students to "construct" their own knowledge by using ideas they learned from their previous experiences. Students apply their previous knowledge gained with preexisting constructs and concepts and integrate this new knowledge to the new situation.

Constructivism has deeper implications for teaching as it calls for a more active role of students in different learning scenarios. Thus, emphasis is on students becoming active learners. This is the reason theorists describe constructivism as student-centered (Rosenblatt, 1978; Fosnot, 1989; and Applebee, 1987). Slavin (2002) mentioned that in a student-centered classroom, the teacher becomes a "guide on the side" instead of "sage on the stage". Teachers scaffold students to learn the concepts instead of delivering the lectures and controlling all classroom activities.

Purposes and Characteristics of Constructivism

According to Cruicksank et al. (2009), as cited by Vega and Prieto (2011), the purpose of constructivist teaching and learning is to allow students to pick up information that is most readily understood and usable. Further, Vega and Prieto (2011) mentioned that constructivists have selected several ideas and brought them together to form a mosaic to make learning activities easily understood and usable. These ideas include:

- Active learning (when students are directly involved in finding out something for themselves) is preferable to passive learning (when students are recipients of information presented by a teacher).
- Learning takes place in communities of learners, that is, in groups or in social situations.
- Learners engage in "authentic and situated" learning, that is, the tasks the students face are concrete rather than abstract. Real-life problems are presented rather than hypothetical ones.
- Learners relate new information to that which they already know, through bridging.
- Learners reflect or think about what they learned.

- Rather than present information to learners, teachers facilitate its acquisition.
- Teachers provide learners with scaffolding needed for them to progress.
- Students make sense of what they thought they knew and incorporate this to new understandings.

In the classroom, different teaching practices make use of the constructivist view of learning. In the most general sense, application of constructivism involves the use of techniques such as experiments and real-world problem solving. This allows students to understand ideas deeper, reflect on, and talk about what they are doing and how their understanding is changing. In such classrooms, the teacher should understand the students' preexisting conceptions, guide them through activities that address their prior knowledge, and consequently build on the latter.

Strategies Grounded in Constructivism

Bransford et al. (2000) as cited by Vega and Prieto (2012) suggested specific strategies for classroom practice. These are examples of learner-centered instructions - that pay careful attention to the knowledge, skills, attitudes, and beliefs that learners bring to the educational setting. They are:

1. Guided discovery. In guided discovery, a teacher identifies a content, arranges information so students can find patterns, and guides students to the goal.
2. Inquiry. This is a strategy in which learners gather facts and observations and use them to examine real world problems (Kauchak & Eggen, 2003).
3. Discussion. This is a strategy based on the constructivist views of learning. Educators design this to stimulate thinking, to help learners reconstruct

understanding by challenging attitudes and beliefs, and to develop interpersonal skills (Keefer, Zeitz, and Resnick, 2000).

4. Cooperative learning. This strategy has three models which include reciprocal questioning, scripted cooperation or JIGSAW, and Student Teams Divisions (STAD).

Facilitated Learning Instruction: Constructivist Approach in Teaching

In a constructivist perspective, the primary responsibility of the teacher is to create and sustain a collaborative problem-solving environment. This allows students to construct their own knowledge while the teacher acts as a facilitator and a guide. The constructivist paradigm suggests a set of instructional principles that can guide the practice of teaching and the design of learning environments. In addition to accommodating the constructivist perspectives, powerful learning environments should be provided by teacher.

Nowadays, educational practices involve the use of multimedia such as audiovisual aids and to use printed and the use of printed materials, like modules to bring about effective teaching-learning. Lumaque (2011) stressed that the concept of facilitated learning instruction transcends these educational practices. He argued that in a facilitated learning instruction, students do more than simply listen to the lecture of the teacher. Students do something that includes processing and application of information.

According to Mckinney (2002) from the Center for Teaching, Learning and Technology of Illinois State University, there should be less emphasis on passing on information such that students simply listen to the teacher. The students must perform activities that require higher order thinking skills and the teacher must focus on developing targeted student's skills. Among the classroom activities which the Center highlights includes listening and talking, writing, reading and reflecting. These are classroom activities promoted by constructivists so more significant learning transpires.

Lumaque (2011) suggested that teacher can adopt facilitated learning instruction, as a teaching approach complementing the use of learning modules. Module writers must design facilitated learning modules that meet the needs, interests, and abilities of the students. Lumaque (2011) further asserted that facilitated learning modules, as designed, intend to facilitate the teaching-learning inside the classroom. However, limited number of learning modules are available for use. Since development of learning modules is time-consuming, this discourages teachers from preparing them. However, when learning modules are available, the activities inside the classroom could ran efficiently.

Boiser (2000) mentioned that teachers who are adopting facilitated learning instruction using learning modules must also provide the needed instructional inputs in the class. Aside from guiding students, teachers could elaborate or discuss in detail lessons which students consider difficult to understand. To achieve effective teaching-learning in the classroom, it is advantageous for students to read the learning modules in advance and to perform the accompanying activities. Thus, students come to class prepared for the day's lesson. When they come prepared, classroom activities go on smoothly and efficiently. There will be sufficient time for the teacher to explain certain parts of the module that students do not understand well.

There is a way teachers can verify the extent to which students understand the lessons presented in the modules. There are self-learning activities in each module that students can perform to assess students' understanding.

The study of Sarraga (1998) showed that teaching-learning becomes more encouraging when teachers use constructivist teaching approaches coupled with cooperative learning methods. Some activities conducted as part of the study include class demonstration, group discussion, film viewing and processing, and group reporting. Such teaching approaches improves sharing and cooperation among the students, as well as encourage team learning, peer tutoring, and group discussion. Further, she reported that students performed better with this approach compared to the lecture method.

Richards and Roe as cited by Lumaque (2002) forewarned that teachers adopting this method might encounter some difficulties in supervising the students. One difficulty is being truthful in providing feedback about the extent to which students understand the modules. Although teachers encourage students to work, independently or with their peers on the activities in each module, there is still a need to check closely the progress of their work. Therefore, Lumaque (2002) suggested that teachers who will adopt this method have to undergo training. The guide prepared for teachers on how to use the modules for facilitated learning instruction may not be sufficient in helping them. Training should help these teachers define clearly their roles when they adopt this instructional method.

Facilitated learning instruction. Facilitated learning enables students to explore, discuss and understand ideas as well as problems and issues. This encourages students to take more control of their learning. Crockett and Foster (2005) emphasized that the teacher's role in facilitated learning instruction is that of a trainer and organizer providing materials and support to learners. In turn, participants learn with and from one another as they identify and find solutions to challenges, problems or other developmental issues. They could set objectives and be responsible their own learning assessment.

Crockett and Foster (2005) further stressed that facilitated learning works well when the student takes more responsibility for his or her own learning. Crockett and Foster (2005) listed the following advantages of this strategy:

(a) Learners use skills like synthesis and analysis.

(b) Strategy involves the learner actively.

(c) Learners interact and learn from each other.

(d) There is no need for large amounts of learning materials.

(e) Learners work in an environment similar to that of the real world.

f) This strategy uses variety of learning methods.

However, this learning strategy has also the following disadvantages. Crockett and Foster (2005) listed the following disadvantages.

(a) Facilitated learning can be - or be seen to be - more expensive.

(b) The pace of instruction is based on the group rather than the individual learner.

(c) The strategy does not define teacher's role clearly.

(d) There is a need for extra facilities to allow for group work.

(e) The learning is time-consuming in proportion to material covered.

(f) Facilitated learning is not fitting in some cultural contexts.

As noted earlier, the teacher's role in facilitated learning is to create and manage collaborative learning experiences or group learning in which exchanges between instructors and learners and among learners occur over time.

Facilitated courses and learning experiences usually take place over a series of weeks (Crockett and Foster, 2005). These include:

(a) On-demand tutorials, presentations, and keynote addresses

(b) Online or face-to-face group discussions and exchanges

(d) Handouts, readings, and links to relevant websites

(e) File and link sharing

(f) Surveys and polls

(g) Virtual real-time or physical classroom sessions, lectures, seminars

(h) Brainstorming sessions (virtual or face-to-face)

(i) Group activities such as role play and games

(j) Field trips

(k) Projects and case studies.

Crockett and Foster (2005) asserted further that facilitated learning is likely to occur in a well-resourced environment with motivated and active participants. They said that most training environments are unlikely to offer the necessary conditions. However, teachers can combine facilitated learning effectively with other training styles to provide many of the benefits inherent in these methods.

Among the approaches mentioned, only three are considered for the study, namely: peer mentoring, on-demand tutorial, and online discussion and file sharing. These three approaches are chosen because of their applicability as facilitated learning activities supplemented by the use of facilitated learning modules. The following subsection presents the benefits of the three chosen facilitated learning activities.

Benefits of peer mentoring, on-demand tutorial, and online group discussion and file sharing. There had been studies citing the benefits of peer mentoring, on-demand tutorial, and online group discussion and sharing. These studies have cited that these facilitated learning activities contribute to the improvement of student performance. Leidenfrost, et al. (2014) found in their study that peer mentoring can produce a number of positive outcomes because this activity can provide growth and learning opportunities for both mentors and mentees, resulting in a "double impact" that is appealing to schools and districts attempting to support students with limited financial and community resources. Moreover, when Rodger and Tremblay (2003) examined the effect of participation of first-year university students in a mentoring program, they found that mentored students had significantly higher final grades than those who did not participate in the mentoring program. Tutorial, on the other hand, has been found also to be an instructional strategy that improves students' performance. Veggel and Amory (2014) found in their study that tutorial sessions enhance students' confidence in mathematics and improve students' performance. They also mentioned that student feedback on the tutorial program provides a deeper insight into student experiences and the value students assign to the tutorials. Furthermore, faculty-led tutorial is as effective as student-led tutorial (Kassah et al., 2005). Online discussion and file sharing is another facilitated learning activity that is considered in this study. Prior researches suggest that the online provision of course materials can have a positive impact on students' performance. The study of Bawaneh (2011) revealed that there is a positive association between the number of online files viewed by students, the number of online discussion messages posted by them, and their performance. His findings support the benefits to be gained by providing course materials online and encouraging both faculty members to use online in providing course materials and students to access the materials posted and to actively participate in online discussion.

Developing Learning Modules for Facilitated Learning Instruction

Lumaque (2011) mentioned that curriculum writers need to follow the necessary procedures in developing the learning materials to ensure that learning materials' objectives are met. Curriculum writers have different views on how to develop these learning materials. However, all their views lead to the development of an effective curriculum material. Hass and Pasky (1993) listed important steps writers must follow in curriculum planning and curriculum writing. These include (a) identification of the content (b) determining objectives (c) selecting, preparing, and carrying out strategies and alternatives, and (d) evaluation.

Identification of the content refers to gathering of data about the intended learners and the human, social, and environmental variables with which the learners interact. Some authors simply describe this step as needs assessment. The data gathered from this step shall serve as input in determining objectives.

In the second step, the curriculum writer uses the gathered data in drafting the objectives of the curriculum material. However, this does not mean deviating from the objectives of pre-planned curriculum materials. Hass and Pasky (1993) pointed out that objectives of pre-planned curriculum materials guide the curriculum writer in drafting specific objectives. The curriculum writer should draft the objectives in such a way that these are achievable by the intended users through the use of the activities in the learning materials.

The third step involves selecting, preparing, and implementing strategies and alternatives. Curriculum writers must know how to identify and select available strategies which are most suitable for the learners.

The fourth step involves evaluation undertaken to identify which of the intended objectives learners have achieved. This step shall provide information about the results of adopting the curriculum material, strategies, alternatives, and content. This shall also provide information about changes teachers have made on the curriculum material. The evaluation also gives information about the learners' achievement and performance with respect to the objectives set thus, helping curriculum writers to develop a more responsive curriculum material.

The University of the Philippines Open University (1999) suggested that curriculum writers may employ the following steps in developing learning modules. These include (a) conducting a baseline study (b) formulation of objectives (c) writing the learning modules (d) conducting formative evaluation, and (e) revision and finalization.

Conducting a baseline study. A baseline study is a form of needs assessment. Needs assessment involves identification of the needs of the target users of the material, the teachers and the students. UPOU (1999) asserts that needs of the students refer to their learning needs about concepts, skills, and interests. On the other hand, the needs of the teachers refer to (a) enriching available learning modules, and (b) developing learning modules.

In undertaking the baseline study, Talisayon (1998) suggested that the curriculum writer must conduct consultation dialogues between and among the teachers handling the course. However, Ornstein and Hunkins (2004) believed that writers should not only include teachers but also participants in this effort like the subject area coordinator, and interested administrators. The group could discuss the different factors to consider in developing the learning modules.

According to Doll (2002), curriculum writers need to provide enough attention on these factors since they are important in developing effective curriculum materials. Among those factors include the students' psychological, social, and cultural background. Students who are the intended users of the learning modules significantly differ from one another. One person is different from another because each person has a set of unique and distinct characteristics.

The environment and the learning experiences of an individual may influence the kind of behavior and attitude one exhibits. Since each student grows and develops in a different environment with varied learning experiences, one can expect that each of them has a unique set of characteristics (Oliva, 2001).

Thus, the end users of curriculum materials differ from one another because they have varied experiences in life. Further, a student's psychological conditions are entirely different from his/her peers. Therefore, it is important to consider various learning styles of students, gender differences, their attitudes and interests, and their behavioral patterns.

The curriculum writer must seriously consider these factors. The group who works on needs assessment must discuss carefully these factors to give more particular attention to the psychological background of the intended users.

To address the need to consider a student's psychological background, Doll (1989) listed practices that show promise of making wiser use of our knowledge of how students learn. These include:

(1) using varied methods of teaching

(2) using multiple teaching materials

(3) organizing instructional groups appropriate to given learning situations

(4) treating students humanely

(5) helping learners accept objectives and invent some of their own

(6) providing adequate opportunity for practicing skills

(7) prizing pupil's ability to develop ideas

(8) emphasizing interrelationships, or "ecological balance" of subjects and subject fields and (9) making the school a workshop for accomplishing concrete learning.

Module writers must consider the socio-cultural background of the students as well. It is important that curriculum materials should be consistent with the socio-cultural background of the intended learners. According to McNeil (2003), society influences the curriculum that educators would like to realize. The family and the community somehow dictate the curriculum which schools must develop. Curriculum writers must be keen in this because it affects the acceptability of the curriculum materials.

Another factor that needs consideration during the needs assessment is the proper selection of the subject matter. Teachers must be mindful of the quality of activities inside the classroom. The subject matter and instructional materials selected should enrich classroom activities. Two common considerations that usually guide teachers in deciding what subject content they should consider in their classes include (1) the nature of the learner and the learning process, and (2) the impact of society at large and the local community on the school. While there are other considerations for teachers and curriculum writers, these two factors have remained important whenever teachers select the subject matter they need to include in the curriculum. Ellis et al. (1995) pointed out some of the reasons teachers must properly select subject matter. These are:

1. Knowledge has already exploded that it is necessary to select subject matter that seems most significant and to remove the inconsequential.
2. The conviction has grown that teachers is teaching inadequate subject matter within allotted learning time.
3. Experiments have shown that subject matter, old and new, can be practical and relatable to the lives of the learners.
4. When curriculum consists of a little knowledge and a little of that, teachers must supplement it, organize it, and integrate it to make it coherent.

Ellis et al. (1995) identified some criteria that teachers may use in choosing the subject matter content:

1. <u>The validity and significance of the content</u>. Some items of content available to learners are likely to be little worth because they are inconsequential or trivial. Teachers should rule out these items.

2. <u>The balance that teachers maintain between the content for survey and the content for in depth study</u>. Students need to see the broad sweep of subject matter.
3. <u>The appropriateness of the content to students and their interests</u>. Casual interest is not difficult to identify. Lasting interest and real need are much more difficult to find out. Curriculum writers may still find out students' enduring interests after a period of time.
4. <u>The durability or lasting quality of content that teacher is stressing.</u> Determining how long an item of content will last as a needed and desirable element is difficult. In general, however, the closer an item of content is to the main ideas or concept, the greater its chance of being retained by students.
5. <u>The learnability of the content</u>. Teachers should not attempt to teach students what they cannot learn. Trying to teach the same content to nearly all types of students has been ineffective in many educational programs. Teachers should be mindful of the individual differences of the students and should consider content which are within the intellectual capability of majority, if not all, of the students.

Ornstein and Hunkins (2004) have also identified several criteria, which module writers should consider in selecting the content of learning materials. The two authors stressed that curriculum writers should consider these suggested criteria in selecting the contents of the learning materials regardless of their philosophical orientations. These include (a) self-sufficiency (b) significance (c) validity (d) interest (e) utility (f) learnability, and (g) feasibility.

Apart from what the two authors have presented, curriculum developers may add other criteria, which they believe, may help students grow and learn better. John Dewey as cited by Ornstein and Hunkins (2004) said that educators are to consider the current experience of learners and then seek to extend these experiences. What the learner knows becomes the means of opening the way to new knowledge. Educators thus serve as agents to help learners achieve connectedness in their development.

Formulation of objectives. In choosing the content of the curriculum material, Talisayon (1998) suggested that a curriculum writer must clearly define first the objectives of the material. This will provide the curriculum writer a clear guide of what direction the material follows.

In clarifying the objectives and the content of the learning material, Ibe (1998) suggested that objectives considered for the learning material must be within the bounds of the country's goals for science education. Goals are broad statements that give a general direction to science programs. The goals of science education as identified by Ibe (1998) include:

1. Science education should develop a fundamental understanding of natural systems;
2. Science education should develop a fundamental understanding of, and ability to use the methods of scientific investigation;

3. Science education should prepare citizens to decide responsibly concerning science-related issues;
4. Science education should contribute to an understanding and fulfilment of personal needs, thus contributing to personal development; and
5. Science education should inform students about science careers.

The Commission on Higher Education (CHED) reiterated in its CMO no. 20 series 2013 that the goal of the general education curriculum is to produce thoughtful graduates imbued with:

1. values reflective of a humanist orientation (e.g., fundamental respect for others as human beings with intrinsic rights, cultural rootedness, and a vocation to serve);
2. analytical and problem solving skills;
3. the ability to think through the ethical and social implications of a given course of action; and
4. the competency to learn continuously throughout life that will enable them to live meaningfully in a complex, rapidly changing and globalized world while engaging [in] their community and the nation's development issues and concerns.

These goals provide the necessary direction for various colleges and universities in the Philippines in formulating their respective objectives for science education. These may also serve as guide for curriculum writers in developing learning materials. Private schools need to integrate the country's goals of science education into its school curriculum.

According to Lumaque (2011), curriculum writers must frame the objectives of the instructional material in agreement with the country's goal in science education as well as with the school's goals and objectives. Therefore, the need for a consultation dialogue among teachers is important in developing learning modules. The module writer must seek support of other teachers. These teachers have substantial information on important goals to pursue because of their experiences in teaching the subject. Curriculum writers should highly consider consultation with other teachers in developing learning materials.

Writing the curriculum material. According to Johnson (1997), there are no specific guidelines on how curriculum writers prepare learning materials. However, he pointed out that it must contain essential parts which aim to develop the student's process skill and their critical thinking skills. Further, he said that this is essentially true for curriculum materials in the sciences. The UP Open University (1999) suggested that a curriculum material must contain the following parts: (a) readiness test and key (b) lesson proper (c) study guide (d) mastery test and key, and (e) teacher's guide. This suggestion is somewhat similar to the recommendation of Hidalgo as cited by Lumaque (2002). An instructional material or a module is complete when it contains the following parts:

1. Title. It should be briefly, comprehensively, and interestingly stated.
2. Target population. This specifies level and characteristics of students to which the writer directs the module.

3. Overview. It gives the students a bird's eye view of the topic covered in the module. This background prepares the students of what is in store for them and at the same time motivate them.
4. Objectives. The students should know exactly what the teacher expects from them in going through the module's learning objectives. To make objectives clear and comprehensible to students, module writers should frame these objectives based on specific and measurable criteria.
5. Instruction to the learners. Since the module is self-learning material, the writer should expect students to carry out suggested activities, answer specific questions, and perform assignments and other related activities. To enable them to do these, students need instructions which are clear, short, simple, and specific.
6. Entry behavior and prerequisite skills. The module also specifies what entry behavior and prerequisite skills the learner should have to enable them to use the module successfully. This will provide student the preliminary assessment whether the module is within his ability. If he feels he does not have the necessary behavior and skills, he may skip the module and instead concentrate on development of prerequisite knowledge and skills before he works on the module.
7. Pre-test. This determines what the learner already knows about the topic. If the results show that he has mastered it, he may continue to the next module.
8. Pre-test feedback and evaluation. This part indicates whether student's answers to the pre-test are correct. The writer should provide the key to

correction within the module. Such key to correction is referred to as pre-test feedback.

9. Learning activities. This part is the heart of the module. This specifies the different activities that student must undertake to achieve the specific learning objectives. Such activities include the various lessons, study sheet, assignments, tests, and even suggested projects.

10. Post-test. When students had performed all the learning activities in the module, he will take a post-test aimed at finding how far he has learned from the module.

11. Post-test feedback and evaluation. The post-test feedback, just like the pre-test feedback, serves as the key to correction. Also, the post-test evaluation, provides the grade equivalents of the different scores students obtained in the test.

12. Teacher's guide. This is a manual which will provide teachers with the pointers, helpful alternatives, and background information to strengthen the teacher's mastery of the topics. The guide clarifies what the teacher needs to know, provides tips on the use of the module, calls the attention of teacher to highlight striking points, and suggests enrichment activities to increase learning.

On the other hand, Parker (2007) said that a self-instructional module is a self-contained, independent unit of prepared instruction targeted for specific instructional objectives. The module is self-directing in nature since it includes instructions on how students will follow various investigations. The writer should also include a listing of the materials and other references that should accompany the text of the module. For this, Parker (2007) suggested that curriculum developers must include (a) overview (b) pretest (c) objectives (d) learning resources (e) learning activities (f) enrichment activities (g) self-evaluation exercises, and (h) posttest.

The UP Open University (1999) suggested that whatever format the writer follows, he or she must follow a set of criteria in developing a well-written curriculum material. These criteria include:

1. The concepts and skills reflected in the learning material must be accurate. The curriculum writer must evaluate the accuracy of ideas and skills of science curriculum materials from the viewpoint of scientists. It is therefore necessary for a scientist to review the learning material for accuracy of concepts and skills.
2. The reader must understand clearly the concepts and skills the writer wants to convey. In writing curriculum materials, the writer should explain concepts and describe skills in short paragraphs of short and simple sentences. The goal is to communicate effectively with the readers.
3. The material must have appeal to intended users such that learners continue reading the material until the end. This will happen if the curriculum material contains statements, explanations, and strategies that catch and sustain the interest of its intended users.
4. The curriculum writer must employ creative ways of presenting concepts and skills. He should have a sense of originality in presenting the material. However, the writer must be accurate in the explanation of established

scientific theories and concepts. This criterion is considered a mark of excellence, provided the writer has satisfied the other criteria too.

Conducting a formative evaluation. Although curriculum writers are experts in their respective fields, other experts should evaluate the learning materials they have developed. Davis (1995) described curriculum evaluation as an effort that focuses on determining whether the curriculum material as designed, developed, and organized produces the needed results. Further, he said that this activity identifies the strengths and weaknesses of the curriculum material before its implementation and the effectiveness of its delivery after implementation. One of the approaches in evaluating curriculum materials according to Ornstein and Hunkins (2004) is by conducting formative evaluation. This is an evaluation undertaken before implementing the curriculum material, and deemed to improve the existing curriculum material. Ellis et al. (1995) defined formative evaluation as one used by curriculum developers in gathering data to revise learning material to make it more efficient and effective.

Formative evaluation involves gathering pieces of evidence to decide on how to revise a curriculum material while the writer is still in the process of development. David (1995) suggested that if formative evaluation needs evaluating a simple curriculum material, involvement of teachers handling the subject might be enough. The author also said that teachers should not only limit their focus on the intended effects of the curriculum material when conducting formative evaluation. They should record and examine the presence of unintended effects.

On the other hand, the UP Open University (1999) suggested that curriculum writers must evaluate instructional materials based on criteria. These include: (a) accuracy (b) clarity (c) appeal, and (d) originality.

The accuracy of science curriculum materials refers to the accuracy of the scientific ideas and skills from the perspective of a scientist or a science educator. Thus, science teachers must review the curriculum material for accuracy of ideas and skills. On the other hand, clarity refers to the comprehensiveness of the learning material. When curriculum developers prepare learning materials, their primary aim is to communicate their ideas with readers in a clearer fashion. Talisayon (1998) stressed that writing is a form of communication that needs clarity of ideas from the viewpoint of the reader for it to become effective.

A curriculum material which catches and keeps the interest of the students has an appeal to them. The curriculum writer must be creative and innovative to increase the appeal of the learning materials. Talisayon (1998) suggested that learning materials must consider titles that catch the attention more easily. For example, instead of "Concentration of Solutions," as a title, the writer can consider "How much acid is in your vinegar?" Similarly, the writer can use a story or an anecdote to motivate the reader. The use of diagrams, figures, tables, or graphs may also improve the material's appeal to the reader.

Aside from areas that need evaluation, Talisayon (1998) also highlighted the need to evaluate the learning material based on its student involvement index, readability, and communication index.

The curriculum developer could measure the student's involvement index of a curriculum material using the procedure of Romey (1965). The value of student's involvement index serves as basis to find out the extent to which the learning material involved students in other activities apart from reading. While using the instructional material, students perform other activities apart from reading the material. Students may solve problems, prepare diagrams and illustrations, perform simple laboratory activities, and other relevant exercises intended to help students understand the concepts and principles. To some extent, the student involvement index measures the appeal of the curriculum material. If students perform the activities included in the learning material, this becomes meaningful to them. Therefore, one can say that the learning material has an appeal to students.

Curriculum developers may also determine the readability or reading ease of the learning material by following the procedure of Fry (1968). This procedure is explained in detail in the chapter on Methodology. The readability of the material shows whether the material matches the grade level of the intended user. This is important because this assures the curriculum writer that the written material falls within the understanding level of the intended users.

Communication index refers to the readability of the learning modules as seen by the students. It indicates whether students can readily understand the concepts and whether they can follow the instructions of the learning modules without difficulty. The curriculum developer could measure the communication index using the guidelines developed by Talisayon (1983), which are discussed in Chapter 3.

Revision and finalization of the instructional material. The results of the formative evaluation serve as the basis for revision of the learning material. Before printing the learning material for distribution, the curriculum writer must review and include the comments and the suggestions of experts who evaluated the learning material. Talisayon (1998) pointed out that this activity is an opportunity for the curriculum writer to prove the scientific value of openness to ideas. However, curriculum writers may disagree with the comments or suggestions of the evaluator. Disagreement between curriculum writer and evaluator only applies to the manner of presenting the ideas because matters related to the accuracy of the content are not arguable. According to Talisayon (1998), if the writer strongly believes in his conviction, the writer being the author has the last say.

Evaluating the Effectiveness of the Facilitated Learning Material

According to Ellis et al. (1995), a curriculum developer conducts summative evaluation to get the total picture of quality of the developed learning material. The curriculum writer carries out summative evaluation after development and implementation of the learning material. This evaluation focuses on the effectiveness of the curriculum material, in which the basis is students' performance. The result of summative evaluation can help teachers and other parties involved in developing the learning material to draw conclusion about how well the learning material has worked. It will also provide them information on how they can possibly improve the learning material. Reyes (2000) as cited by Lumaque (2011) listed several curriculum evaluation models which can serve as a guide. Some of these include Metffessel-Michael Evaluation Model, Provus' Discrepancy Evaluation Model, Stake's Congruence Contingency Model, and Stufflebeam's Context, Input, Process and Product Model. However, she stressed that in evaluating the learning material, the quasi-experimental design is most suitable.

Corollary to the above-mentioned models of evaluation, Best and Kahn (1998) suggested that a writer should adopt Pretest-Posttest Nonequivalent Group design if an experiment in classroom settings will be conducted. They highlighted that this design is applicable in classroom experiments where the experimental and control groups are intact classes. Further, they said that this design is also appropriate for evaluating the learning materials used.

As discussed in the earlier part of this chapter, Lumaque (2011) argued that the use of learning modules complement learning instruction. Thus, this study delves into how thoroughly developed and evaluated facilitated learning modules affect student performance.

Advantages of Using Modules in Teaching

There had been many researches citing the advantages and benefits of using modules in teaching. First is the students' preference to self-paced nature of learning. In a survey conducted by Mak and Georges (1997), thirty-eight (38) students showed high levels of satisfaction with using the modules because of the self-paced nature of workbooks in particular. These students also indicated a clear preference for learning from self-paced workbooks compared to learning from textbooks. Modular teaching can be linked to the idea of a flexible method of instruction similar to the method used in Alternative Learning System (ALS). Morilla mentioned that using modules is the most appropriate teaching techniques in Alternative Learning System (ALS) Programs to help the learner grow and develop at his/her own pace. She further emphasized that through modular teaching, learning can take place anytime and anyplace depending on the convenience and availability of the learners. Morilla enumerated the following advantages of using modular approach of instruction, namely:

1. It establishes a system of assessment other than marks or grade.
2. Learners study the modules in their own working environment.
3. Learners can study without disturbing the normal activities and responsibilities.
4. Modules can be administered to individual use, small group or large group.
5. It enables the learner to have control over his/her learning.

In addition to the advantages enumerated above, Sejpal (2013) added the following advantages of using modules in teaching, namely:

1. Learning became more effective.
2. Modules are flexible so that implementation can be made by a variety of patterns.
3. It is more appropriate to mature students.
4. Accept greater responsibility for learning.
5. It already got wider accessibility in the present educational scenario.

Chemistry, in general require, high level of mathematical skills in order to understand and apply the concepts. Thus, learning chemistry is easier when the students have better skills in mathematical manipulations. Bodner (1983), as cited by Espinosa (2009) said that chemistry achievement is directly related to student's mathematical and perception skills. That is, students who possess better mathematical skills performed better than in class. Seiler (2004) supported this statement in his study. He found out that as the mathematical ability level increases, the ease of getting high score in chemistry and physics exams also increases.

Mathematics is an essential skill for chemistry students to master (Grove & Pugh, 2012). This is the reason why mathematical chemistry emerged as an important field of chemistry. Mezey (2016) pointed out that mathematical chemistry is a truly interdisciplinary subject, a field of rapidly growing importance. He also pointed out that as chemistry becomes more and more amenable to mathematically rigorous study, it is likely that chemistry will also become an alert and demanding consumer of new mathematical results.

Furthermore, relevant studies showed that the students' conceptual understanding is affected by mathematical skills. One notable study that investigated this relationship is the one conducted by Adigwe (2013). He found in his study that there was significant improvement in achievement in stoichiometry as result of mathematics instruction. He also found that there mathematics skills correlated significantly with achievement in chemical stoichiometry.

Because the subject requires mathematics, the use of supplemental learning materials such as learning modules is necessary. In a study conducted by Lumaque (2004), he observed a better performance of a class using learning modules in chemistry than the class that did not use learning modules. Moreover, another study conducted by Lumaque (2011) revealed that performance of nursing students using facilitated learning modules was better than those who did not use facilitated learning modules.

In addition, remediation process such as the use of supplemental learning modules in subjects that require mathematical skills was also found useful in learning the subject.

In the same study conducted by Adigwe (2013), he found that there was significant improvement in achievement in chemical stoichiometry after remediation.

The relationships of the constructs are discussed in the following section of this chapter.

Conceptual Framework

Figure 1 shows the conceptual framework of the study. It depicts a causal relationship indicating that the use of facilitated learning modules in introductory analytical chemistry affects students' knowledge of analytical chemistry concepts and application of mathematical and statistical tools in analytical chemistry. The learning modules developed for this study contained activities anchored on the constructivist-based facilitated learning instruction. The figure shows that the dependent variable is student performance that includes knowledge of introductory analytical chemistry and knowledge of using mathematical and statistical tools in introductory analytical chemistry. The independent variable is the use of facilitated learning modules in analytical chemistry. These modules were anchored on constructivist-based facilitated learning instruction and served to guide and supplement student learning of introductory analytical chemistry. Facilitated learning instruction is employed to both groups. It included strategies like peer mentoring, on demand tutorial, and online discussion and file sharing used in both groups. However, only the experimental group made use of the facilitated learning modules to supplement instruction and in performing the peer mentoring, on demand tutorials, and online discussion and file sharing. The control group only had the common reference materials such as textbook while doing the facilitated learning activities. The facilitated learning modules also contained self-learning activities. Self-learning activities refer to the examples in the modules in which the students in the experimental group have to learn and understand by themselves. These learning activities also include assignments in which these students have to perform by themselves without the supervision of the teacher. The framework further shows that knowledge of introductory analytical chemistry correlates with application of essential mathematical and statistical tools in introductory analytical chemistry.

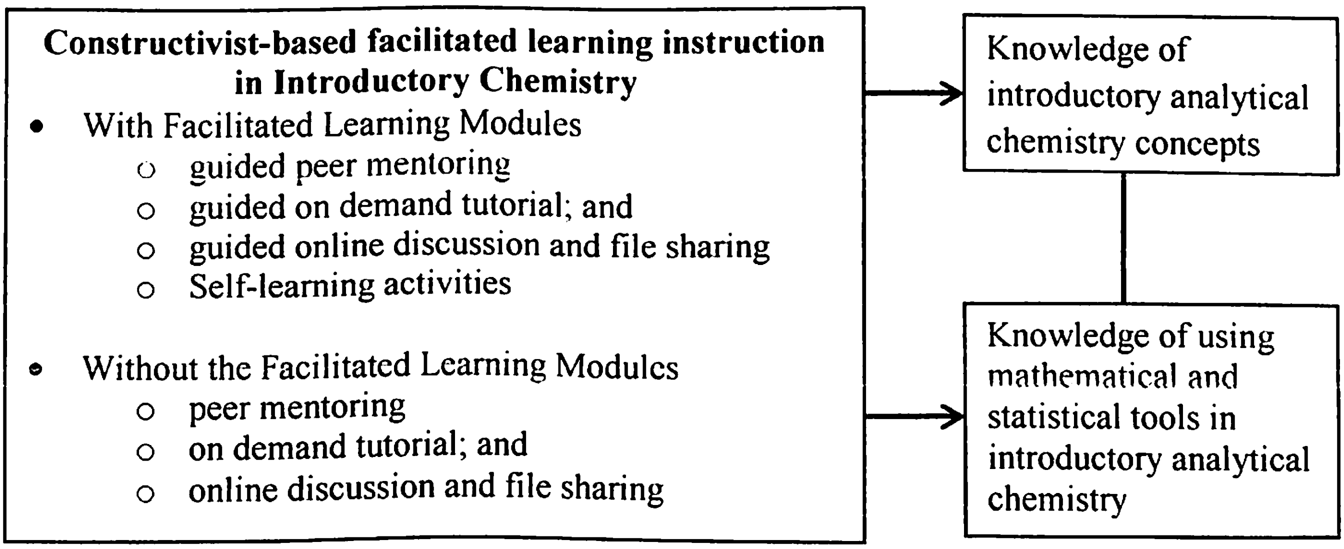


Figure 1. Conceptual framework of the study.

In the development and evaluation of the learning modules, appropriate steps were taken to ensure that these learning materials respond to the needs and interests of the end users. Talisayon (1998) highlighted that students read learning materials that catch their interest and such interest provides them motivation that can help them perform better in class.

Eggen and Kauchak (2001) stressed that teachers could use the learning modules regardless of the teaching strategy that they may adopt. In this study, the researcher used the learning modules with facilitated learning instruction. The facilitated learning instruction is another form of a teaching approach grounded on the principles of constructivism. Facilitated learning instruction provides opportunities to involve students actively in classroom dynamics. With this approach, students are not simply listeners and followers of instructions but active participants in activities that strengthen the generation of ideas. The following are approaches that provide opportunities for students to participate actively: group discussions, peer mentoring, tutorials and coaching, presentation of solved problems, performing seat works together in a group, and answering questions from classmates.

Among the facilitated learning approaches mentioned, only three are considered for the study, namely: peer mentoring, on-demand tutorial, and online discussion and file sharing. These three approaches are chosen because of their applicability as facilitated learning activities supplemented by the use of facilitated learning modules. The benefits of the three facilitated learning activities are discussed in the previous sections of this chapter.

Furthermore, the emphasis of facilitated learning instruction is on students becoming active learners since facilitated learning instruction is student-centered. With this approach, the teacher becomes the guide, helping students discover the concepts instead of giving lectures and controlling classroom activities (Fink, 2001).

Hypotheses

The null hypotheses of the study are:

1. The use of the facilitated learning modules does not significantly influence student performance.

2. Knowledge of using mathematical and statistical tools in introductory analytical chemistry does not significantly correlate with knowledge of introductory analytical chemistry.

The alternate hypotheses of the study are:

1. The use of the facilitated learning modules significantly influences student performance.
3. Knowledge of using mathematical and statistical tools in introductory analytical chemistry significantly correlates with knowledge of introductory analytical chemistry.

Definition of Terms

The following terms are defined as follows as they were used in this study.

Appeal of the content refers to the extent to which the facilitated learning modules can catch and sustain interests of the end-users.

Appropriateness of the content refers to the extent on how the researcher selected and presented concepts, theories, drills, exercises and other learning activities in the modules. It also includes ways of ensuring that these activities fall within the learning principles in chemistry education and match the students' learning abilities.

Attainability of the objectives refers to the extent to which the teaching and learning tasks assisted in realizing objectives of the facilitated learning modules as planned without neglecting the students' learning capacities.

Clarity of the objectives refers to how clear and unambiguous the curriculum writer drafted the objectives of the facilitated learning modules from the view of the end-users.

Conformity with standards refers to the extent to which the developed facilitated learning modules are consistent with the school's syllabus and the CHED's Minimum Learning Competencies.

Face content refers to organization and representation of topics included in the facilitated learning modules' content.

Facilitated learning instruction is an active teaching-learning approach adopted by the teacher in handling the introductory analytical chemistry classes in this study.

Facilitated learning module refers to the supplementary learning material developed by the curriculum writer for teaching-learning that adopts facilitated learning instruction.

Form refers to the method, appearance, and characteristics of the facilitated learning modules making them distinct for the intended purpose.

Innovativeness of the content refers to the originality and creativity of the curriculum writer in presenting the concepts and mathematical and statistical manipulations included in the modules.

Knowledge of introductory analytical chemistry in this study refers to the understanding level of the introductory concepts of analytical chemistry such expressions of concentrations, chemical equilibrium, acid-base equilibrium, other aspects aqueous equilibria, and gravimetric analyses. This was measured using the scores obtained by the students in the objective-type component of the posttest.

Knowledge of using mathematical and statistical tools in introductory analytical chemistry in the study refers to the skill level of students in applying mathematical and statistical tools necessary to solve problems about expressions of concentrations, chemical equilibrium, acid-base equilibrium, other aspects aqueous equilibria, and gravimetric analyses. This was measured using the scores obtained by the students in the problem-solving component of the posttest.

Relevance of the objectives refers to the extent to which the objectives of the facilitated learning modules can guide analytical chemistry instructors in developing instructional plans for effective teaching-learning.

Student performance refers to competencies, skills, and attitudes learned through the experiences of the students that occur during the teaching-learning process in the specific chemistry concept. This is the dependent variable in this study that is measured in terms of knowledge of introductory analytical chemistry and application of mathematical and statistical tools in introductory analytical chemistry.

Chapter 3
METHODOLOGY

This chapter describes the research design of the study. It includes the descriptions of respondents and instruments used in the study. It also describes the features of facilitated learning modules and how it supported facilitated learning instruction. The chapter further elaborates the procedures in data gathering and the use of suitable statistical tools in analyzing the data of the study and in interpreting the results.

Research Design

The study involved two phases. The first phase covered the development of facilitated learning modules in analytical chemistry on topics that require mathematical and statistical tools. The second phase of the study tackled the assessment of the effectiveness of facilitated learning modules' effectiveness through evaluation of the students' performance in analytical chemistry.

The first phase of the study was a research and development endeavor. This phase of the study employed both qualitative and quantitative analyses to develop the facilitated learning modules. The qualitative aspect of this phase focused on the evaluation of the facilitated learning modules' face content and form by chemistry education experts. The relevant comments and suggestions of these experts were incorporated into the final forms of the facilitated learning modules. The quantitative aspects of this phase focused on the evaluation of the facilitated learning modules' objectives and content by analytical chemistry instructors and the determination of the facilitated learning modules' student's involvement index, grade level and communication index. Figure 2 shows the research framework of the first phase of the study.

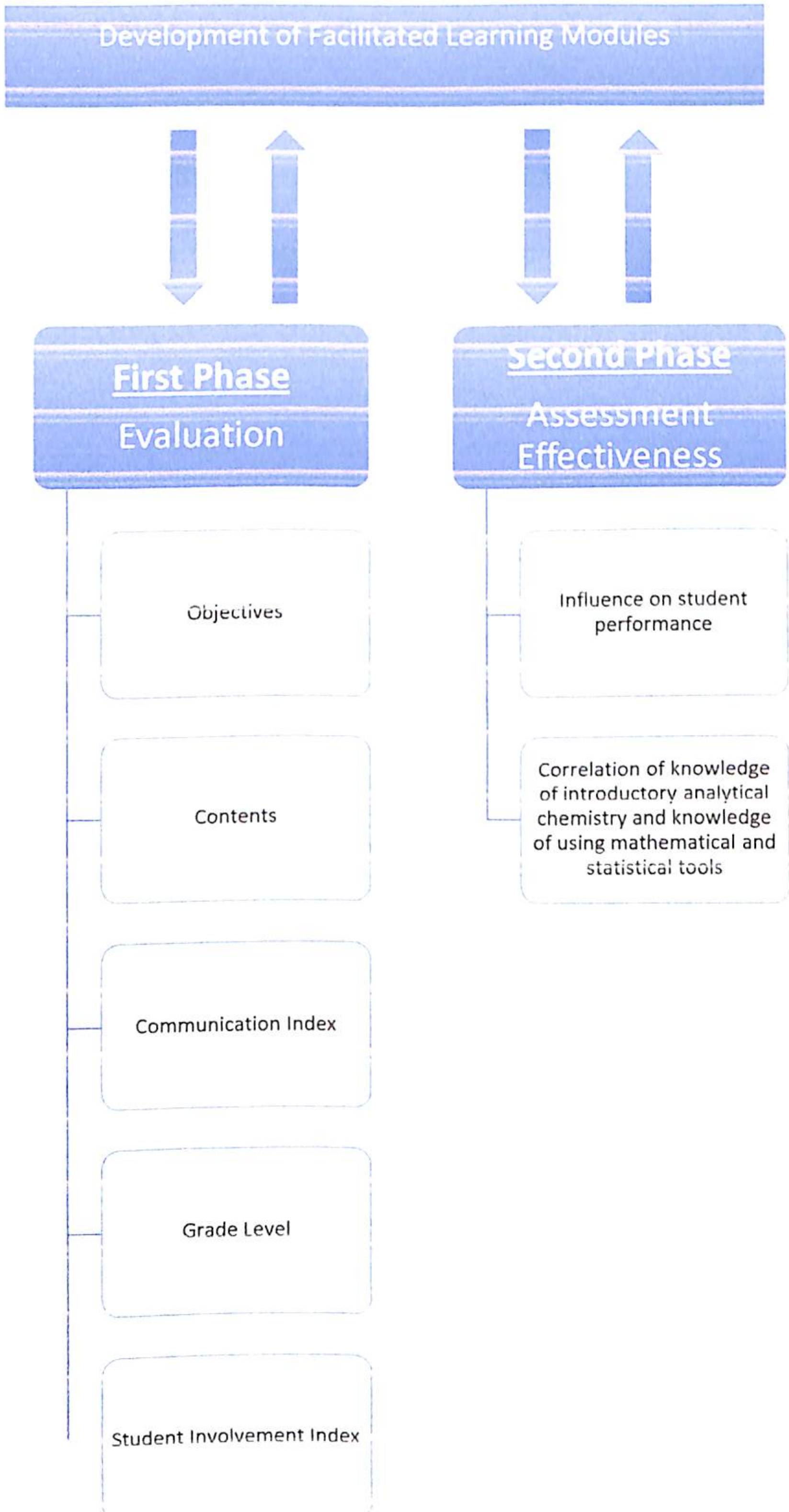


Figure 2. Learning modules development and evaluation framework.

Analytical chemistry instructors evaluated the learning modules' objectives in terms of attainability, clarity, and relevance. They used an evaluation tool developed by Lumaque (2011) (refer to appendix B) whose permission was personally sought for use in this study. Attainability of the objectives refers to the extent to which the teaching and learning tasks assisted in realizing objectives of the facilitated learning modules as planned without neglecting the students' learning capacities. Talisayon and Yu (1997) said objective is attainable if the users of the module are able to answer an appropriate test item as indicated by a class mean score on a test addressing the objectives of the module. In addition, Lumaque (2011) mentioned that attainability of the objectives refers to the extent to which objectives are stated in a measurable, realistic, and time-bounded manner. Clarity of the objectives refers to how clear and unambiguous the curriculum writer drafted the objectives of the facilitated learning modules from the view of the end-users. Talisayon and Yu (1997) emphasize that writers write curriculum materials not to impress but to communicate with the reader. According to Lumaque (2011), if objectives are stated clearly, students would have an idea about the coverage of the module after reading the objectives.

The contents of the learning modules were also evaluated in terms of appropriateness, appeal, innovativeness, and conformity to standards by the analytical chemistry instructors using the same evaluation tool. Appropriateness refers to the extent on how the writer selected and presented concepts, theories, drills, exercises and other learning activities in the modules. It also includes ways of ensuring that these activities fall within the learning principles in chemistry education and match the students' learning abilities. Lumaque (2011) mentioned that content of the module is appropriate if this is suitable to the reading and comprehension level of the students. Appeal of the content refers to the extent to which the facilitated learning modules can catch and sustain interests of the end-users. Talisayon and Yu (1997) considered curriculum material most-appealing if the user does not stop reading until he/ she gets to the end. Lumaque (2011) on the other hand considered curriculum material appealing if presented in a technically appropriate manner and the material is attractively packaged. This means that the layout is appropriate in a manner that can attract the attention of the reader. Innovativeness refers to the originality and creativity of the curriculum writer in presenting the concepts and mathematical and statistical manipulations included in the modules. Talisayon and Yu (1997) said that a curriculum writer can create new ways of presenting concepts and skills. In this study, analytical chemistry instructors evaluated this aspect to assess the extent to which the writer has developed a unique way of presenting the discussions of the mathematical manipulations in the module. Lastly, conformity to standards refers to the extent to which the developed facilitated learning modules are consistent with the school's syllabus and the CHED's Minimum Learning Competencies. Lumaque (2011) emphasized that a curriculum material conforms to the standards if the modules cover the important concepts and skills for chemistry instruction. The instructors looked into this aspect and rated the modules based on how the content conform to the standards set by the CHED.

The next step of the first phase is the determination of the student's involvement index, grade level and the communication index. Second-year medical technology students from the research locale were requested to carry out the stipulated procedures. The data obtained by these students were used by the researcher to compute the mentioned indices. Student's involvement index refers to the measure of the student's level of participation in the learning modules. This index was calculated using Romey's (1965) procedures. This value was calculated using the following formula:

$$\text{Student Involvement Index} = \frac{\text{Total Number of Sentences in Category B}}{\text{Total Number of Sentences in Category A}}$$

Category A includes sentences citing facts, stated conclusion, definitions and questions answered immediately. Category B includes questions requiring students to analyze data, statements requiring student to formulate conclusion, and directions to students to perform and analyze some activity and solve problems. Appendix C presents the table showing how the counting of sentences was carried out in each category. According to Romey (1965), if the student's involvement index is greater than 1.00, the reader shows involvement in what he or she reads. In addition, apart from reading, the students could also perform other activities and could still understand the mathematical manipulations presented in the modules. Some of the activities which students can perform while reading the modules include solving problems in analytical chemistry such as statistical treatment of data and solution concentrations, calculator drills, plotting calibration curves, and reading other analytical chemistry books.

The grade level of the modules refers to the reading age of the users. This was determined using the graph readability of Fry (1968). The grade level was determined by locating the point on the readability graph. The point was defined by the average number of syllables per 100 words (abscissa) and the average number of sentences per 100 words (ordinate), in the first, middle and last pages of the learning modules. Specific regions in the graph correspond to grade levels. The point whose coordinates are defined falls on a specific region which represents a grade level. Further details of the procedures are presented in Appendix D. According to Talisayon (1998), if the grade level of a learning material matches the grade level of intended users, the writer has developed and presented the material in a manner easily understood by the intended users.

The communication index of the learning modules refers to the readability of the learning modules as perceived by the students. This was measured to determine whether students can understand and follow the instructions in the learning modules without difficulty using Talisayon's (1983) guidelines (refer to Appendix E). Ten students were requested to read the learning modules and list those words that they found unclear as they went through the modules. Using the 100-word sample considered in the graph readability formula in determining student's involvement index, these students listed unclear words they found in the sample. The number of students who found a word in the sample unclear was counted. The frequency of occurrence of all unclear words found by each student was also counted. The total number of unclear word and the total number of words used in the samples were determined. The communication index, CI, for words of the module was calculated using the following formula:

$$CI = \frac{\text{Sum of (fX)}}{(Nr)(Nx)}$$

where:

X	=	number of readers indicating a given unclear word
f	=	number of times unclear word appears in the samples of words
Nr	=	total number of unclear words
Nx	=	total number of words in the samples

Using the data obtained from the students' evaluation and the Talisayon's guide, the communication index (CI) of the facilitated earning modules was computed and checked if this value falls within the range of acceptable values for communication index which is $0 \leq CI \leq 0.01$. If the computed value falls within the indicated range, the students find words in the learning modules simple and easy to understand. Thus, students can easily follow mathematical procedures presented in the modules.

The second phase of the study employed quasi-experimental method that utilized pretest-posttest nonequivalent groups design. This design involved the use of two groups which had not been constituted by randomization. Figure 3 presents the research design of the second phase of the study. It can be seen in Figure 3 that the independent variable is the use of facilitated learning modules, which is the treatment used in the study. The dependent variable is the student performance measured using the posttest scores comprising knowledge of using mathematical and statistical tools in introductory analytical chemistry and the knowledge of introductory analytical chemistry.

1st Year **Medical Technology Classes**			
Experimental Group	O_1	X	O_2 O_3
Control Group	O_1		O_2 O_3

Figure 3. Quasi-experimental pretest-posttest nonequivalent groups design of the second phase of the study.

In Figure 3, O_1 refers the pretest scores of students in Mathematics and Statistical Tools in Introductory Analytical Chemistry; O_2 and O_3 refer to the posttest scores of students in Mathematics and Statistical Tools in Introductory Analytical Chemistry and Introductory Analytical Chemistry, respectively; and X refers to the treatment given to the experimental group which was the use of facilitated learning modules. Although both the experimental and the control used facilitated learning instruction as learning strategy, only the experimental group used the facilitated learning modules as supplementary materials during the conduct of facilitated learning activities. The control group used only the conventional learning materials such as textbooks without access to the facilitated learning modules while performing the facilitated learning activities.

This phase of the study aimed to assess the effectiveness of the facilitated learning modules on student performance and to correlate the knowledge of using mathematical and statistical tools in introductory analytical chemistry with the knowledge of introductory analytical chemistry concepts. This phase began with identifying two intact classes in analytical chemistry classes during the second semester of 2015-2016. One of the two classes was randomly assigned as the experimental group and the other as the control group. Before treatment, a pretest was administered to both the experimental and control groups. The purpose of the pretest was to measure the knowledge of students in using basic mathematics in introductory and statistics before the treatment. The treatment given to the experimental group was the use of the facilitated learning modules.

After the treatment, a posttest was administered to both groups. Knowledge of using mathematical and statistical tools in introductory analytical chemistry was then correlated with the knowledge in introductory analytical chemistry using the scores in the two components of the posttest.

Instruments

The instruments used in the study are grouped by phase in which they were used.

First phase of the study. One of the instruments used in the study is the *Content and Form Evaluation Tool* shown in Appendix A. This was used by the chemistry education experts during the early stage of development of the facilitated learning modules. This tool asked chemistry education experts to evaluate the facilitated learning modules in terms of face content and form. There is a portion in the instrument where these experts were asked to cite their comments and suggestions. All relevant comments and suggestions were addressed one by one and corresponding revisions were made on the learning modules to improve their face content and form. Two chemistry education experts evaluated the face content and form of the facilitated learning modules. Both experts have doctorate degree in chemistry education and are faculty members from two different universities in the research locale.

Another instrument used in this phase was the tool for evaluating the *Objectives and Content Evaluation Tool* shown in Appendix B. This was the evaluation tool used by analytical chemistry instructors in assessing the facilitated learning modules' objectives and content. Ten analytical chemistry instructors evaluated the learning modules' objectives and content using this form. Some of these instructors have doctorate degrees in chemistry and chemistry education while some have master's degree in chemistry. This instrument was developed by Lumaque (2011) whose permission was sought personally. Some statements in this tool were revised to suit the study particularly the fact that the subject considered in the study is analytical chemistry while the subject in the original draft was general chemistry. The objectives of the facilitated learning modules were assessed in terms of attainability, clarity, and relevance. On the other hand, the content of the facilitated learning modules was evaluated in terms of appropriateness, innovativeness, appeal, and conformity to standards. This tool asked the respondents to indicate the extent to which they agree or disagree on a statement in the evaluation tool. The scores were then analyzed and interpreted using a rubric. Lumague (2011) pilot-tested the tool together with the rubric among chemistry teachers in the research locale.

Second-year medical technology students of Notre Dame of Marbel University served as the group of respondents for the development phase. These students were asked to carry out the procedures included in the respective tools to determine the student's involvement index, grade level and communication index. The data obtained by the students were utilized to measure the student's involvement index, grade level and communication index of the facilitated learning modules. These students took analytical chemistry during their first year in the program. Thus, they are familiar with the topics covered in analytical chemistry. Standardized instruments and procedures to measure the student's involvement index, grade level, and communication index of the facilitated learning modules were adopted from existing standardized instruments. Specifically, a standard instrument developed by Romey (1965, refer to Appendix C) measured the student involvement index of the learning modules. The result would show the extent to which students could undertook other activities while reading the facilitated learning modules. This means the ratings given by these students could indicate if readers could also perform solving problems, balancing chemical equations, writing and drawing formulas, and browsing other reference materials apart from reading the modules. The researcher determined the grade level of the facilitated learning modules using the data obtained by the students from the procedures indicated in Edward Fry's (1968) readability graph (refer to Appendix D). The procedure involves plotting the calculated value in the graph to determine which grade level this value falls. The communication index was calculated using the guidelines developed by Talisayon (1983, refer to Appendix E). The resulting value of this index indicates whether the readability of each of the facilitated learning modules falls within the acceptable limit.

Second phase of the study. In this phase of the study, three instruments were used to determine if the facilitated learning modules were effective in improving the performance of the students in introductory analytical chemistry. The first instrument used was the pretest. This was administered (refer to Appendix F) before the treatment was given. This pretest measured the knowledge of the medical technology students in using mathematical and statistical tools in introductory analytical chemistry. The pretest contains questions either copied word for word or adapted from questions existing in algebra and statistics books. Existing standardized tests on algebra and statistics were used in this study. This was to ensure that the questions included in the pretest were actually covered in their algebra and basic statistics. This consisted of 45 multiple-choice questions which the students took for 1.5 hours. Three mathematics instructors of Notre Dame of Marbel University examined the content validity of the test. The reliability of the test questionnaires was also determined using the test-retest method. When the pretest was administered to a different group of students twice, a high positive association value of 0.694 was obtained. This indicated that a good association between the scores obtained in the first and second administrations of the pretest existed. Another instrument used in this phase was the posttest (refer to Appendix G). The posttest was administered to both groups after the treatment period of ten weeks. Sixty (60) percent of the posttest items were problem-solving questions while forty (40) percent of the items were of knowledge-type. These questions assessed the students' skills in applying mathematical and statistical tools in introductory analytical chemistry and their understanding of introductory analytical chemistry. The validity and reliability of the posttest were also assessed using suitable methods. The validity of the posttest was determined by logical analysis of the content which was done by the researcher and other analytical chemistry instructors in the research locale. The reliability of the posttest on the other hand was determined by test-retest method utilizing the same group of students who were used in the determination of the reliability of pretest. A high positive correlation value of 0.685 was obtained which indicated that a good correlation existed between the scores of students in the first and second administrations of the posttest.

The posttest included two types of questions – problem-solving and objective types. Scores in the problem-solving type represented scores in the knowledge of using mathematical and statistical tools in introductory analytical chemistry while scores in objective type represented scores in the knowledge of introductory analytical chemistry.

The third instrument was a journal (refer to Appendix H) where student mentors and mentees from both the experimental and control groups wrote their feedback after the intervention was given. Particularly, they wrote what they thought were the advantages and disadvantages of using facilitated learning activities like peer mentoring, on-demand tutorial, and online file sharing and group discussion as learning strategies. Student mentors and mentees in the experimental group were also asked to include in their feedback on the advantages of using the facilitated learning modules as supplementary learning materials in doing peer mentoring, on-demand tutorial, and online file sharing and group discussion.

Facilitated Learning Modules

In the course of the study, introductory analytical chemistry was taught using facilitated learning instruction in both the experimental and control groups. Various teaching strategies that fall within the context and methods of facilitated learning instruction were utilized. In particular, peer mentoring, on-demand tutorial, and online file sharing and group discussions were used in the facilitated learning instruction other than the constructivist-approach lecture. The experimental group however, was provided with facilitated learning modules as supplementary materials in learning introductory analytical chemistry through facilitated learning instruction.

These facilitated learning modules focused on the use of statistical and mathematical tools in introductory analytical chemistry. Being constructivist in nature, the modules focused on activities that develop skills and involve higher-order thinking. These added learning materials served as aids in simplifying the applications of mathematical and statistical tools in introductory analytical chemistry. The facilitated learning modules served as lesson guides for the teacher and the students of the experimental group in dealing with the topics that need mathematical and statistical tools. Thus, lessons in the facilitated learning modules served as basis of the teaching-learning experiences happening inside the classroom of the experimental group.

All the facilitated learning modules contain the following: (a) Title, (b) Introduction, (c) Facilitated Learning Activity, (d) Objectives, (e) Time Frame, (f) Check-up Test and Feedback, (g) Lesson Proper, (h) Assignment, (i) Key Answers, (j) Summary, and (k) References. The Title presents the main topic that is to be covered in the module while the introduction discusses the importance of the topic in understanding other topics in analytical chemistry and its applications to their everyday life. The Objectives are formulated based on what students can do after learning the topics in the modules while time frame indicates the length of time allocated for each module. Check-up Test is designed to determine the prior knowledge of the students before learning the module while feedback shows and explain the answers. Lesson Proper discusses the content of the module while assignment is provided to let students practice the mathematical and statistical procedures they learned from the module. The section on Key Answers gives all the answers to the assignment while Summary wraps up what has been covered in the module. Finally, the References list the books and other material.

These learning modules also employed strategies that fall in the context and application of facilitated learning instruction and guided students in experimental group when they participated in the facilitated learning activities, specifically in peer mentoring, on demand tutorial, and online file sharing and group discussions.

Table 1

Matrix of Facilitated Learning Activity per Module

Module (Topic)	Facilitated Learning Activity
1(Statistical Testing and Treatment of Data I)	Peer Mentoring
2(Statistical Testing and Treatment of Data II)	Peer Mentoring
3 (Expressions of Concentration)	Peer Mentoring
4 (Chemical Equilibrium)	On-demand Tutorial
5 (Acids and Bases)	Peer Mentoring
6 (Other Aspects of Aqueous Equilibria)	Online File Sharing and Group Discussion
7 (Gravimetric Methods of Analysis)	Peer Mentoring

Each facilitated learning module was complemented by a specific facilitated learning activity. Table 1 shows the matrix of the facilitated learning activity utilized per module.

The succeeding sections describe these facilitated learning activities and how these were carried out in the experimental group using the facilitated learning modules and in the control group without the facilitated learning modules.

Peer mentoring. One of the strategies adopted in this study was peer mentoring. Students from both experimental and control classes were divided to form groups with at least five members each. The experimental had nine groups while the control had eight. Each group selected a mentor and co-mentor. Other members of the group served as mentees. Mentors and co-mentors were identified based on their scores in the pretest and their grades in the previous chemistry subject. Nine top performing students in the experimental group and eight top performing students in the control; groups were identified as group mentors. The next top nine performers in the experimental group and the next eight performers in the control group were identified as co-mentors to assist the group mentors in the mentoring activities. Pairing of the mentor and the co-mentor was also based on their ranks in the pretest and class performance. In the experimental group, top 1 performer was designated as mentor and was paired with top 18 performer as co-mentor while top 2 performer was designated as mentor and was paired with top 17 performer as co-mentor, and so on. In the control group, top 1 performer was designated as mentor and was paired with top 16 performer as co-mentor of top 1 mentor while top 2 performer was designated as mentor and was paired with top 15 performer as co-mentor, and so on. This process of identifying and assigning mentors and co-mentors was followed to achieve intellectual balance among the groups and to ensure that the quality of peer mentoring was uniform in all the groups in the experimental and control groups.

Each peer-mentoring session took place for at least 1.5 hours depending on availability of time among the group mentors and the mentees. The experimental group held sessions inside the classroom at 4:00 – 5:30 PM, TTh. The control group held their sessions at 3:30 – 5:00, MW. Sometimes, groups held their sessions either in the university library or in their houses when they need time longer than 1.5 hours. Also, groups held peer mentoring at least once a week depending on availability of time and the demand for such activity especially when a long test was approaching.

Before each peer-mentoring session, a problem set was assigned for the groups to work on. The teacher provided instructions on how groups should carry out the session. Only students in the experimental group used facilitated learning modules as supplementary learning materials. The teacher also provided possible references for all groups in both the experimental and control groups. The teacher gave experimental and control groups different schedules to prevent the latter from seeing the facilitated learning modules used by the experimental group. The teacher assigned experimental group Tuesdays and Thursdays while Mondays and Wednesdays for the control group. If a group decided to extend a session held outside the campus, the researcher specifically stressed that only the students belonging to the experimental group can use the facilitated learning modules. Further, the teacher-researcher emphasized that students belonging to the control group were not allowed to join the experimental group during sessions conducted outside the campus, and vice versa. The teacher asked the group leader how the group conducted the mentoring session outside the campus the following day, or during the next class session. With this, the teacher would know if there were students belonging to other groups that had joined them during mentoring session.

After treatment, the teacher required each group to submit a report on how the group carried out the peer mentoring. The teacher also directed the group leaders to include in their reports effects of peer mentoring on the group's understanding of analytical chemistry and the mathematical tools involved in solving analytical chemistry problems.

On-demand tutorial. Another facilitated learning instruction approach used was the on-demand tutorial sessions. The teacher designed this to offer students the opportunity to clarify discussions on the mathematical manipulations with the instructor as the tutor, to lessen confusions about mathematical procedures. This was designed to help students gain confidence in dealing with problem solving in analytical chemistry which they found more difficult than the problem solving they encountered in general chemistry. There were two tutorial sessions conducted for each group because of limited availability of the teacher. The teacher-tutor conducted each tutorial session on a Saturday afternoon that ran for two hours each session.

In the tutorial session the teacher-tutor discussed important problem solving techniques to highlight the advantage and disadvantage of such technique for the first hour. The teacher-tutor earmarked the remaining hour for students to raise questions on topics that confuse them. The tutor ensured that he entertained as many questions as possible during session. Again, the tutor allowed use of facilitated learning modules only for the experimental group. The tutorial sessions in the control group were conducted without the use of the facilitated learning modules. Instead, they made use of other materials such as their notebooks and books, which were also used in the experimental group.

Online file sharing and group discussion. The third facilitated learning approach used in the study was the online file sharing and group discussion. This approach provided students with opportunities to interact and exchange insights and thoughts with the other students and with the teacher. This also allowed them to access some learning materials uploaded online by the teacher. The teacher created for each class a Facebook account for this activity. This is where the teacher uploaded useful materials to allow access to the students. Uploaded materials included scanned solutions of quizzes the instructor failed to discuss because of time constraints and lectures students asked for inclusion. In each material posted, the researcher allowed the students to react and comment on the solution to clarify points they might not have understood. The teacher allowed other students to comment by providing explanation to the student who raised clarification or reaction. The teacher also allowed students to post their own solutions. Again, only the experimental group was allowed to use learning modules for this strategy. Furthermore, the researcher allowed students in the experimental group to comment on the solutions presented in the learning modules for further online discussions. The online file sharing and group discussions in the control group were conducted without the use of the facilitated learning modules. Instead, they posted solutions of problems for group discussion either from textbooks or from lectures that they did not understand clearly during the regular class sessions.

According to Lumaque (2011), facilitated learning modules allow students to feel as if they are listening to the presentation of the teacher while reading the modules. He also reiterated this statement in his suggestion being one of the chemistry education experts in this study. All these would make the facilitated learning modules different from other learning modules and other learning materials.

The parts of learning modules suggested by UPOU (1999) and Lumaque (2011) as discussed in Chapter 2 are similar to the parts considered in this study. There were also parts added that were considered essential and some parts were omitted because they were not necessary. The procedure on the conduct of the facilitated learning activity and the assignment were the parts added while target population, entry behavior and prerequisite skills and feedback on the assignment were the parts not included. The facilitated learning modules have the following parts to fit their purpose:

(a) Title

(b) Introduction

(c) Facilitated learning activity

(d) Learning objectives

(e) Time frame

(f) Check-up test and feedback on the check-up test

(g) Lesson proper

(h) Assignment

(i) Answer key to check-up test and assignment

(j) Summary

(k) References.

These learning modules were given one or two days before the lecture on the topic or the conduct of the facilitated learning activity. As a guideline, students in experimental group read the learning modules in advance. Thus, both facilitated learning instruction and use of facilitated learning modules were utilized in the experimental group. The classroom activities of the control group did not use the facilitated learning modules.

Data Collection Procedures

The study gathered data in each of the two phases of the study – during the development of the facilitated learning modules (first phase) and during the assessment of these facilitated learning modules' effectiveness on improving student performance (second phase).

First phase data collection. In particular, data gathered in the first phase are listed below:

(a) comments and suggestions made by chemistry education experts on the face contentand form of the facilitated learning modules;

(b) evaluation of the learning modules' objectives and content by the analytical chemistry instructors; and

(c) evaluation of the grade level, student's involvement index, and communication index of the learning modules.

All comments and suggestions gathered from the evaluations of the chemistry education experts and chemistry instructors relevant to the improvement of the facilitated learning modules served as bases for the revision of the learning modules. The comments and suggestions characterized the essential features of the facilitated learning modules, face content and form as perceived by these experts. After the comments and suggestions were already incorporated, analytical chemistry instructors then evaluated the facilitated learning modules based on objectives and content using a questionnaire (refer to Appendix B). Using a researcher-developed rubric, the corresponding scores showing the extent of respondents' agreement and disagreement on statements included in the questionnaire were recorded. The means of the recorded scores given by the instructor-respondents were computed and interpreted using a rubric presented as Table 2 in Chapter 4. The results of this evaluation served as basis to further improve the objectives and contents of the learning modules.

Furthermore, using the specific validated instruments, the student's involvement index, grade level, and the communication index of the learning modules were assessed. Each instrument contains the procedures in carrying out these determinations. Second-year medical technology students carried out the recommended procedures in each instrument, since they are familiar with analytical chemistry, having already finished the subject.

Second phase data collection. The data gathered in the second phase consisted of scores earned by the experimental and control groups in the pretest and posttest. In undertaking assessment of the learning modules' effectiveness, the pretest-posttest nonequivalent design was utilized. Both the experimental and control groups took the pretest before the start of the treatment. Students were given 1.5 hours to answer forty-five (45) multiple-choice questions. Only the experimental group used the facilitated learning modules as supplementary learning materials. These modules complemented the existing materials used during facilitated learning instruction and the learning activities held inside or outside the classroom.

The treatment ran for only 10 weeks of the semester. The treatment did not cover the entire semester because the last part of the course does not need mathematical and statistical tools as pointed out in the course syllabus.

After the treatment, both the control and experimental groups took the posttest on February 20, 2016. The researcher used pretest and post-test scores of students in both groups to assess the effectiveness of the learning modules on student performance.

Both groups took the same set of tests containing objective and problem-solving types as posttests for three hours. The scores in objective-type items served as their scores in knowledge of introductory analytical chemistry. Their scores in the problem-solving items served as their scores in knowledge of using mathematical and statistical tools in introductory analytical chemistry. In addition, the posttest scores of both groups in the objective-type and problem-solving questions were used to correlate the knowledge of using mathematical and statistical tools with the knowledge of introductory analytical chemistry.

After the treatment, the researcher also gathered feedback from the student mentors and mentees from both the experimental and control groups regarding the utilization of the peer mentoring, on-demand tutorial, and online file sharing and group discussion as the facilitated learning activities. A journal form was used where these student mentors and mentees from both the experimental and control groups were allowed to write their feedback particularly the advantages of using facilitated learning activities as learning strategies. Student mentors and mentees in the experimental group were also asked to include in their feedback the advantages of using the facilitated learning modules as supplementary learning materials. In particular, these students from the experimental group were asked about how the facilitated learning modules helped enhance the conduct of facilitated learning activities. Finally, the feedback of students from both the experimental and the control groups were compared in order to see how the facilitated learning modules helped enhanced the conduct of the facilitated learning activities.

Data Analyses

Data gathered during the development of the learning modules and during the assessment of the learning modules' effects on student performance were analyzed and interpreted. The Statistical Packages for Social Sciences, SPSS Version 20 software was used in analysing the data. Analyses of the data were done by phase. The succeeding sections describe how data in each phase were analyzed.

First phase data analysis. The data gathered in the early stage of first phase (development) did not require statistical tool for analysis as these were comments and suggestions of chemistry education experts. This only involved incorporation of comments and suggestions into the drafts of facilitated learning modules. With regards to the following aspects, (a) objectives of the learning modules based on attainability, clarity, and relevance; and (b) content based on its appropriateness, innovativeness, appeal, and conformity to standards, teacher respondents rated the module by indicating the extent to which they agree or disagree with each of the statements under each criterion using the *Objectives and Content Evaluation Tool* shown in Appendix B. Mean scores in each statement were calculated based on the teacher respondent's evaluation. Moreover, these scores were interpreted with the help of a rubric or a guide developed by Lumaque (2011).

The modules' student's involvement index, grade level, and the communication index were also computed following the procedures stipulated in each instrument mentioned (refer to Appendix C, Appendix D, and Appendix E). The resulting values served as basis to decide whether the learning modules matched the characteristics of the end users.

Second phase data analysis. For the data in the second phase, independent samples

t-test and analysis of covariance were employed. Specifically, the independent samples t-test was used to establish that the two groups were comparable in terms of their aptitude and skills in mathematics and statistics as applied to introductory analytical chemistry. On the other hand, analysis of covariance (ANCOVA) was used to determine if a significant difference existed between the posttest scores of students using the facilitated learning modules and those who did not. The pretest scores of both groups served as the covariate to eliminate the effects of the prior knowledge of mathematics and statistics of students in both groups before the treatment. Thus, the improvement in the posttest scores of the experimental group could be solely attributed to the use of the facilitated learning modules. Significant difference existed if the significance value is less than 0.05.

Moreover, Pearson's r was used to determine if knowledge in using mathematical and statistical tools correlates with knowledge in introductory analytical chemistry. Pearson's correlation was considered because the data were raw scores which are continuous. This study made use of a rubric cited by Sevilla, et al. (1996) to determine the degree of correlation. Table 2 below shows the rubric which lists interval values with matching degree of correlation. The degree of correlation was marked by the interval to which the calculated value fell. The values ranged from 0 to 1, ranging from negligible correlation to high correlation as the matching degrees of correlation.

Table 2

Interpretations of Correlation Values by Sevilla, et al. (1996)

Correlation Value	Interpretation
0.80 – 1.00	High Correlation
0.60 – 0.79	Moderately High Correlation
0.40 – 0.59	Moderate Correlation
0.20 – 0.30	Low Correlation
0.01 – 0.19	Negligible Correlation

The feedback written on the journals by the student mentors and mentees regarding the utilization of the peer mentoring, on-demand tutorials, and online file sharing and group discussions were gathered. These feedback provided by the students from both groups were read twice and the common answers pertaining to particular advantages of utilizing the facilitated learning activities were listed and categorized. Each category represented a common advantage mentioned by the students. Specific feedback pertaining to how the use of facilitated learning modules helped students in the experimental group enhance the conduct of facilitated learning activities were also listed and categorized. Each category represented a specific and common manner as to how the use of facilitated learning modules enhanced the conduct of facilitated learning activities. Further, feedback raised by the mentors and mentees served as proofs to support the hypotheses of the study that the use of facilitated learning modules as supplementary learning materials during the conduct of facilitated learning activities improved student performance in the experimental group.

Chapter 4
RESULTS AND DISCUSSION

This chapter presents the results of the study based on the sequence of questions in the statements of the problem presented in the first chapter.

Essential Features of the Facilitated Learning Modules

The use of facilitated learning modules was intended to help students develop their mathematical and statistical skills necessary in solving problems in introductory analytical chemistry. This strategy involved students performing facilitated learning activities alongside reading the modules' content to further process the information in order to deepen their understanding of the mathematical and statistical tools. Included in the learning modules were guidelines and mechanics of the facilitated learning activities. The facilitated learning modules included discussion of the mathematics and statistics part of the lesson where mathematical procedures were dealt with in detail. Reviews of basic chemistry concepts were also included. These chemistry concepts were discussed alongside mathematical and statistical procedures.

There were seven facilitated learning modules developed. Each module contained the following parts: title, introduction, objectives, time frame, check-up test, facilitated learning activity, lesson proper, assignment, answer key, summary, and references. The modules also included a teacher's guide and preface as introductory parts to provide guidelines in using the modules. Modules 1 and 2 covered statistical testing for treatment of data. These modules tackled statistical tools and techniques as applied to analytical chemistry. These two modules highlighted basic statistical tools, reporting and computing data, tests of significance, and other applicable statistical tests. Finding mean, median, mode, range, standard deviation, pooled standard deviation, relative standard deviation, relative error, percent relative error, part per thousand error, and dimensional analysis were also discussed in Module 1. These basic statistical tools were reviewed as these were necessary tools utilized in dealing more complex statistical treatment of data. Module 2, on the other hand, covered complex statistical tools such as confidence interval, t-test test, z-test, F-test, and Q-test. These are the statistical tests used in the following applications: (1) defining a numerical interval around the mean of a set of replicate analytical results within which the population mean can be expected to lie with a certain probability, which is called the confidence interval (CI); (2) determining the number of replicate measurements required to ensure that an experimental mean falls within a certain range with a given level of probability; (3) estimating the probability that (a) an experimental mean and a true value or (b) two experimental means are different; and (4) deciding with a certain probability whether an apparent outlier in a set of replicate measurements is the result of a gross error and can be rejected or retained.

Moreover, Module 3 dealt with a review of the different expressions of concentrations while Module 4 focused on the basics of chemical equilibrium such as writing equilibrium-constant expressions until discussions regarding Le Chatelier's principle. It also introduced techniques in solving problems involving equilibrium. Module 5 discussed acidic and basic solutions focusing on ionization and calculation of pH of these solutions. Module 6 covered other aspects of chemical equilibria. It discussed common-ion effect, buffers, and the solubility-product constant. Lastly, Module 7 was about the techniques and calculations involved in gravimetric methods of analysis.

Various teaching strategies that could be classified as facilitated learning instruction were used to complement the use of facilitated learning modules. Other than the lecture method, peer mentoring, file and link sharing, online group discussions, and on-demand tutorial sessions were also used. The following sections discuss how the use of facilitated learning modules helped students in performing the facilitated learning activities.

Peer mentoring. The usefulness of the facilitated learning modules in peer mentoring was assessed through the reports presented by both the student mentors and the student mentees. Emerging points regarding the usefulness of the learning modules on the conduct of peer mentoring based from the student journals were identified. First emerging point raised by student mentors was that the facilitated learning modules served as quick reference or guide for mentors whenever they needed to answer queries of their mentees having difficulty with the lessons. Here are the statements directly quoted from the student mentors:

> *Student Mentor 1, Experimental Group.*
> *"As a mentor, I had encountered several inquiries regarding the topics so it was really hard to answer the questions of my group mates and finding the answers directly from a bulky book. But the modules have summarized information regarding those inquiries that I could easily understand and share with my mentees.*

It can be said that the modules helped the mentors in addressing specific difficulties of the mentees without browsing the very bulky textbook because explanations of the topics covered in the lecture could be found readily in the modules. Another point raised by student mentors was that the facilitated learning modules were simplified and easy to understand as expressed by the following student mentors in their reports.

Student Mentor 2, Experimental Group:

"The modules are simplified and easier to understand. The concepts and the solutions of the problems are explained in a manner where every word is easily understood. The modules are also in summarized form. Therefore, I can discuss the topics to my group mates with confidence during my mentoring because I understood the discussions in the modules.

Student Mentor 3, Experimental Group:

"Comparing with the textbook, we understood the topics particularly the mathematical procedures better. Also, our confusion in understanding the procedures in solving problems is not as high as when we are using textbook.

It can also be noted that the modules helped the mentors impart the lessons to the mentees with ease and confidence because they understood the discussions on the modules. Because the students understood the words clearly, they were also able to understand the mathematical procedures included in the modules.

Although peer mentoring helped the students belonging to the control group, the student mentors and mentees in this group encountered difficulty in understanding the discussions in the textbook. Aside from difficulty in finding the specific topics in the textbook to be discussed during mentoring, the discussions in the textbooks are lengthy and the mathematical procedures are not discussed in detail. The mathematical procedures in the textbooks are difficult to understand especially for students who have less background in mathematics. Here is one of the statements raised by Student Mentor 4 in the control group.

Student Mentor 4, Control Group:

"Overall, the peer mentoring activity has helped us because we had the chance to share what we know about the lessons particularly the problem solving in analytical chemistry. However, I have difficulty as a mentor because I also have difficulty in understanding the discussions in the textbook since these are more complex for me to understand."

The use of facilitated learning modules also helped the mentees do the peer mentoring as reported in their journals. One of these was that the modules served as guide in what they had to focus on. In other words, the modules served as a ready reference that they used as a substitute to the bulky textbook. Moreover, they found the modules more useful because the discussions were in summarized form that most of the techniques in solving problems were there. Below are the statements quoted from the mentees in the experimental group.

Student Mentee 1, Experimental Group:
"We used the modules as guides for our peer mentoring activities. They were appropriate for the activities because they are simplified in form that we can browse as quick reference whenever we wanted to clarify mathematical techniques."
Student Mentee 2, Experimental Group:
"The modules helped me understand topics in analytical chemistry because we have a guide regarding the lesson. The modules presented clear and understandable examples in order for us to cope up with the lessons. Examples and further explanations about the topics were useful to deepen our understanding mathematical tools used in analytical chemistry.

Student Mentee 3, Experimental Group:
"The modules act as our guide in doing the peer mentoring activity. With the help of the modules, it was easier for us to understand, learn, and solve problems regarding our lessons in analytical chemistry.

Moreover, the mentees understood the discussions in the modules because they were simple and easy to understand. The mentees thought that the modules were helpful for the mentors in understanding the discussions, which made their mentoring a lot easier because the mentees easily understood the mentors.

Student Mentee 4, Experimental Group:
"For the peer mentoring activity, mentors cannot really memorize the mathematical procedures and concepts behind particular topics. But with the modules, our mentor was able to make us understand betterbecause the mentor understood the discussions clearly. In some instances, we even had meaningful exchanges of ideas because both the mentors and mentees understood the topics.

Student Mentee 5, Experimental Group:

"The examples in the modules are discussed thoroughly that we were able to understand the examples more easily. The peer mentoring was more effective in study groups with the modules because the mentors and mentees alike were guided in the study.

Further, the mentees considered the examples in the facilitated learning modules as homework that the mentees could do themselves without the presence of the teacher in order to enhance their understanding of analytical chemistry.

Student Mentee 6, Experimental Group:

"The modules included assignments we that we answered after the peer mentoring activity. With the modules, we strived hard to study the modules by having group study with my classmates to help one another."

Peer mentoring also helped the mentees in the control group since they had extra sessions to discuss within the group lessons which were difficult to understand. Through peer mentoring, both the mentor and mentees were able to share what they know about the lessons particularly the mathematical procedures involved in analytical chemistry. However, the peer mentoring in the control group was not done as effectively as that in the experimental group. This may be because student mentors in the control group experienced difficulty in understanding the discussion in the textbook as reported by Student Mentor 4 and they do not have an additional resource material to refer to.

Student Mentor 4, Control Group:

"Overall, the peer mentoring activity has helped us because we had the chance to share what we know about the lessons particularly the problem solving in analytical chemistry. However, I have difficulty as a mentor because I also have difficulty in understanding the discussions in the textbook since these are more complex for me to understand."

The difficulty of students in understanding the complex mathematical procedures in the textbook was also raised by the students in the experimental group. However, this particular problem was addressed in the experimental group because this group used the facilitated learning modules that contained mathematical solutions which are explained in a manner that the students in the experimental group could easily understand. This advantage of the students in the experimental group may have contributed to enhance their performance in the posttest.

The mentees in the control group also encountered similar problems encountered by their mentors. The mentees also had difficulty in understanding complicated mathematical procedures which were not discussed in detail in the textbook as reported by Student Mentee 7 of the control group.

Student Mentee 7, Control Group
"As a mentee, I have encountered problems. First is regarding the lessons that I had encountered is I cannot understand what my mentor is teaching to me because he can't explain the said lesson properly. He also has difficulty in understanding the solutions in the textbook. Second is the schedule. Not all of us were available for a specific scheduled session."

In general, peer mentoring was found useful as a facilitated learning instruction for both the experimental and control groups. Both the experimental and control groups benefited from the peer mentoring activity. Here are statements quoted from the reports of student mentors and mentees on how the peer mentoring affected the learning of the students from both experimental and control groups.

Student Mentor 5, Experimental Group:
"This mentoring really helped us a lot as reflected on the last assignments and quizzes that we have. Our scores have improved from the previous class works or quizzes. Also, the techniques and steps that were being taught during the mentoring were applied on the actual solving of the problems in class. So this means a job well done for all of us."

Student Mentor 6, Control Group:
"The peer mentoring was very beneficial to both the mentor and the mentees. Both parties were motivated to study and understand the lessons. I

would recommend tohave the mentoring for a longer period of time in order to avoid conflicts on the schedule of the whole class and have a longer time to cover all the chapters necessary for the final exam."

It is apparent from the comments above that peer mentoring helped students address the difficulties they faced not only in solving problems in analytical chemistry but also in understanding analytical chemistry ideas. A mentor also learned while mentoring because he/she needed to review what was intended for discussion during a specific session. These findings are consistent with studies conducted regarding peer mentoring. As cited in Chapter 2, Leidenfrost, et al. (2014) found in their study that peer mentoring can produce a number of positive outcomes because this activity can provide growth and learning opportunities for both mentors and mentees, resulting in a "double impact" that is appealing to schools and districts attempting to support students with limited financial and community resources. Moreover, when Rodger and Tremblay (2003) examined the effect of participation of first-year university students in a mentoring program, they found that mentored students had significantly higher final grades than those who did not participate in the mentoring program.

The peer mentoring also helped students gain confidence in dealing with solving problems in analytical chemistry. This manifested in the improvement of students' scores in quizzes after mentoring. In two short quizzes, one on expressions of concentration and the other one on gravimetric methods of analysis, both groups obtained significantly higher scores. The experimental group got mean scores of 6.96 out 10 total points and 8.13 out of 10 total points in expressions of concentration and gravimetric method of analysis, respectively. Meanwhile, the control group got mean scores of 5.34 out of 10 total points and 6.21 out of 10 total points in expressions of concentration and gravimetric methods of analysis, respectively. These mean scores of both the experimental and control groups were relatively higher than the scores of both groups in other quizzes when no facilitated learning activity was conducted prior to the administration of these quizzes. Further, it can be said that better performance of both groups in quizzes after peer mentoring was not because the degree of difficulty of the two quizzes on concentration expressions and gravimetric analysis are different from the quizzes on other topics without the peer mentoring. This can be supported by statements raised by students in both groups regarding the advantages of peer mentoring activity.

Although both groups obtained higher mean scores in these quizzes, it can be noted that the experimental group had higher mean scores in both quizzes. This can be attributed to the use of facilitated learning modules by the experimental group. Students claimed that mentoring motivated them to study since they understood the lessons more clearly as reflected in the feedback below:

> *Student Mentor 7, Experimental Group:*
> *"I can say that peer mentoring has really helped each one of us to fully understand those complicated lessons, for we are able to learn techniques, and how to understand certain problems from each of the members."*

In effect, students understood the lesson on mathematical manipulations because they learned various techniques in dealing with this aspect of mathematical problem solving.

Moreover, the reports revealed that some students lacked understanding of the basic chemistry concepts such as identifying weak acids and weak bases. One of the student mentors raised the comment as follows:

Student Mentor 8, Experimental Group:

"As a whole the mentoring session was more of a review session. All of the members got the gist of most of the chapters but what they lack was the basic fundamentals in approaching and handling the questions. For example in the chapter of titration, their common questions were: "How do you know a buffer solution is formed?", "How do you know if it is a weak base or acid?", "How do you write the chemical equations for buffer solutions?" To rectify this problem, we did clarifications of the chapter as well as solve the example questions in a step-by-step format using the learning modules. When I feel they have grasped the concept, I allowed them to try the questions from the quizzes and exercises from the modules and textbook. In the end they could solve the questions but it took them a bit of time and also a little reminders got them back into track when the get stuck solving the questions. Among all the chapters, their biggest problems were the chapter on acid-base titrations and buffer solutions. The rest of the chapters required their own personal revision and practice. In conclusion as the leader I felt that we met the needs of the group but I am still unsure if the members are able to tackle the exam as the environment in which we practiced clearly differed from an examination environment."

The mentees had difficulty in the following topics: finding out if a certain titration of acid and base produced a buffer, balancing chemical equations involved in acid-base titrations, comparing strengths of acids and bases and calculating the pH of solution resulting from titration. As supplementary learning materials, students used the learning modules in understanding these difficult topics in analytical chemistry.

According to the student mentors, availability of a common time for group members became a drawback. Despite the 1.5-hour allotted for mentoring during break time, some students hesitated to join because of other reasons. This problem explained why groups needed to move the schedule of mentoring. Also, this drawback limited the frequency of mentoring in a week. Thus, these groups conducted one session only per week. This particular concern was raised by one of the student mentors in his statements as follows.

Student Mentor 9, Control Group:

"We had trouble managing our time so we only had 5 sessions. On the first week of our mentoring, we hadn't had our sessions because of our PE Practicum. And during the remaining weeks, some of my mentee couldn't attend in some of the sessions due to some other appointments."

Only students in the experimental group used facilitated learning modules during the conduct of every mentoring. The study did not compare the effectiveness of peer mentoring on performance of students in the two groups because both groups used peer mentoring. Besides, peer mentoring is not a variable considered in the study. Peer mentoring was used as one of the facilitated learning activities because it is deemed more appropriate for the conduct of this study.

On-demand tutorial. The researcher adopted on-demand tutorial as the second facilitated learning activity used in the study. This offered students the opportunity to address difficulties they encountered during peer mentoring and during classroom lecture. This study only had two tutorial sessions each for the control and the experimental groups because of limited time the instructor was available for tutorial session.

Again, only the experimental group used the facilitated learning modules. During the tutorial session, the instructor-tutor discussed examples and problems given as quizzes or assignments. In addition, the tutor also tackled the examples and problems presented in the facilitated learning modules with the experimental group.

The on-demand tutorial helped the students gain confidence in dealing with problem solving in analytical chemistry which they found more difficult than problem solving they encountered in general chemistry. Another obvious effect of tutorial was improvement of scores of both groups in one of the quizzes. In a quiz on acids and bases, the experimental group got an average score of 17.4 out of 30 total points while the control group got 15.6. The statement below is a feedback from student regarding the conduct of tutorial sessions.

Student 9, Experimental Group
"We have improved and enhanced our skills in analyzing and answering problems since we were able to clarify our doubts to the instructor about executing mathematical solutions during the tutorial sessions. Also, the learning modules served as our guide during the tutorial which made the session easier for both the tutor and us because we were able to focus on important topics included in the modules."

Although on-demand tutorial helped both experimental and control groups improve their performance, the researcher did not compare the effect of tutorial on the performance of two groups because on-demand tutorial is not variable in the study.

Online file sharing and group discussion. The research also adopted online file sharing and group discussion as the third facilitated learning strategy used in the study. This approach provided opportunity for students to exchange insights and thoughts with other students or with the instructor. This also allowed them to access some learning materials uploaded online by the instructor in a Facebook page created for each class.

This strategy did not result to more productive interactions among the students. This study noted minimal interactions despite the volume of scanned solutions of quizzes and assignments for online discussions. The students from both groups simply liked the brief instructions with the uploaded file posted by instructor. They just downloaded the file and read on their own. Students seem to lack interest in interacting online when they were asked to read and respond to questions related to the materials for discussion.

However, the social media account served as medium for students to interact with the instructor. They simply sent the instructor messages to ask questions about topics in textbook or in learning modules. Some sent messages to inquire about concerns such as schedules of activities in the class.

Only the experimental group used learning modules for this activity. The study did not compare the effects of this strategy on performance of students in both the experimental and control groups because this strategy is not one of the variables under investigation in this study.

One essential feature of the facilitated learning modules is the inclusion of many examples in which the mathematical and statistical tools used in introductory analytical chemistry are presented in a step-by-step process that students could easily understand. These examples are presented in such a way that the initial problems are simple ones and additional examples are given which gradually become more complex. The examples are presented logically to ensure that students understand simple problems before they deal with complicated ones.

Another feature of the modules is the manner with which the discussions are presented. These discussions are written in a conversational manner, as if the students are listening to the teacher in the classroom.

In addition, the guidelines on how to use the facilitated learning activity in each module are explained thoroughly to ensure that students in the experimental group are properly guided when they implement the facilitated learning activity.

Development of the Facilitated Learning Modules

The facilitated learning modules used in this study anchored on the constructivist approach since educational theorists believe that facilitated learning instruction adheres to constructivism. Presentation of content started with reiteration of preexisting ideas which the students were already familiar with or at least had prior knowledge about. In other words, facilitated teaching-learning triggered the thinking of students into a stage where they processed or applied their prior knowledge, ideas, and understanding.

The modules were written in such a way that students would do more than simply reading the discussion of mathematical procedures. Students did more than just reading because they processed and applied information drawn from the learning modules. Facilitated learning activities such as peer mentoring, on-demand tutorial, and online file sharing and group discussion were also incorporated in the learning modules for the students to further deal with and apply information. The guidelines and mechanics of these activities are discussed in Chapter 3.

Face content and form of the facilitated learning modules. Two chemistry education experts evaluated the learning modules' face content and form before evaluation of the objectives and contents. The following are verbatim comments and suggestions raised by the first expert

1. *"If you are working with a facilitated module, the students upon reading it feels that he/she is listening to presentation of the teacher. I only have observed this at the end of the chapter. If this is your approach, then your nodule is most likely similar to other reading materials."*

2. *"Do you intend to use other text aside from this module for your class? Would it be better if you cite also the main text if there is? It seems you only have listed references I do not find any citation in your module."*

3. *"Have you included solution to the problems you have assigned to your students?"*

The modules were revised to incorporate comments and suggestions of the first expert. Comment number 1 was consistent with the nature of facilitated learning instruction as carried out. Therefore, the presentation of lessons was changed in such a way that students felt like they were listening to lectures of the teacher while reading the modules. This manner of presentation was sustained from the introductory part until the end of each module.

Another point considered by the researcher was citation of references from which the researcher adopted a certain chemistry idea and mathematical procedure. The researcher cited reference textbooks as part of the introduction of each module. Each module only included final answers to the assignments provided as part of the answer key. The researcher did not include complete solutions of problems purposely to allow students to apply their problem-solving skills without being too much dependent on the modules. Further, the writer believed examples given in each module were enough for the students to understand mathematical procedures.

The second expert gave the following verbatim comments and suggestions.

1. *"The modules are well-designed, language used is simple and easily understood. The layout is attractive and instructions are easy to follow."*
2. *"The learning modules are free from conceptual errors."*
3. *"Suggestion: Acknowledge the sources of the pictures, graphs, and tables that are not your own should be acknowledged by citing them below."*
4. *"Add references at the end of each module, if applicable."*
5. *"Check minor corrections in the text."*

The second expert perceived that the researcher wrote the modules in a manner that could easily be understood by students. This suggests that students could perform the activities with ease since the students could understand the instructions clearly. She also noted that the layout of the modules was appealing. Modules that are engaging to the readers maintain interest in reading (Lumaque, 2011). She also found the modules free from conceptual errors suggesting that chemistry ideas and mathematical procedures were accurate. This means that learning modules presented chemistry concepts and mathematical procedures consistent with other reference materials in analytical chemistry and mathematics.

The learning modules also contained properly labeled pictures, figures or tables and recognized sources of materials adapted from other textbooks. The learning modules also had a References section found in the last part of each module. This listed the resources used in developing the learning modules. Finally, the entire script of the learning modules was revised to remove minor writing errors.

Objectives and contents of the facilitated learning modules. Analytical chemistry instructors from three different universities near the research locale, who had taught analytical chemistry evaluated the objectives and content of the seven facilitated learning modules based on a specific set of criteria. Attainability, clarity, and relevance served as basis for evaluating the objectives of the learning modules. Appropriateness, innovativeness, appeal, and conformity to standards were the basis for evaluating the content of the learning modules.

The instructors rated the modules using a scale of 1 to 4 to show the extent of their agreement or disagreement to statements related to each of the criteria given for objectives and for content. Mean scores of the ratings given by the instructors on each statement were calculated. These mean scores then served as the basis for computing grand mean scores of the sub-areas under objectives and content. The mean score of the main area was based on the mean score of each sub-area.

Table 3 serves as the guide in interpreting the mean scores obtained from the evaluation of the instructors on the learning modules. The table contains rating scales that indicates interval values wherein the mean score falls. Each rating scale has matching interpretation to show the extent of agreement or disagreement of instructors. The researcher used this table to interpret the results of evaluation made by the instructors.

Table 3

Interpreting Teachers' Evaluation on the Objectives of the Seven Facilitated Learning Modules

Response	Rating Scale	Objectives of the Learning Modules		
		Attainability	Relevance	Clarity
Strongly Agree	3.28 – 4.00	Highly Attainable	Very Relevant	Very Clear
Agree	2.52 – 3.27	Attainable	Relevant	Clear
Disagree	1.76 – 2.51	Unattainable	Irrelevant	Unclear
Strongly Disagree	1.00 – 1.75	Definitely Unattainable	Definitely Irrelevant	Definitely Unclear

Since the researcher used the same rubric as in Lumaque's study (2011), the minimum value set as passing mark is a rating equal to at least 2.52 in all areas and sub-areas in order to make the evaluation acceptable. This minimum value suggests agreement of instructors on the area or sub-area considered, as reflected in Table 3.

Objectives of the facilitated learning modules. The following sub-sections present the discussion of the results of the evaluation of the three instructors. Interpretations of the results are based on Table 3

Attainability of the Objectives

The instructors evaluated attainability of the modules' objectives based on the specified indicators in Table 3. A sample of the instructor's ratings is shown in Appendix L. Table 3 is used to interpret the results of evaluation of the instructors. Table 4 presents the mean scores in each indicator and the corresponding interpretation in terms of attainability of the objectives.

Table 4

Teachers' Ratings on the Attainability of the Learning Objectives of the Seven Learning Modules

Indicators	Mean	Interpretation
The objectives are formulated within the learning capabilities of the intended end-users.	3.90	Highly attainable
The topics in each module can be covered within the allotted time indicated in the module.	3.40	Highly attainable
The objectives of the learning modules are formulated based on the general objectives of the course syllabus.	3.90	Highly attainable
The time element for realizing the objectives of the learning modules is based on the course syllabus time frame.	3.50	Highly attainable
The objectives are stated in a measurable, realistic, and time bounded manner.	3.70	Highly attainable
Average	3.68	Highly attainable

On the average, the modules got a score of 3.68 in terms of attainability of objectives. This indicates that the objectives of the learning modules were highly attainable based on Table 3. The evaluators strongly agreed that objectives as written, were within the learning capacities of the intended users. This means that students could perform the objectives of the learning modules as perceived by the teacher evaluators. One of the objectives included in Module 2 was formulated as follows:

> *After the end of the module, students would be able to locate the confidence interval of a set of data using different methods based on whether or not the standard deviation s is a good measure of population standard deviation σ.*

As shown in Table 4, the teachers strongly agreed that the stated objectives in a measurable, realistic, and time-bound as written.

Clarity of the Objectives

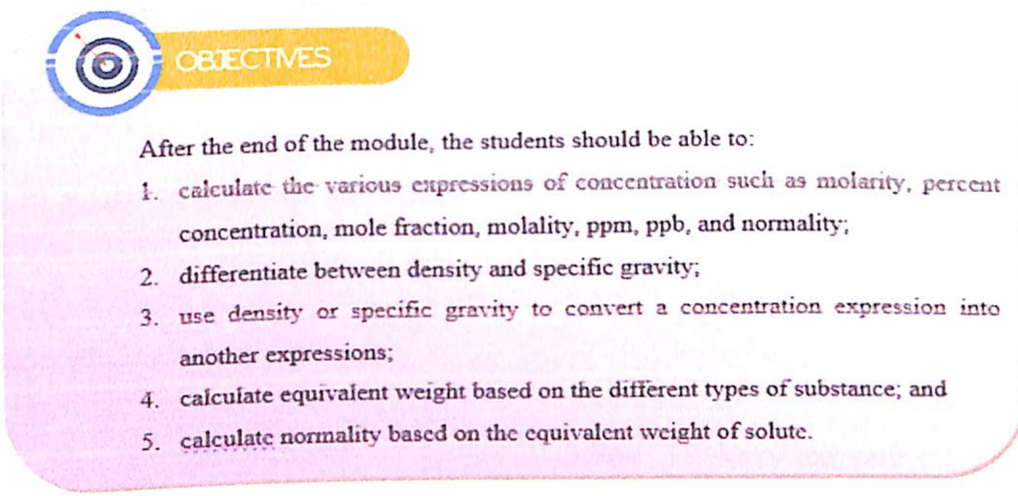
Table 5 shows the results of evaluation regarding the clarity of the learning modules' objectives. Results showed that the modules got an average rating of 3.80 in terms of clarity of objectives. This suggests that in general, the

Table 5

Teachers' Ratings on the Clarity of the Learning Objectives of the Seven Learning Modules

Indicators	Mean	Interpretation
The objectives of the facilitated learning modules clearly state what the students must achieve.	4.00	Very clear
The objectives are formulated using simple words which can easily be understood by the intended users	3.80	Very clear
The objectives are stated in terms of student learning outcomes.	3.60	Very clear
Upon reading the objectives, the students will have an idea about the coverage of the learning module.	3.80	Very clear
The objectives of the learning modules serve as instructions which are clear, unambiguous, and easy to follow.	3.80	Very clear
Average	3.80	Very clear

objectives of the learning modules were clearly stated. Specifically, the teacher evaluators strongly agreed that the objectives stated what the students must achieve. In addition, they perceived that students could easily perform activities since the language used is easily understood. Figure 4 indicates such characteristics of the modules' objectives.



OBJECTIVES

After the end of the module, the students should be able to:

1. calculate the various expressions of concentration such as molarity, percent concentration, mole fraction, molality, ppm, ppb, and normality;
2. differentiate between density and specific gravity;
3. use density or specific gravity to convert a concentration expression into another expressions;
4. calculate equivalent weight based on the different types of substance; and
5. calculate normality based on the equivalent weight of solute.

Figure 4. Objectives of Module 3 showing clarity of objectives.

Relevance of the Objectives

Table 6 shows the results of the evaluation of the two instructors on the relevance of the modules' objectives. Based on the results, it was found that the modules got a mean score of 3.76 in terms of the relevance of its objectives. Based on Table 3, this indicates that the objectives of the modules are very relevant.

The UPOU (1999) as cited by Lumaque (2011) pointed out that relevant objectives become the instructional guide of teachers in identifying classroom activities. Also, the objectives help teachers identify portions of the lessons that

Table 6

Teachers' Ratings on the Relevance of the Learning Objectives of the Seven Learning Modules

Indicators	Mean	Interpretation
The objectives serve as guide for the formation of instructional activities.	3.90	Very relevant
The objectives serve as an information disseminator about the expectations of the teachers on student performance.	3.60	Very relevant
The objectives will guide the teachers on what they ought to cover in the class.	3.80	Very relevant
The objectives will guide the students on what they ought to learn in this course.	3.80	Very relevant
The objectives serve as target statements that will guide the end-users about the standards and expectations of the course.	3.70	Very relevant
Average	3.76	Very relevant

need more emphasis. Further, the objectives provide directions to the teachers, thus facilitating the modules guided students on what they ought to learn in the subject. Figure 5 demonstrates these characteristics of the module's objectives.

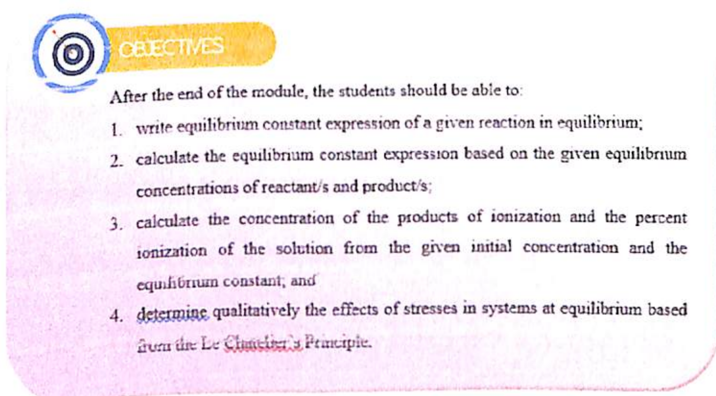


Figure 5. Objectives of Module 4 showing relevance of objectives.

The students are also aware of the competencies the teacher expects from them. Therefore, objectives directed both learner and teacher toward meeting the standards and expectations of the subject.

Table 7 shows the summary of evaluation regarding the seven learning modules' objectives. In summary, the ratings indicate that instructors found the objectives of the modules highly attainable, very clear, and very relevant. They perceived that the objectives were written in a specific manner and identified clearly what students need to achieve.

Table 7

Teachers' Evaluation Rating on the Objectives of the Seven Facilitated Learning Modules

Area	Mean Rating	Qualitative Description
Attainability	3.68	Highly attainable
Clarity	3.80	Very clear
Relevance	3.76	Very relevant

Content of the facilitated learning modules. In terms of content, the instructors evaluated the content of the facilitated learning modules in four specific areas, namely: appropriateness, appeal, innovativeness, and conformity to standards.

Appropriateness of the Contents of the Facilitated Learning Modules

Table 8 presents the results of evaluation in terms of appropriateness of the learning modules. On average, the modules got a score of 3.78 for appropriateness of its contents. This indicates that the content of the seven learning modules are very appropriate. The instructors strongly agreed that the learning modules contained activities which are appropriate to the age of the intended users. They found that content conforms to accepted principles in analytical chemistry. The instructors signified that the activities in the modules were appropriately designed to help students improve their mathematical and statistical skills used in analytical chemistry. Further, they found that the content of learning modules satisfied the indicated objectives because students could perform the recommended activities. Instructors also perceived that the modules were developed within the reading ability of the users.

Table 8

Teachers' Ratings on the Appropriateness of the of the Seven Facilitated Learning Modules' Content

Indicators	Mean	Interpretation
The concepts presented in these learning modules conform to the accepted principles in chemistry education.	3.60	Very appropriate
The activities in the learning modules are appropriate in helping students understand the concepts and principles.	3.70	Very appropriate
The contents are appropriate to meet the objectives of the facilitated learning modules.	3.80	Very appropriate
The learning activities are designed to guide the students in realizing the objectives of the facilitated learning modules.	4.00	Very appropriate
The contents of the learning modules are suitable to the understanding level of the students.	3.80	Very appropriate
Average	3.78	Very appropriate

The instructors' evaluation suggested that the researcher had incorporated the suggestions of Ellis, et al. (1995), who stressed that a writer must consider properly the learners' interest in selecting content of the modules. In addition, activities included in the learning modules reflected two of the criteria suggested by Ornstein and Hunkins (2004). These authors suggested that the writer must consider learnability and utility of learning materials regardless of philosophical orientation of the curriculum writer. The latter implies that students should be able to learn the topics covered in the modules. This further suggests that students could use what they learned from the modules as frequently as necessary.

Appeal of the Contents of the Learning Modules

Table 9 shows the results of the evaluation about the appeal of the modules' content. With a mean score of 3.53, the instructors strongly agreed that the modules' content is appealing in general. They observed that the learning modules (Appendix O) contain important features such as tables, graphs and figures, which are necessary for understanding the subject matter easily. They also recognized that the learning modules (Appendix O) were packaged attractively because the latter included graphics that enhanced the presentation of content and sustain the interest of the readers.

Aside from attractive layout and design, the modules also contained engaging activities where students do the detailed mathematical procedures in solving problems. The modules also contain exercises for the students to work on after they understood the mathematical procedures.

Table 9

Teachers' Ratings on the Appeal of the of the Seven Learning Modules' Content

Indicators	Mean	Interpretation
The learning modules are expected to capture the interest of the reader	3.50	Very appealing
The approaches adopted by the writer in presenting the concepts and examples sustain the reader's interest.	3.40	Very appealing
Graphics included in the learning modules are balanced and help in sustaining the interest of the reader.	3.40	Very appealing
In general, the facilitated learning modules are attractively packaged.	3.50	Very appealing
The learning modules have been presented in a technically appropriate manner.	3.80	Very appealing
The layout of the learning modules combines attractiveness with utility.	3.60	Very appealing
Average	3.53	Very appealing

According to Talisayon (1998), a learning material is appealing to users if they could read the material continuously until they get to the end. This happens if the learning material contains sentences and approaches that catch and sustain the interest of the readers. The beginning paragraphs in Module 1 (Statistical Testing for Treatment of Data I) on page 1 highlighted the application of statistics in treating experimental data. This motivated users to keep reading the succeeding paragraphs. This claim can be supported by the comment raised by one of the instructors:

> *"The module writer emphasized the usefulness of statistics in the beginning paragraphs of Module 1. I think citing the application of the topics in the daily activities of the students is important to motivate them to keep reading the modules."*

Innovativeness of the Facilitated Learning Modules

Table 10 shows the results of evaluation for innovativeness of the seven learning modules. On average, the modules got a score of 3.53 for innovativeness. This indicates that the raters considered the learning modules as very innovative in general. They believed that the writer has developed a unique way of presenting mathematical and statistical tools in introductory analytical chemistry. The use of a simplified technique in presenting the mathematical tools used in analytical chemistry and the writing style that sustains the students in reading, just as if they were listening to an instructor, made the modules unique. Thus, the evaluators affirmed that students could easily understand and follow the manner of presentation.

Table 10

Teachers' Ratings on the Innovativeness of the Seven Learning Modules' Content

Indicators	Mean	Interpretation
The writer has developed a unique way of presenting the concepts and principles.	3.60	Very innovative
The solutions to learning exercises are presented in a distinct manner that students can easily understand.	3.80	Very innovative
The learning modules are carefully designed thus, showing novelty.	3.40	Very innovative
The facilitated learning modules exhibit originality.	3.30	Very innovative
Average	3.53	Very innovative

Figure 6 demonstrates this characteristic of the modules.

	$HClO_4(aq)$ ⇌	$H^+(aq)$ +	$ClO_4^-(aq)$
Initial (M)	0.100	0	0
Change (M)	- x	- x	- x
Equilibrium (M)	0.100 – x	x	x

We can now substitute these equilibrium concentrations to the K_a equation.

$$K_a = \frac{[H^+][ClO_4^-]}{[HC_2H_3O_2]}$$

$$1.10 \times 10^{-2} = \frac{(x)(x)}{(0.100 - x)} = \frac{x^2}{(0.100 - x)}$$

Rearranging the equation to solve for x,

$$1.10 \times 10^{-2}(0.100 - x) = x^2$$

$$0.001 - 0.01\,x = x^2$$

$$x^2 + 0.01\,x - 0.001 = 0$$

This is a quadratic equation. To solve for x, we can have two options. First is to use the quadratic and the second is to use a scientific calculator capable of solving equations on the second degree.

(a) Using the quadratic formula

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

where: a = 1 b = 0.01 c = - 0.001

$$x = \frac{-0.01 \pm \sqrt{(0.01)^2 - 4(1)(-0.001)}}{2(1)}$$

$$= \frac{-0.01 \pm \sqrt{(0.01)^2 - 4(1)(-0.001)}}{2(1)}$$

$$= \frac{-0.01 \pm \sqrt{(0.0001) + (0.004)}}{2}$$

$$= \frac{-0.01 \pm \sqrt{(0.0041)}}{2}$$

$$= \frac{-0.01 \pm 0.06403}{2}$$

At this point, you have two possible roots or values of x because of the ± sign. The first root can be obtained by using the (+) sign while the second root can be obtained by using the (−) sign.

$$x_1 = \frac{-0.01 + 0.06403}{2} \quad \text{and} \quad x_2 = \frac{-0.01 - 0.06403}{2}$$

$$x_1 = 0.0270 \quad \text{and} \quad x_2 = -0.0370$$

The negative value of x which x_2 = - 0.0370 has to be rejected because concentration of a species cannot be negative. Therefore, only the x with a positive value, x = 0.0270 is accepted as the amount of $HClO_4$ reacted. Thus,

$[H^+]$ = 0.0270 M and $[ClO_4^-]$ = 0.0270 M

So the equilibrium concentration of $HClO_4$ is

$[HClO_4]$ = 0.100 M - 0.0270 M = 0.073 M.

(b) Using a scientific calculator, the value of x in a quadratic equation can also be obtained. The following procedures can be followed for this technique. However, he sequence may vary depending on the brand of the calculator for they differ in the language. Before following this procedure, it is suggested to read and understand the calculator manual particularly in solving the value of x in quadratic equation. Note that the calculator that is demonstrated here is CASIO fx-991ES.

Step 1. With the calculator ON, Press the key SET UP to display the functions you want your calculator to perform. For this particular determination, select 5 to set it up to EQN mode.

Step 2. Look for the equation in the second degree because there are four (4) options displayed. To choose quadratic equation, select 3. You will see the letters a, b, and c are being displayed

Step 3. With *a* highlighted, enter 1 then press the "equals" key (=). At this point, *b* ishighlighted. You now enter the value 0.01 or .01 and then press the "equals" key (=) again to finish entering the *b* value and to highlight *c*. Enter now0.001 as the value of *c* by pressing first the key (-) followed by entering 0.001 or .001, then press the "equals" key (=). At this point, all the values of a, b, and c are being entered. The calculator is now ready to give the values or roots of x.

Step 4. To obtain the values of x, press the "equals" key (=) and wait for the X_1 to be displayed. After a short while, the calculator now displays X_1 = 0.027015…which can be rounded off based on the number of significant figures required as how the answer should be reported. In this case, X_1 = 0.0270 having three (3) significant figures. To obtain the value of X_2, press again the "equals" key to display the value of X_2. In this case, the calculator displays X_2 = - 0.0370156… When you press again the "equals" key (=) again, the calculator will go back to a, b, and c display to determine values of x for another quadratic equation. You do not have to proceed any further because you already have the values or roots for your quadratic equation.

Step 5. Decide which of the two roots of x should be accepted and which should be rejected. Again, concentration cannot be negative, hence only the X_1 should be accepted and that X_2 should be rejected. Therefore the equilibrium concentrations are as follows:

$[H^+]$ = 0.0270 M

$[ClO_4^-]$ = 0.0270 M

$[HClO_4]$ = 0.100 M - 0.0270 M = 0.073 M.

Step 6. Press MODE and select COMP by pressing 1 to return to normal computation mode.

Figure 6. A screen capture of a step-by-step mathematical procedure in solving a chemical equilibrium problem.

This uniqueness of presentation was obvious when the step-by-step procedure to obtain the numerical value of variables in higher-order equations using a calculator was thoroughly explained in Module 4 (Chemical Equilibrium). The most appropriate solutions to the problems in the examples given were carefully selected to help students improve their mathematical skills in problem solving in analytical chemistry.

The rating suggested that the principles set forth by UPOU (1999) guided the module writer. According to UPOU, a writer must create ways of presenting ideas and skills with a sense of originality in developing curriculum materials. Further, according to UPOU (1999) guidelines, a module writer does not have to come up with new theories, principles, or laws since the latter is the work of a scientist.

Conformity to Standards

This uniqueness of presentation was obvious when the step-by-step procedure to obtain the numerical value of variables in higher-order equations using a calculator was thoroughly explained in Module 4 (Chemical Equilibrium). The most appropriate solutions to the problems in the examples given were carefully selected to help students improve their mathematical skills in problem solving in analytical chemistry.

The rating suggested that the principles set forth by UPOU (1999) guided the module writer. According to UPOU, a writer must create ways of presenting ideas and skills with a sense of originality in developing curriculum materials. Further, according to UPOU (1999) guidelines, a module writer does not have to come up with new theories, principles, or laws since the latter is the work of a scientist.

The instructors noted that learning modules cover the minimum learning competencies prescribed by CHED. Each module contains important concepts and appropriate procedures in carrying out mathematical manipulations to deepen understanding of analytical chemistry.

Table 11

Teachers' Ratings on the Conformity to Standards of the Seven Learning Modules' Content

Indicators	Mean	Interpretation
The Minimum Learning Competencies for analytical chemistry as prescribed by the Commission on Higher Education are included in the facilitated learning modules.	3.80	Strongly conforming
The contents of the facilitated learning modules cover the important concepts and principles for chemistry instruction.	3.80	Strongly conforming
The tables and figures in these learning modules are appropriately presented for chemistry instruction.	3.40	Strongly conforming
The solutions to learning exercises in the facilitated learning modules are presented following the steps acceptable for chemistry instruction.	3.80	Strongly conforming
Average	3.70	Strongly conforming

Table 11 shows the evaluation results of the modules in terms of conformity to standard. Instructors gave a mean score of 3.40 for presentation of instructions. This suggests that presentation of topics is suitable for chemistry instruction for tertiary level. This implies that the chemical principles and problem-solving techniques are presented in a way that they are in agreement with the standards of chemistry education. In addition, the instructors gave an average score of 3.80 on presentation of learning exercises. This suggests that the module followed the necessary steps in presenting learning exercises acceptable for chemistry education. The latter indicates that the module writer presented methods or techniques used by textbook writers that are suitable and adequate for intended users to follow and understand.

Table 12 shows the summary of the evaluation results regarding the content of the learning modules. The high ratings suggest that content of the seven learning modules are suitable for analytical chemistry and for students. The instructor-raters believed that topics included in the modules were appropriate, especially the application of mathematical and statistical tools in analytical chemistry. The examples were presented in a manner easily understood by

Table 12

Summary of Teachers' Evaluation Rating on the Content of the Seven Facilitated Learning Modules

Area	Mean Rating	Qualitative Description
Appropriateness	3.78	Very appropriate
Appeal	3.53	Very appealing
Innovativeness	3.53	Very innovative
Conformity to standards	3.70	Strongly conforming

intended users. The instructor-raters confirmed that learning competencies set by CHED for analytical chemistry were applied in the learning modules. A verbatim feedback raised by one of the instructors, as follows, validated this finding.

> *"The topics included are appropriate for the age of the intended users. The discussions are clearly presented that can easily be understood by the students. Also, the minimum learning competencies set by the CHED were met."*

They are appealing enough to sustain the interest of the readers. This means that the modules were developed such that students' interest in the choice of the modules' content is given due importance. This is consistent with what Ellis et al. (1995) pointed out that in choosing the subject matter, writers must consider the interest of students since this is important in order to keep them read the modules. The step-by-step procedures in carrying out mathematical manipulations as shown in Figure 6 kept readers' interest. Also, motivations in the beginning paragraphs of the modules as mentioned by one of the instructor-raters in the quoted statement shown before kept the interest of the readers. Figure 7 shows this characteristic of the modules. The learning modules were also highly rated in terms of innovativeness and conformity to standards. The presentation of the essential parts of the learning modules agrees with acceptable norms and standards in chemistry education such as formulation of the learning objectives and time frame of each module.

Introduction

Let me begin my lecture by recalling some essential information you already knew about this topic. Let me ask you few questions before I start my discussions.

Why is experiment necessary to subjects like chemistry? What activities were carried out when you performed your experiment? What did you obtain when you performed your experiment? How did you manipulate the results of your experiment? What did you do then with these manipulated results?

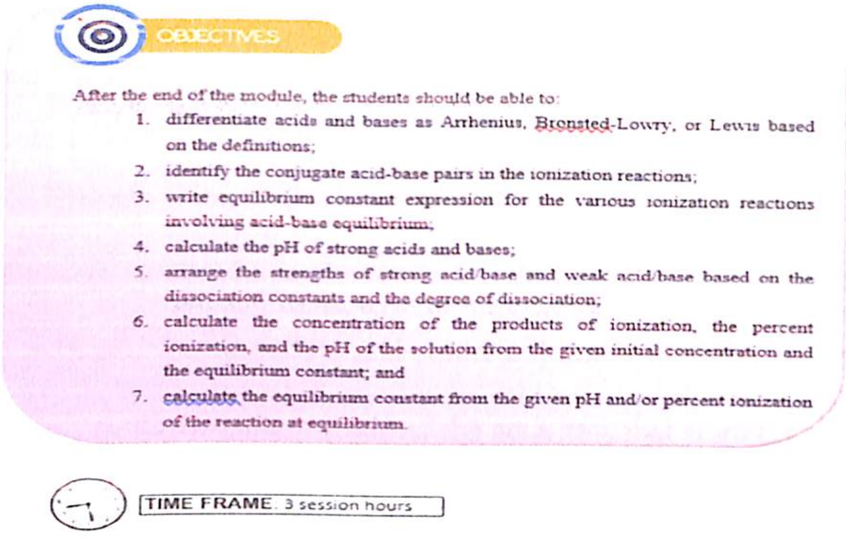
You are all made aware that being an experimental science, chemistry involves laboratory activities designed to explain scientific theories. In your general chemistry laboratory, you did not only measure the value of the scientific property but you also gathered data as part of the experimentation. Perhaps the bigger challenge that you encountered was how you were going to manipulate or treat the data systematically in order to find the value of the property that was being measured.

Interestingly, statistics will teach you how to manipulate or treat experimental data systematically. As a scientific study, statistics is not only used in treating experimental data as it is also utilized extensively in almost all fields of disciplines. One common situation that every one of you might have already encountered is finding the simple mean or the average of the values. This is a situation that we usually experience not only in the laboratory particularly in treatment of data but also in every day activity.

Figure 7. Screen capture of the Module 1 introductory part.

Figure 8 shows a screen-capture of the objectives of one of the modules to demonstrate these characteristics. Further, the instructor-raters were certain that modules were innovative in the sense that new approaches were used in presenting solutions to problems. One of the instructor-raters said the statement as follows:

> *"The writer had presented the solutions in a very detailed fashion. This is somewhat different from how conventional authors of analytical chemistry present mathematical procedures, which do not have so much details of the solutions."*



OBJECTIVES

After the end of the module, the students should be able to:

1. differentiate acids and bases as Arrhenius, Bronsted-Lowry, or Lewis based on the definitions;
2. identify the conjugate acid-base pairs in the ionization reactions;
3. write equilibrium constant expression for the various ionization reactions involving acid-base equilibrium;
4. calculate the pH of strong acids and bases;
5. arrange the strengths of strong acid/base and weak acid/base based on the dissociation constants and the degree of dissociation;
6. calculate the concentration of the products of ionization, the percent ionization, and the pH of the solution from the given initial concentration and the equilibrium constant; and
7. calculate the equilibrium constant from the given pH and/or percent ionization of the reaction at equilibrium.

TIME FRAME: 3 session hours

Figure 8. Screen-capture of the objectives and time frame showing conformity to standards.

These approaches could help students deepen understanding of suitable mathematical manipulations in working on analytical chemistry problems and applying chemical principles in general. The latter was shown when a step-by-step procedure was used in the mathematical and statistical manipulations related to analytical chemistry problems, as shown in Figure 6.

Student's involvement index of the facilitated learning modules. Following the procedures recommended by Romey (1965), the calculated value of the student involvement index was 1.34. This value was calculated using the following formula:

$$\text{Student Involvement Index} = \frac{\text{Total Number of Sentences in Category B}}{\text{Total Number of Sentences in Category A}}$$

Category A includes sentences citing facts, stated conclusion, definitions and questions answered immediately. Category B includes questions requiring students to analyze data, statements requiring student to formulate conclusion, and directions to students to perform and analyze some activity and solve problems. Appendix C presents the table showing how the counting of sentences was carried out in each category.

According to Romey, if the student's involvement index is greater than 1.00, the reader shows involvement in what he or she reads. In addition, apart from reading, the students could also perform other activities and could still understand the mathematical manipulations presented in the modules. Some of the activities that students can perform while reading the modules included solving problems in analytical chemistry such as statistical treatment of data and solution concentrations, calculator drills, plotting calibration curves, and reading other analytical chemistry books. Figure 9 presents an example in Module 2 wherein students performed calculator drills to check how the values in the table were obtained.

Example 2.8

5.00-mL aliquots of a solution containing phenol barbital were carefully measured into five separate 50.00-mL volumetric flasks and made basic with KOH. The following volumes of a standard solution of phenobarbital (2.000 μg/mL) were added into each flask: 0.000, 0.500, 1.00, 1.50 and 2.00-mL. The fluorescence of each of these solutions was measured with fluorometer, which gave values of 3.26, 4.80, 6.41, 8.02, and 9.56, respectively. Determine the equation of the best fit curve. From the best fit curve, determine the x-intercept.

Solution

This is a typical external standard addition problem. The relationship of the fluorescence signal and the volume of the standard solution is expressed in the form of an equation of the straight line as follows:

Volume of the standard (x_i), mL	Signal (y_i)	x_i^2	y_i^2	x_iy_i
0.000	3.26	0.000	10.6276	0.00
0.500	4.80	0.250	23.04	2.40
1.00	6.41	1.00	41.0881	6.41
1.50	8.02	2.25	64.3204	12.03
2.00	9.56	4.00	91.3936	19.12
x_{ave} = 1.00	**y_{ave} = 6.41**			
$\sum x_i = 5.00$	**$\sum y_i = 32.05$**	**$\sum xi^2 = 7.50$**	**$\sum yi^2 = 230.6497$**	**$\sum x_iy_i = 39.96$**

$y = m\,x - b$; where y = signal, x = volume of the standard solution, m = slope, b = y-intercept

A least-square analysis can be used to determine the values of m and b. Using the derived equations of m and b are given as follows

$$m = \frac{S_{xy}}{S_{xx}} \quad \text{and} \quad b = y_{ave} - m x_{ave}$$

where

$$S_{xy} = \sum x_i y_i - \frac{\sum x_i \sum y_i}{N} \quad \text{and} \quad S_{xx} = \sum x_i^2 - \frac{(\sum x_i)^2}{N}$$

The variables in the equations are evaluated using the table below.

Substituting these values into the equations above, we get

$$S_{xy} = 39.96 - \frac{(5.00)(32.05)}{5} = \mathbf{7.91} \quad \text{and} \quad S_{xx} = 7.50 - \frac{(5.00)^2}{5} = \mathbf{2.50}$$

Also,

$$m = \frac{7.91}{2.50} = \mathbf{3.164} \quad \text{and} \quad b = 6.41 - 3.164(1.00) = \mathbf{3.246}$$

Therefore the equation of the signal- volume of standard should be

$y = 3.164\,x + 3.246$

Figure 9. Screen capture of Example 2.8 involving multiple activities while reading the module.

The latter were observed when students performed activities or answered assignments while reading the pages of the modules. Getting involved in all the activities in the modules helps students gain deeper understanding of ideas and mathematical skills in analytical chemistry. The statement raised by a student supports this finding.

> *"I learn a lot of mathematical techniques. I was able to perform calculator drills while reading the solution of the examples."*

Grade level of the facilitated learning modules. The researcher determined the grade level of the modules using the graph readability formula of Fry (1968). This readability graph is utilized for estimating reading age or grade level of a learning material. The grade level is determined by locating the point on the readability graph. The point is defined by the average number of syllables per 100 words (abscissa) and the average number of sentences per 100 words (ordinate), in the first, middle and last pages of the learning modules. Specific regions in the graph correspond to grade levels. The point whose coordinates are defined falls on a specific region which represents a grade level. Further details of the procedures are presented in Appendix D.

The second-year students taking up medical technology evaluated the grade level of the facilitated learning modules. The calculated average value of the number of syllables per 100 words and the number of sentences per 100 words revealed a point that fell on the region of Grade 11. This computed grade level matched that of the intended users who are first-year medical technology students. According to Talisayon (1998), if the grade level of a learning material matches the grade level of intended users, the writer has developed and presented the material in a manner easily understood by the intended users.

Communication index of the facilitated learning modules. The communication index measures the learning material's clarity and/ or difficulty from the point of view of students. UPOU (1999) stressed that an instructional material becomes less difficult to understand if presented clearly. The researcher used the data obtained from the evaluation of second-year medical technology students using Talisayon's (1983) Communication Index presented in Appendix E.

Ten students were requested to read the learning modules and list words that they found unclear as they went through the modules. Using the 100-word sample considered in the graph readability formula in determining student's involvement index, these students listed unclear words they found in the sample. The number of students who found a word in the sample unclear was counted. The frequency of occurrence of all unclear words found by each student was also counted. The total number of unclear words and the total number of words used in the samples were determined. The Talisayon's (1983) communication index, CI, for words of the module was calculated using the following formula:

$$CI = \frac{\text{Sum of (fX)}}{(Nr)(Nx)}$$

where: X = number of readers indicating a given unclear word

f = number of times unclear word appears in the of words

samples

Nr = total number of unclear words

Nx = total number of words in the samples

Using the data obtained from the students' evaluation and Talisayon's guide, the communication index (CI) of the facilitated earning modules was computed at 0.009.

This value falls within the range of acceptable values for communication index which is $0 \leq CI \leq 0.01$. This indicates that students found the words in the learning modules simple and easy to understand. Thus, students can easily follow the mathematical procedures presented in the modules. This is consistent with the comment of a chemistry education expert, presented earlier in this chapter, who said that the learning modules in the study used simple and understandable language.

Influence of the Facilitated Learning Modules on Student Performance

In order to determine if the facilitated learning modules influence the performance of the students in introductory analytical chemistry, it is important to establish that the knowledge and skills of the students from both the experimental and the groups were comparable. Thus, their pretest scores prior to the intervention were compared using the independent samples t-test. Moreover, performances of students in terms of the application of mathematical and statistical tools were also compared.

Performance of students in the posttest. Before the intervention, the researcher compared the pretest scores of the experimental group with that of the control groups to establish that the two groups are comparable in terms of their mathematical and statistical knowledge and skills. A total of 95 students took the pretest on basic mathematics and statistics simultaneously. Forty-nine (49) of them belonged to control group while 46 belonged to the experimental group. Table 13 summarizes the results of the descriptive statistics of the scores of the two groups in the pretest.

Table 13

Descriptive Statistics of the Pretest Scores of the Two Groups

	Respondents	N	Mean	Std. Deviation	Std. Error Mean
Pretest	Control Group	49	21.57	5.16	.74
	Experimental Group	46	20.30	4.61	.68

As reflected in Table 13, the mean score of the experimental group is 20.30 (SD = 4.61) while the control group has 21.57 (SD = 5.16). Out of 45 maximum points, 31 was the highest score in the experimental group while the control group had the highest score of 38. Results of the independent samples t-test comparing the performance of the control and the experimental groups in the pretest are shown in Table 14. Based on the results, the mean scores of the two groups prior to the intervention were not significantly different with t (93) = 1.26 and p = .21. This means that prior to the intervention, the experimental and the control groups were comparable in terms of their mathematical and statistical knowledge and skills.

Table 14

Independent Samples T-Test for Pretest Scores Comparison

	T	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Pretest	1.26	93	.21	1.27	1.01

After the intervention, where students in the experimental group used the facilitated learning modules and the control group did not, the students from both groups took the posttest. Note that the same instructional strategies and materials were used in both groups. The study was conducted for 10 weeks. The posttest was administered to both experimental and control groups to find out whether the use of the learning modules improved the performance of the experimental group in introductory analytical chemistry. The total score of the posttest was 130 points.

The analysis of covariance (ANCOVA) was used to find out if the experimental group performed better than the control group. The pretest scores of the two groups served as the covariate. Table 15 shows the descriptive statistics comparing the posttest mean scores of the two groups.

Table 15

Descriptive Statistics of the Posttest Scores of the Two Groups

Group	Mean	Std. Deviation	N
Control Group	62.82	24.78	49
Experimental Group	69.20	20.74	46

From Table 15, it is notable that the posttest mean score of the experimental group is higher at 69.20 (SD = 20.74) than that of the control group at 62.82 (SD = 24.78). On the other hand, Table 16 shows the results of the ANCOVA comparing the posttest scores of the two groups with the pretest score as the covariate. Results showed that students' performance in the pretest is linearly related to their performance in the posttest with $F(1, 92) = 42.24$ and $p < .001$. This implies that the data of this study satisfy the assumption of ANCOVA for the covariate (performance in the pretest), that is,

Table 16

Analysis of Covariance Results of the Posttest Performance of Students with their Pretest Scores as the Covariate

Source	Type III Sum of Squares	df	Mean Square	F	Sig. (p-value)
Pretest	15364.77	1	15364.77	42.24	.000*
Groups of Respondents	2196.10	1	2196.10	6.04	.016*
Error	33463.81	92	363.74		

$R^2 = .328$ (Adjusted $R^2 = .313$); $*p < .05$

the covariate must be linearly related to the dependent variable (performance in the posttest). Results of the ANCOVA further show that grouping of the students had a significant effect on their performance in the posttest with $F(1, 92) = 6.038$ and $p = .016$. This indicates that there is a significant difference between the adjusted posttest mean scores of the experimental and control groups after controlling for the influence that their pretest scores may have on their posttest scores. Looking at the mean scores of the students in both groups, it can be noted that those exposed to the use of facilitated learning modules performed significantly better than those who were not exposed to the facilitated learning modules. This result corroborates with what students in the experimental group said in their journals.

Student 10, Experimental Group

"The facilitated learning modules helped me perform better in class because I was able to solve problems using the mathematical techniques in dealing with analytical chemistry problems."

Student 11, Experimental Group

"I found the modules very helpful in analytical chemistry. They served as quick reference where I can easily find the mathematical procedures involved in solving analytical chemistry problems. The modules are also easy to understand because the author used simple language."

It can be noted from the statement of the student that the facilitated learning modules helped them enhance their mathematical skills in solving analytical chemistry problems. The fact that students gained better mathematical skills in solving analytical chemistry resulted to deeper understanding of the analytical chemistry concepts, just as what one of the students said in her journal as follows:

Student 12, Experimental Group

"Not only that I understood the mathematical procedures as explained in the modules, I also understood better some analytical chemistry concepts as shown in the mathematical equations."

The above statement means that the students were able to understand better the relationships of various chemical properties as these are represented as variables in mathematical equations that they encountered in the facilitated learning modules.

Further, the findings of this study are consistent with the findings of Lumaque (2011) when he conducted a similar study on the effectiveness of facilitated learning modules in classroom instruction. He found out that the use of facilitated learning modules improved the performance of students in general chemistry.

In addition, with the learning modules' self-paced nature, students may have high levels of satisfaction in using the modules because they could always go back to the exercises and examples in the modules any time they would want to. This is consistent with the findings of the study of Mak and Georges (1997) which reported that students preferred workbooks like learning modules compared to learning from textbooks. This finding can be affirmed by one of the students who preferred the facilitated learning modules used in this study over the bulky textbook in analytical chemistry. The verbatim statement of the student regarding this observation was discussed earlier in this chapter.

The next sections discuss the performance of the students in both the experimental and control groups, in terms of knowledge of the application of mathematical and statistical tools and knowledge of introductory analytical chemistry.

Performance of students in application of mathematical and statistical tools. This study also examined the posttest scores by module of both groups to find out in which module the experimental students showed higher scores than the control group. Table 16 shows the average scores of both the control and experimental groups in the seven modules.

Topics included in each of the modules and course syllabus served as basis for the coverage of the posttest. The posttest contained both objective-type and problem-solving questions. This study assigned total points for each module in the posttest based on the degree of complexity of the problem and the coverage of introductory analytical chemistry content.

Table 17 shows the total points and mean scores obtained by both groups in the application of mathematical and statistical tools in each of the seven modules.

Table 17

Summary of Posttest Mean Scores and Independent Samples T-Test Results of Knowledge of the Application of Mathematical and Statistical Tools in Introductory Analytical Chemistry

Module (Topic)	Total Points	Posttest Mean Scores		Independent Samples T-test Results	
		Control	Experimental	t value	Sig. (2-tailed)
1(Statistical Testing and Treatment of Data I)	8	5.22	6.13	2.43	.017
2(Statistical Testing and Treatment of Data II)	12	5.70	7.59	4.08	.000
3 (Expressions of Concentration)	12	6.31	7.02	1.32	.191
4 (Chemical Equilibrium)	12	4.73	4.83	0.16	.874
5 (Acids and Bases)	12	3.73	3.76	0.06	.956
6 (Other Aspects of Aqueous Equilibria)	12	4.53	4.67	0.25	.804
7 (Gravimetric Methods of Analysis)	8	5.63	6.98	2.41	.018
Total	78	36.05	41.32		

There is one problem-solving question in each module. However, total points assigned are not uniform as this is based on the degree of complexity of the problem. Modules 2 (Statistical Testing and Treatment of Data II), 3 (Expressions of Concentration), 4 (Chemical Equilibrium), 5 (Acids and Bases) and 6 (Other Aspects of Aqueous Equilibria) are assigned twelve points each while eight and ten points were assigned for problem-solving question in Modules 1 (Statistical Testing and Treatment of Data I), and 7 (Gravimetric Methods of Analysis), respectively. The questions in the posttest are found in Appendix G. A scoring rubric was used in assigning points to the solutions provided by the students.

Posttest scores revealed that the experimental group had a higher mean score (M = 6.13) in the problem-solving question related to Module 1 (Statistical Testing for Treatment of Data I) than the control group (M = 5.22). This suggests that the experimental group performed better in introductory statistical analysis and basic algebra in this module. To validate this finding, the independent samples t-test comparing the performance of the control and the experimental groups in Module 1 (Statistical Testing for Treatment of Data I) was used. The result of this test is shown in Table 18.

Table 18

Independent Samples T-Test Comparing Scores of both Groups in Application of Mathematical and Statistical Tools in Module 1

	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Module 1 (Statistical Testing and Treatment of Data I) Math and Stat Score	2.43	81.46	.017	0.91	0.37

Based on the results, after the intervention, the mean scores of the two groups in Module 1 were significantly different with t(81.46) = 2.43 and p = .017. This means that the experimental group performed significantly better than the control group in the application of mathematical and statistical tools in Module 1. This module covered central value, precision and accuracy, and dimensional analysis.

Similarly, the experimental group had a higher mean score (M = 7.59) in the problem-solving question related to Module 2 (Statistical Testing for Treatment of Data II) than the control group (M = 5.70). This implies that the experimental group performed better in solving problems on finding confidence intervals, tests for significance, and comparing two precisions. The independent samples t-test results shown in Table 19 further indicate that the mean scores of the two groups are significantly different with t (93) = 4.08 and p < .001. This means that the experimental group performed better than the control group in the application of mathematical and statistical knowledge in Module 2 (Statistical Testing and Treatment of Data II). This module covered complex statistical analysis such as the use of confidence interval, z-test, t-test, F-test, and Q-test. These tests are applied in the statistical treatment of data in chemical analysis.

Table 19

Independent Samples T-Test Comparing the Scores of both Groups in Application of Mathematical and Statistical Tools in Module 2

	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Module 2 (Statistical Testing and Treatment of Data II) Math and Stat Score	4.08	93	.000	2.04	0.50

Further, students in the experimental group got a high mean score (M = 6.98) in the problem-solving question related to Module 7 (Gravimetric Methods of Analysis) than the control group (M = 5.63). This suggests that students gained better mathematical skills and techniques in calculating the purity and composition of the sample in chemical analysis. The independent samples t-test results shown in Table 20 further indicates that the mean scores of the two groups in Module 7 are significantly different with t (93) = 2.41 and p = .018. This means that the experimental group performed better than the control group in terms of their mathematical and statistical knowledge of the topics included in Module 7.

Table 20

Independent Samples T-Test Comparing the Scores of both Groups in Application of Mathematical and Statistical Tools in Module 7

	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Module 7 (Gravimetric Methods of Analysis) Math and Stat Score	2.41	93	.018	1.35	0.56

Students in the experimental group also had a higher mean score (M = 7.02) in problem-solving question related to Module 3 (Expressions of Concentration) than the control group (M = 6.31). However, the independent samples t-test results revealed no significant difference between the mean scores of both groups in Module 3 with t (81.37) = 1.32 and p = .191. Table 21 shows the results of independent samples t-test for Module 3. This suggests that students in both groups have comparable mathematical skills in calculating expressions of solution concentrations such as molarity, mole fraction, and parts per million of solute.

Table 21

Independent Samples T-Test Comparing the Scores of both Groups in Application of Mathematical and Statistical Tools in Module 3

	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Module 3 (Expressions of Concentration) Math and Stat Score	1.32	86.34	.191	0.72	0.54

However, although students in the experimental group obtained a slightly higher mean score (M = 4.83) than the control group (M = 4.73) in the problem-solving question regarding topics covered in Module 4 (Chemical Equilibrium), this difference is not statistically significant with t(93) = 0.16 and p = .874. Table 22 shows these results. This suggests that students in both groups have comparable mathematical skills in calculating equilibrium constants and equilibrium concentrations.

Table 22

Independent Samples T-Test Comparing the Scores of both Groups in Application of Mathematical and Statistical Tools in Module 4

	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Module 4 (Chemical Equilibrium) Math and Stat Score	0.16	93	.874	0.09	0.58

With regard to the problem solving question in Module 5 (Acids and Bases), students in both the experimental (M = 3.76) and control groups (M = 3.73) have almost the same mean scores. The independent samples t-test presented in Table 23 resulted to a non-significant t (93) = .06 at p = .956. This suggests that students in both groups have comparable mathematical skills in solving problems involving acids and bases. They also have comparable skills in solving pH values, acid-base ionization constants, and percent ionization.

Table 23

Independent Samples T-Test Comparing the Scores of both Groups in Application of Mathematical and Statistical Tools in Module 5

	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Module 5 (Acids and Bases) Math and Stat Score	0.06	93	.956	0.03	0.48

Finally, students in the experimental group obtained low mean score (M = 4.67) but slightly higher than the control group (M = 4.53) in problem-solving question regarding topics covered in Module 6 (Other Aspects of Aqueous Equilibria). The independent samples t-test results show that the mean scores of the two groups are not significantly different. Table 24 shows the independent samples t-test results for the mean scores for Module 6.

Table 24

Independent Samples T-Test Comparing the Scores of both Groups in Application of Mathematical and Statistical Tools in Module 6

	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Module 6 (Other Aspects of Aqueous Equilibria) Math and Stat Score	0.25	93	.804	0.14	0.58

Based on the results, the mean scores of the two groups after the intervention were not significantly different with t (93) = 0.25 and p = .804. This suggests that students in both groups have comparable mathematical skills in solving problems involving other aspects of aqueous equilibria such as buffers and solubility products.

From the results by module discussed above, the Modules 1, 2, and 7 helped the students in the experimental group solve problems related to analytical chemistry. It can be inferred that frequent exposure to problem-solving in Modules 1, 2, and 7 improved the mathematical and statistical knowledge and skills of these students. However, Modules 3, 4, 5, and 6 seemed to have not influenced the mathematical and statistical knowledge and skills of students. Specifically, these were solving problems related to concentrations, chemical equilibrium, acid-base equilibria particularly acid-base titrations, and solubility equilibria. This finding affirms concerns raised by some of the student mentors regarding the difficulty of most of their members on these topics.

Performance of students in introductory analytical chemistry. This study also examined the posttest results of both groups in introductory analytical chemistry. Table 25 shows the mean scores of both control and experimental groups in the seven modules in introductory analytical chemistry. Table 25 shows the total points and the mean scores obtained by both groups in introductory analytical chemistry in each of the seven modules. There are eight (8) questions assigned for each module except Module 1 which had only 4 questions. The first part of the questions in the posttest was about introductory analytical chemistry. Each correct answer for each item was given one point.

Table 25

Summary of Posttest Mean Scores and Independent Samples T-Test Results of Knowledge of Introductory Analytical Chemistry

Module (Topic)	Total Points	Posttest Mean Scores		Independent Samples T-test Results	
		Control	Experimental	t value	Sig. (2-tailed)
1(Statistical Testing and Treatment of Data I)	4	3.12	3.70	3.62	.001
2(Statistical Testing and Treatment of Data II)	8	5.08	5.85	2.17	.033
3 (Expressions of Concentration)	8	4.41	5.17	2.25	.027
4 (Chemical Equilibrium)	8	3.24	2.89	-1.28	.203
5 (Acids and Bases)	8	2.86	2.43	-1.77	.080
6 (Other Aspects of Aqueous Equilibria)	8	3.02	2.70	-1.25	.214
7 (Gravimetric Methods of Analysis)	8	4.41	5.46	3.20	.002
Total	52	26.14	28.20		

Analogous to the posttest scores in the application of mathematical and statistical tools, the experimental group earned higher mean scores than the control group in objective-type questions related to Modules 1, 2, 3, and 7. The mean score (M = 3.70) of the experimental group was higher than the control group (M = 3.12) in objective-type questions related to Module 1 (Statistical Testing for Treatment of Data I). This suggests that the experimental group gained more knowledge in terms of introductory statistical analysis and basic algebra. The results of the independent samples t-test comparing the performance of the control and the experimental groups in Module 1 are shown in Table 26.

Table 26

Independent Samples T-Test Comparing Scores of both Groups in Knowledge of Introductory Analytical Chemistry in Module 1

	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Module 1 (Statistical Testing and Treatment of Data I) Knowledge Score	3.62	78.05	.001	0.57	0.16

As shown in Table 26, the mean scores of the two groups in Module 1 were significantly different with t (78.05) = 3.63 and p =.001 after the intervention. This means that the experimental group had significantly gained more knowledge than the control group in terms of central value, precision and accuracy, and dimensional analysis.

Similarly, the experimental group had a higher mean score (M = 5.85) than the control group (M = 5.08) in objective-type questions related to Module 2 (Statistical Testing for Treatment of Data II). Further, the independent samples t-test results shown in Table 27 indicates that the mean scores of the two groups are significantly different with t (93) = 2.17 and p = .033. This means that the experimental group performed significantly better than the control group in complex statistical analysis such as the use of confidence interval, z-test, t-test, F-test, and Q-test, and in comparing two precisions.

Table 27

Independent Samples T-Test Comparing Scores of both Groups in Knowledge of Introductory Analytical Chemistry in Module 2

	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Module 2 (Statistical Testing and Treatment of Data II) Knowledge Score	2.17	93	.033	0.77	0.35

Furthermore, students in the experimental group obtained a higher mean score (M= 5.17) than the control group (M = 4.41) in the objective-type questions related to Module 3 (Ways of Expressing Concentrations). Table 28 shows the results of independent samples t-test comparing the mean scores of the two groups in terms of their knowledge in ways of expressing concentrations. Based on the results, the mean scores of the two group are significantly different with t (93) = 2.25 and p = .027. This suggests that the posttest mean score of the experimental group is statistically higher that of the control group in terms of their knowledge of topics included in Module 3. This means that students in the experimental group had a better understanding of solution concentrations such as molarity, mole fraction, and parts per million of solute than the control group.

Table 28

Independent Samples T-Test Comparing Scores of both Groups in Knowledge of Introductory Analytical Chemistry in Module 3

	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Module 3 (Expressions of Concentration) Knowledge Score	2.25	93	.027	0.77	0.34

Furthermore, students in the experimental group got a higher mean score (M = 5.46) than the control group (M = 4.41) in objective-type questions related to Module 7 (Gravimetric Methods of Analysis). The independent samples t-test results of posttest scores on the knowledge of introductory analytical chemistry for Module 7 are shown in Table 29. Based on the results, the mean scores of the two groups in Module 7 are significantly different with t (93) = 3.20 and p = .002. This means that the experimental group performed significantly better than the control group in terms of knowledge of gravimetric methods of analysis.

Table 29

Independent Samples T-Test Comparing Scores of both Groups in Knowledge of Introductory Analytical Chemistry in Module 7

	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Module 7 (Gravimetric Methods of Analysis) Knowledge Score	3.20	93	.002	1.05	0.33

However, students in the experimental group obtained lower mean score (M= 2.89) than the control group (M = 3.24) in objective-type questions regarding topics covered in Module 4 (Chemical Equilibrium). Although this was so, the independent samples t-test results for Module 4 shown in Table 30 revealed that this difference is statistically significant with t (93) = -1.28 and p = .203. This means that the posttest mean score of the experimental group is statistically comparable to that of the control group in terms of knowledge of the topics included in Module 4. This suggests that students in both groups have comparable understanding of the concepts regarding equilibrium constants and equilibrium concentrations.

Table 30

Independent Samples T-Test Comparing Scores of both Groups in Knowledge of Introductory Analytical Chemistry in Module 4

	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Module 4 (Chemical Equilibrium) Knowledge Score	-1.28	93	.203	-.35	0.28

Students in the experimental group obtained a mean score (M = 2.43) while the control group obtained a mean score (M = 2.86) in objective-type questions regarding topics covered in Module 5 (Acids and Bases). Table 31 shows the independent samples t-test results for the mean scores for knowledge of the topics included in Module 5.

Table 31

Independent Samples T-Test Comparing Scores of both Groups in Knowledge of Introductory Analytical Chemistry in Module 5

	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Module 5 (Chemical Equilibrium) Knowledge Score	-1.77	93	.080	-.42	0.24

As shown in Table 31, the mean scores of the two groups after the intervention were not significantly different with t (93) = -1.77 and p = .080. This means that students in both groups have comparable level of understanding of acids and bases pH values, acid-base ionization constants, and percent ionization.

Lastly, the experimental and control groups got lower mean score (M = 2.70) than the control group (M = 3.02) in objective-type questions related to topics covered in Module 6 (Other Aspects of Aqueous Equilibria). The independent samples t-test results shown in Table 32 revealed that the mean scores of the two groups are not significantly different with t (93) = -1.25 and p = .214. This suggests that students in both groups have comparable knowledge of other aspects of aqueous equilibria such as buffers and solubility products.

The latter findings suggest that the knowledge of the experimental group on topics related to chemical equilibrium, acid-base equilibria particularly acid-base titrations, and solubility equilibria are comparable with that of the control group.

Table 32

Independent Samples T-Test Comparing Scores of both Groups in Knowledge of Introductory Analytical Chemistry in Module 6

	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Module 6 (Other Aspects of Aqueous Equilibria) Knowledge Score	-1.25	93	.214	-.32	0.26

Thus, the use of facilitated learning modules did not enhance the knowledge of the experimental group regarding the topics covered in Modules 4, 5 and 6. This can be explained by the fact that these topics are difficult affirming the concerns raised by some of the student mentors regarding the difficulty of most of their members on these topics.

The comparable performances of the experimental and the control groups in Modules 4, 5, and 6 can be attributed to the particular facilitated learning activities used in the experimental group for these modules. On-demand tutorial and online group discussion and file sharing were used for these modules. The limited length of contact time during on-demand tutorial did not permit the instructor-tutor to discuss detailed mathematical procedures in solving problems related to topics in Module 4. Both groups used peer mentoring for topics related to Module 5. But the conflicts of schedules for some of the members of each group prohibited the groups to thoroughly discuss topics related to Module 5 that resulted to poor performance on this module. Moreover, online group discussion and file sharing of topics related to Module 6 did not result to meaningful interactions among the students. Hence, these constraints could have been the reasons why the use of facilitated learning modules did not enhance the performance of the experimental group in these modules.

In addition, it is obvious that both the experimental and control groups obtained low scores in the three modules which were all related to the principles and applications of chemical equilibria. One notable reason could be the difficulty of the chemical concepts inherent to chemical equilibrium. According to Pekmez (2010), topics in chemical equilibrium includes the most abstract concepts such as its dynamic nature, the distinction between equilibrium and non-equilibrium situations, and the mental manipulations of Le Chatelier's principle (Kousathana & Tsaparlis, 2002). Further, the students showed erroneous execution of the mathematical procedures involved in the problem-solving questions in these topics. This is because of the complexity of the mathematical procedures involved in solving problems which resulted to poor understanding of the chemical concepts. Gultepe (2013) said that most chemistry teachers believe that problem solving leads to understanding chemistry concepts. This author also said that one factor that hinders students learning chemistry is inadequate algorithmic skills. Despite the fact that these students should have taken advantage of the facilitated learning modules as supplementary learning materials, they still showed difficulty in problem solving related to chemical equilibria. Gultepe (2013) also said that teaching students in algorithmic-mode problems does not guarantee successful understanding of conceptual problems.

Relationship of Knowledge in the Mathematical and Statistical Tools Application and Introductory Analytical Chemistry

The researcher also correlated knowledge of introductory analytical chemistry with application of mathematical and statistical tools in introductory analytical chemistry. The researcher performed correlation of the variables in the two groups based on their posttest scores.

The researcher split scores of students obtained from the problem-solving questions and objective-type questions in the posttest. Scores in problem-solving questions represent scores for application of mathematical and statistical tools. Scores in objective-type questions represent scores for knowledge of introductory analytical chemistry. The scores obtained by both groups in the objective-type questions were correlated with the scores they obtained in the problem-solving questions using *Pearson's correlation*. Correlation of the knowledge of the application of mathematical and statistical tool with the knowledge of introductory analytical chemistry was performed on the two groups. The following paragraphs present more descriptive and quantitative statistical results to further elaborate the findings.

Figure 10 shows the plot of the points representing ordered pairs of application of mathematical and statistical tools involved in introductory analytical chemistry and knowledge of introductory analytical chemistry. The figure demonstrates a qualitative description of correlation of the two variables considered. The figure reveals positive correlation of the variables because the plots lean toward or slope to the right. This suggests that scores in the knowledge of analytical chemistry is directly correlated with scores in the application of mathematical and statistical tools. This implies that students who earned high scores in the application of mathematical and statistical tools also obtained high scores in knowledge of introductory analytical chemistry.

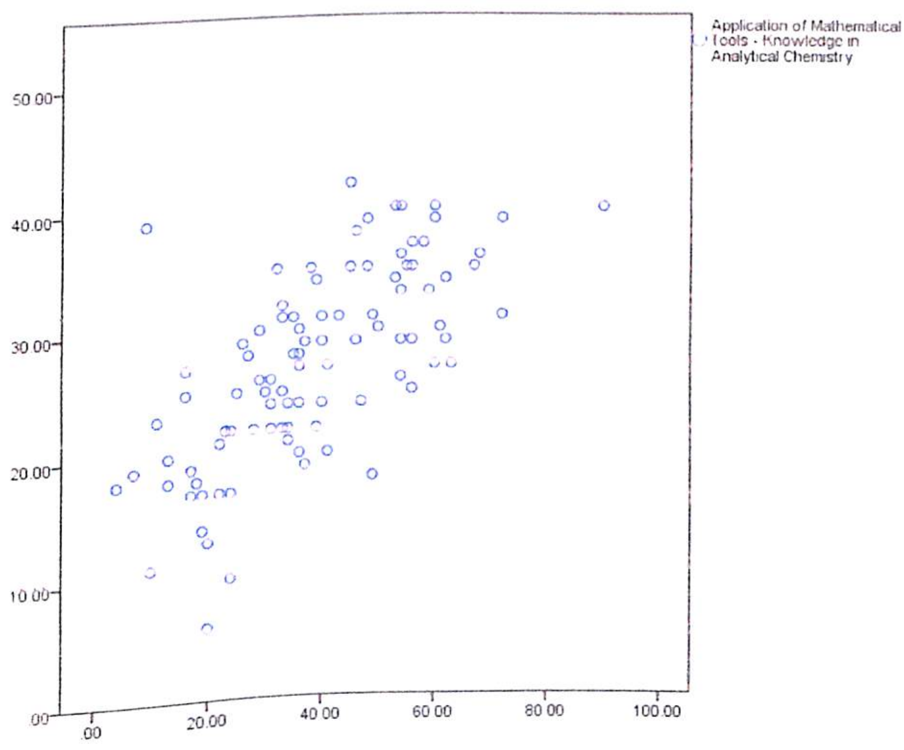


Figure 10. Scattered plot of the scores in application of mathematical and statistical tools in introductory analytical chemistry vs. scores in introductory analytical chemistry

The finding based on Figure 10 is a general statistical result and needs closer examination of the students' scores in both application of mathematical and statistical tools and knowledge of introductory analytical chemistry.

Table 33 shows the descriptive statistics of the scores of the students in application of mathematical and statistical tools and their scores in introductory analytical chemistry. Application of mathematical and statistical tools shows higher standard deviation than the knowledge of introductory analytical chemistry for both groups. This suggests that the posttest scores of students obtained in the application of mathematical and statistical tools are farther from the mean while scores obtained in introductory analytical chemistry are closer to the mean. This means that the mathematical and statistical skills of students vary to a greater extent than their understanding of the concepts in introductory analytical chemistry. This finding is observed for both the experimental and the control groups.

Table 33

Descriptive Statistics of the Scores of Students in Application of Mathematical and Statistical Tools and in Introductory Analytical Chemistry

	Mean	Std. Deviation	N
Application of Mathematical Tools	38.64	17.136	95
Knowledge in Analytical Chemistry	27.26	7.704	95

Further, results of the *Pearson's correlation r* presented in Table 34 show the degree of correlation of the two variables. Results of the *Pearson's correlation* show that a significant moderately strong positive correlation (Sevilla, et al., 1996) exists between

Table 34

Pearson's Correlation of Knowledge of Application of Mathematical and Statistical Tools and Knowledge of Introductory Analytical Chemistry for the Two Groups

	N	Pearson's Correlation r	Sig. (2-tailed)
Knowledge of Application of Mathematical and Statistical Tools Knowledge of Introductory Analytical Chemistry	95	.67	.000

the scores of students in the application of mathematical and statistical tools and in introductory analytical chemistry with $r\ (93) = .67$ and $p < .001$. This means that high scores in application of mathematical and statistical tools were significantly associated with high scores in introductory analytical chemistry. This result affirms the statement of Urdouso (2011), which says that proper understanding of chemical principles such as solubility, molar ratios, pH and equilibrium requires a good working knowledge of basic mathematics. Moreover, this finding supports the statement of Bangash (2005), which says that the knowledge of mathematical skills in chemistry greatly enhances the student's learning and understanding of the material in the texts and also increases their research capability particularly in the analysis and presentation of their experimental data.

Chapter 5
SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

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

Summary

The study involved development of facilitated learning modules in introductory analytical chemistry. The modules focused on the essential mathematical and statistical tools used in introductory analytical chemistry. It also assessed the effectiveness of the learning modules in improving student performance. Seven learning modules were developed to cover the topics on Statistical Testing for Treatment of Data I and II, Ways of Expressing Concentrations, Chemical Equilibrium, Acids and Bases, Other Aspects of Chemical Equilibria, and Gravimetric Method of Analysis. Each module contained the following: (a) Title, (b) Introduction, (c) Facilitated Learning Activity, (d) Objectives, (e) Time Frame, (f) Check-up Test and Feedback, (g) Lesson Proper, (h) Assignment, (i) Key Answers, (j) Summary, and (k) References.

First phase of the study. The development phase began with the evaluation of the modules' face content and form by chemistry education experts from two universities in area of where the research was conducted. This study then incorporated these experts' relevant comments regarding the face content and form of the modules. These comments and suggestions characterized the essential features of the facilitated learning modules as perceived by the experts.

The comments and suggestions of the experts who evaluated the modules include the following:

(a) Facilitated learning modules allow students to feel as if they are listening to the lecture of the instructor while reading the modules.

(b) References must be properly cited in the main text of the modules if information was obtained from other sources.

(c) Solutions to problems given as assignment should also be provided.

(d) Facilitated learning modules must be well-designed, Language used should be simple and easily understood.

(e) Layout should be attractive and instructions are easy to follow.

(f) Facilitated learning modules must be free from conceptual errors. Sources of the pictures, graphs and tables which were not made by the module writer must be acknowledged and cited.

(g) References should be added at the end of each module, if applicable.

(h) Minor corrections in the text must be checked.

The next stage of the development phase was the evaluation of the modules' objectives and content. This was done by 10 selected analytical chemistry instructors from three different universities in Mindanao. The evaluation was done using the tool developed by Lumaque (2011). The instructors evaluated the modules' objectives based on attainability, clarity, and relevance. In addition, the instructors evaluated the modules' content based on appropriateness, appeal, innovativeness, and conformity to standards. The instructors found that the objectives of the modules were highly attainable, very clear, and very relevant. The modules' contents were very appropriate, very innovative, very appealing, and strongly conforming to standards.

The last stage of the development phase involved determination of student's involvement index, grade level, and communication index of the facilitated learning modules. This study also made use of standard tools such as Romey's (1965) procedure, Talisayon's guide (1983), and Fry's Readability Graph (1968) in determining the student's involvement index, the communication index, and the grade level, respectively, of the learning modules. The resulting student involvement index of the learning modules was 1.34, using Romey's (1965) procedure. This result suggests that the modules would engage the end users while using the modules. The value of the communication index was 0.009 which is within the acceptable range according to Talisayon's guide (1983). Further, the grade level of the learning modules was Grade 11 using the Fry's Readability Graph (1968) which matched the grade level of intended end-users.

Second phase of the study. This phase of the study was the assessment of the facilitated learning modules' effectiveness in improving student performance in introductory analytical chemistry. This study used a pretest-posttest nonequivalent groups design in determining the effectiveness of the learning modules. This part of the study involved two introductory analytical chemistry classes of medical technology students during the second semester of SY 2015-2016. The researcher randomly assigned one class as experimental group with 46 students and the other as the control group with 49 students. The researcher taught both classes to avoid teacher-factor biases. Both classes utilized facilitated learning instruction. Use of facilitated learning modules supplemented the instruction in the experimental group only. The control group used only the textbook which was a common learning material to both groups.

Before the treatment, both groups took a diagnostic pretest on basic algebra and statistics. The purpose of this pretest was to establish that the two groups involved in the study were comparable in terms of mathematical and statistical skills prior to the treatment. Independent samples t-test was used in comparing the pretest scores of the two groups. Results revealed a non-significant t-value of 1.259 with $p = .211$. Statistically, this suggests that there was no significant difference between the pretest scores of the two groups. This means that both the experimental and the control groups were comparable in terms of mathematical and statistical skills.

After the treatment, the two groups took the posttest. The results of the posttest served as the basis in assessing the modules' effectiveness in improving student performance in introductory analytical chemistry. This study used analysis of covariance (ANCOVA) to determine if there was a significant difference between the posttest scores of the two groups. The pretest scores of the two groups served as the covariate. Results of the ANCOVA revealed an F-value equal to 6.038 (with significance value equal to .016 which is less than 0.05). This shows that there was a statistically significant difference between the posttest scores of the two groups. Specifically, results revealed that students from the experimental group ($M = 69.196$) performed better in the posttest than the control group ($M=62.816$). This may be attributed to the use of the modules as supplementary learning materials among those in the experimental group. Thus, the use of the modules helped improve the performance of experimental group students in introductory analytical chemistry.

Although the ANCOVA results revealed that the experimental group generally performed better in the posttest than the control group, there were modules where there were no significant differences between the posttest mean scores of the two groups. Thus, posttest scores of the two groups in the application of mathematical and statistical tools and introductory analytical chemistry were compared to find out if significant differences existed in each module. To compare the posttest mean scores of the two groups in both the application of mathematical and statistical tools and introductory analytical chemistry, the independent samples t-test was used.

Results per module showed that the experimental and the control groups significantly differ in their mean scores in both application of mathematics and statistical tools and introductory chemistry in Module 1 (Statistical Testing for Treatment of Data I) with $t(81.46) = 2.428$ ($p = .017$) and $t(78.05) = 3.623$ ($p = .001$), respectively. In fact, the experimental group's mean scores were higher than that of the control group. This suggests that the experimental group performed better in basic statistical tools and dimensional analysis. The experimental group also had higher scores in knowledge of the application of mathematical and statistical tools and introductory analytical chemistry in Module 2 (Statistical Testing for Treatment of Data II). These differences in the mean scores were significant with $t(93) = 4.075$ ($p < .001$) for application of mathematical and statistical tools and $t(93) = 2.168$ ($p = .033$) for introductory analytical chemistry. This suggests that students in the experimental group had better understanding of the concepts and skills related to statistical treatment of analytical data. Moreover, the experimental group also had higher scores in knowledge of the application of mathematical and statistical tools and knowledge of introductory analytical chemistry in Module 3 (Expressions of Concentrations). However, the independent samples t-test revealed no significant difference between the mean scores of the two groups in the application of mathematical and statistical tools with t (81.365) = 1.317 and p = .191 but with significant difference in the introductory analytical chemistry with t(93) = 2.246 and p = .027. This finding suggests that even though the experimental group had deeper understanding of the concepts related to expressions of concentrations, the two groups had comparable mathematical skills in dealing with problems related to concentration expressions. This could be attributed to the fact that topics included in Module 3 were already tackled in their previous chemistry subject that both groups took during the previous semester. Further, the experimental group also had higher scores in the application of mathematical and statistical tools and introductory analytical chemistry in Module 7 (Gravimetric Methods of Analysis). Results further showed significant differences between the mean scores of the two groups in both the application of mathematical and statistical tools with t (93) = 2.406 (p = .018) and in introductory analytical chemistry with t(93) = 3.197 (p = .002). This finding suggests that the experimental group had better mathematical skills and deeper knowledge of gravimetric methods of analysis than the control group.

From the results, it can be noted that the experimental group gained deeper understanding of statistical analysis, confidence intervals, tests for significance, comparing two precisions, various expressions of concentrations, and gravimetric methods of analysis. This can be attributed to their more frequent exposure to various mathematical procedures in the modules, where examples are explained using more simplified mathematical procedures than the textbook that has examples which students could hardly understand. This can be supported by the statement expressed by the students in the experimental group, as follows:

"The examples in the modules are explained in detail that I could easily understand compared with the examples in the book which I could hardly understand."

Student 12, Experimental Group

"I got higher score in our quiz on concentrations because I was able answer not only the problem solving well but also the explanation questions."

Student 13, Experimental Group

From the statements above, it can be said that students gained deeper understanding of the concepts pertaining to the relationship of the properties as represented in the mathematical equations that they manipulated and solved.

Moreover, although the experimental group had higher mean score in problem-solving in Module 4 (Chemical Equilibrium) than the control group, and the control group had higher mean score in the objective-type questions in Module 4 than the experimental group, the independent samples t-test showed no significant difference between these mean scores. This suggests that students in both groups have comparable mathematical skills in calculating equilibrium constants and equilibrium concentrations as well as understanding of the concepts related to these topics.

Moreover, students in both the experimental and control groups have almost the same mean scores of 3.76 and 3.73, respectively, in the problem-solving questions in Module 5 (Acids and Bases). Independent samples t-test results revealed that these mean scores were not significantly different with $t(93) = .055$ ($p = .956$). Also, for Module 5, the mean scores of the two groups in introductory analytical chemistry were not significantly different with $t(93) = -1.772$ ($p = .080$). These findings suggest that students in both groups have comparable mathematical skills in solving problems related to acids and bases as well as comparable level of understanding of acids and bases pH values, acid-base ionization constants, and percent ionization.

The experimental group also had higher mean score in problem-solving in Module 6 (Other Aspects of Aqueous Equilibria) than the control group, while the control group had higher mean score in the objective-type questions in Module 6 than the experimental group. These differences were not statistically significant though with $t(93) = .249$ ($p = .804$) for application of mathematical and statistical tools, and $t(93) = -1.251$ ($p = .214$) in introductory analytical chemistry. These findings suggest that students in both groups have comparable knowledge and mathematical skills in solving problems involving other aspects of aqueous equilibria such as buffers and solubility products. This suggests that the use of facilitated learning modules were not sufficient in enhancing the problem-solving skills of the students related to calculating equilibrium constant and concentrations, acid-base ionization, solubility and buffer calculations.

Use of particular facilitated learning activity for specific module could have been the reasons why there were comparable performances of the two groups in Modules 4, 5, and 6. On-demand tutorial was used for Modules 4 and 5 while online group discussion and file sharing was used for Module 6. The limited length of contact time during on-demand tutorial did not permit the instructor-tutor to discuss detailed mathematical procedures in solving problems related to topics in Modules 4 and 5. Also, online group discussion and file sharing as facilitated learning activity for Module 6 did not result in meaningful interactions among the students.

Lastly, correlation between knowledge of the application of mathematical and statistical tools involved and knowledge of introductory analytical chemistry was also determined. The posttest scores in objective-type and problem-solving questions served as basis for this correlation. The scatterplot (refer to Figure 10 of Chapter 4) revealed that scores of students in the application of mathematical and statistical tools were directly proportional to their scores in introductory analytical chemistry. Furthermore, a *Pearson correlation coefficient* was computed to assess the relationship between the knowledge of students in the application of mathematical and statistical tools and their knowledge in introductory analytical chemistry. Results showed that overall, there was a moderately strong positive relationship between the two variables with $r = .669$ and $p < .001$. This suggests that increases in scores in the application of mathematical and statistical tools were correlated with increases in scores in introductory analytical chemistry. This result affirms the statement of Urdouso (2011), which says that proper understanding of chemical principles such as solubility, molar ratios, pH and equilibrium requires a good working knowledge of basic mathematics. Moreover, this finding supports the statement of Bangash (2005), which says that the knowledge of mathematical skills in chemistry greatly enhances the student's learning and understanding of the material in the texts and also increases their research capability particularly in the analysis and presentation of their experimental data.

Conclusions

Considering the research questions and the findings of this study, the following conclusions are drawn.

1. According to the chemistry education experts who evaluated the facilitating modules based on content and form, the seven facilitating learning modules (a) are self-directing; (b) appropriately cite references; (c) include solutions to problems; (d) are well-designed and easily understood; (e) have attractive layout and simple instructions; (f) are free from conceptual errors; (g) acknowledge sources of the pictures, graphs and tables; (h) include references at the end of each module; and (i) are free from typographical errors.
2. The analytical chemistry instructors perceived the objectives of the modules as very attainable. This means that the objectives are within the learning capacities of the intended users. Also, the modules' objectives are very clear because students could easily perform the activities since they understood the language clearly. The objectives are also relevant because they guided the students on what they ought to learn in the subject. Moreover, the contents of the modules are very appropriate because they contain activities which are appropriate to the age of the intended users. The contents are also very appealing because of the important features such as tables and figures that sustain the interest of the readers and enhance the presentation of the content. The contents are also very innovative because they contain unique ways of presenting simplified techniques in solving analytical chemistry problems. Finally, the contents are strongly conforming to standards regarding the learning competencies set by the Commission on Higher Education for analytical chemistry (refer to Appendix N).
3. The value of student's involvement index is 1.34 based on Romey's (1965) procedures suggesting that students could still perform other activities like

calculator drill and plotting graphs while reading the modules. The value of the communication index was 0.009, suggesting that modules would be acceptable to the intended users like medical technology students based on Talisayon's (1983) guide. The grade level was found to match the grade level of the intended users of the learning modules, which is Grade 11 based on Fry's (1968) readability graph.

4. Use of facilitated learning modules as assessed was effective because they improved student performance. This affirms and strengthens the claim of Lumaque (2011) in his study when he used facilitated learning modules in general chemistry. Further, the improvement of the students' performance in the posttest may have been attributed to the enhanced skills of these students in dealing with mathematical procedures applied in analytical chemistry. The frequent exposure of students to the mathematical manipulations of the relationships of chemical properties in the mathematical equations may have contributed to their deepened understanding of the concepts in introductory analytical chemistry. However, there were certain topics where both the experimental and control groups had comparable performances in the knowledge of using mathematical and statistical tools in introductory analytical chemistry and knowledge of introductory analytical chemistry. These topics include chemical equilibrium (Module 4), acids and bases (Module 5), and other aspects of aqueous equilibria (Module 6). This means that the use of facilitated learning modules did not enhance the knowledge of the experimental group regarding the topics covered in Modules 4, 5 and 6. This can be explained by the fact that these topics are difficult affirming the concerns raised by some of the student mentors regarding the difficulty of most of

their members on these topics. Chemical equilibrium includes the most abstract concepts such as its dynamic nature, the distinction between equilibrium and non-equilibrium situations, and the mental manipulations of Le Chatelier's principle (Pekmez, 2010). Further, complexity of the mathematical procedures involved in solving problems about chemical equilibrium resulted to poor understanding of the chemical concepts.

5. Based on Pearson's correlation, there is moderately high correlation between students' knowledge of the application of mathematical and statistical tools and their knowledge of introductory analytical chemistry. This suggests that those who performed better in the knowledge of the application of mathematical and statistical tools also performed better in the knowledge of introductory analytical chemistry.

Recommendations

Based on the findings of the study, the following recommendations are put forward:

Development of Facilitated Learning Modules

1. To address the need for supplementary instructional materials, curriculum writers may develop facilitated learning modules in analytical chemistry that employ other instructional strategies such as virtual or face-to-face brainstorming sessions, group activities like games, and virtual classroom sessions and seminars.

2. Learning modules could be developed for other topics in analytical chemistry not covered in these modules such as various titrimetric methods of analysis and complexometric titration.
3. The facilitated learning modules may be revised to include stoichiometry because this topic requires good understanding of mathematics.
4. Interested faculty of other disciplines may develop similar learning modules developed in this study to address the need for supplementary learning materials in their respective subject areas.
5. Effectiveness of the facilitated learning modules may be assessed to consider analytical chemistry students from other schools in the research locale to increase the population size.
6. Modules on chemical equilibrium and other aspects of equilibria may be revised to utilize peer mentoring as a facilitated learning activity instead of on-demand tutorial and online group discussion and file sharing.
7. The number of chemistry education experts should be increased in order to gather more inputs regarding the form and content of the learning modules because their inputs are very essential to the final form and content of the learning modules.
8. The number of instructors as evaluators may be increased by considering analytical chemistry instructors from as many schools as possible. This strategy could gather diverse information about the teaching practices of analytical chemistry in different places in order to produce more

meaningful data that could be beneficial to the further improvement of the learning modules.

9. In developing learning modules, writers should use simple language which is understandable and appropriate to the age of the intended users. This, in effect, will improve the clarity of the learning modules and will increase the communication index of the materials.
10. To maximize the use of these learning modules in the laboratory part of the class, the same instructor should handle both the lecture and the laboratory of the analytical chemistry subject. This allows the instructor to have close supervision of the use of the learning modules in the laboratory, since it is the instructor who facilitates the use of these learning modules. This would also allow the instructor to adjust the sequence of topics in both lecture and laboratory.
11. Further study may be conducted to compare the effects of peer mentoring, on-demand tutorial, and online group discussion and file sharing with the use of facilitated learning modules on student performance.

Implications to teaching

1. Based on the findings of the study, the use of facilitated learning modules as supplementary learning material is effective for statistical treatment of data and expressions of concentration. Thus, analytical chemistry instructors may adapt facilitated learning instruction as a teaching strategy along with the facilitated learning modules.

2. Considering the high correlation of the knowledge of the application of mathematical and statistical tools and the knowledge of introductory analytical chemistry, the prior mathematics and statistics subjects may be strengthened and should become prerequisites in analytical chemistry. This would ensure more meaningful teaching and learning of analytical chemistry.
3. Analytical chemistry instructors may use these facilitated learning modules, as developed, to serve as supplementary learning materials for analytical chemistry for medical technology students in the locality.

BIBLIOGRAPHY

Bardini, C., & Pierce, R. (2015). Assumed mathematics knowledge: the challenge of Symbols. *International Journal of Innovation in Science and Mathematics Education (formerly CAL-laborate International), 23 (1).*

Bawaneh, S. (2011). The effects of blended learning approach on students' performance: evidence from a computerized accounting course. *International Journal of Humanities and Social Science. 1(6).*

Beavis, A., & Baker, A. (2013). Supporting the development of quantitative skills in first year chemistry. *In Proceedings of the Australian Conference on Science and Mathematics Education (formerly UniServe Science Conference).*

Best, J. & Kahn, J. (1998). *Research in education.* Boston: Allyn and Bacon.

Boiser, D. (2000). *Strategies for teaching: a modular approach.* Manila: Rex Book Store.

Burden, P. & Byrd, P. 2013). *Methods for effective teaching: meeting the needs of all students, 6th ed.* USA: Pearson Education, Inc.

Davis, E. (1995). *Teachers as curriculum evaluators.* Massachussetts: Allen and Unwin

Doll, R. (2002). *Curriculum improvement.* New York: Allyn and Bacon.

Eggen, P. & Kauchak,P. (2001). *Strategies for teachers.* Massachussetts: Allyn and Bacon.

Ellis, A. et al. (1995). *The school curriculum.* Massachussetts: Allyn and Bacon

Espinosa, A. (2009). Comparative efficiency of modular method in the teaching of high school chemistry. Published Research Article. College of Education, University of the Philippines, Quezon City.

Fry, E. (1968). A Readability Formula that Saves Time. *Journal of Reading, April 1968, 513-578.*

Fink, L. (1999). *Active Learning.* University of Oklahoma.

Hair, J., et al. (1995). *Multivariate data analysis with readings.* New Jersey: Prentice Hall, Inc.

Hass, G. & Parkey, F. (1993). *Curriculum planning.* Massachussetts: Allyn and Bacon.

Hohn, R. (1995). *Classroom learning and teaching.* USA: Longman Publishers.

Ibe, M. (1998). *Issues and trends to science and technology education.* Diliman, Quezon City: UP Open University.

Jackson, D. C., Johnson, E. D., &Blanksby, T. M. (2014). A Practitioner's guide to implementing cross-disciplinary links in a mathematics support program. *International Journal of Innovation in Science and Mathematics Education (formerly CAL-laborate International), 22(1).*

Johnson, R. S. (1997). *Developing individualized instructional material.* New York: Westinghouse Learning Press.

Kassah, S., Abu-Hijleh, MF, and Al-Shboul, Q, H. (2005). Student-led tutorials in problem based learning: educational outcomes and students' perceptions. *Med Teach. 27 (6), 521-6.*

Koc, B. (2000). *Research seminar in science education.* Quezon City: UPOU-OASIS.

Koc, B. and Talisayon, V. (1998). *Seminar in advanced statistics applied in education.* Quezon City: UPOU-OASIS.

Leiderfrost, B. et al. (2014). The impact of peer mentoring on mentee academic performance: is any mentoring style better than no mentoing at all. *International Journal of Teaching and Learning in Higher Education, 2016 (1), 102-111.*

Loughlin, W. A., Watters, D. J., Brown, C. L., & Johnston, P. R. (2015). Snapshot of mathematical background demographics of a broad cohort of first year chemistry science students. *International Journal of Innovation in Science and Mathematics Education (formerly CAL-laborate International), 23(1).*

Lumaque, L.A.(2011). *"Facilitated learning module".* Unpublished Dissertation. Notre Dame of Marbel University, Koronadal City.

Lumaque, et al. (2004). Preparedness of secondary school students in Cotabato City for sciencecareer. *NDU Research Journal.* Notre Dame University: Cotabato City.

Lumaque, L.A. (2002). *"Developing an instructional material in general and inorganic chemistry".* Unpublished Dissertation, Notre Dame University, Cotabato City.

Mak, A. & Georges, A (1997). Benefits of self-paced learning modules for teaching quantitative methods in environmental science. *International Journal of Science Education, 19(7), 835-848.*

Margaret, C. & Foster, J. (2005). Training the trainer resource pack. *The Archives-Skills Consultancy on behalf of the ICA Section on Archival Education and Training.*

McKinney, K. (2002). *Active Learning*. Illinois State University.

McNeil, J. (2003). *Curriculum: the teacher's initiative*. New Jersey: Pearson Education, Inc.

Morilla, M. (2016). Advantages of using modular approach in instruction. *Alternative Learning System*. Article published online.

Muijs, D. & Reynols, R. (2011). *Effective teaching: evidence and practice, 3rd ed.* London: SAGE Pubilcations, Inc.

Oliva, P. (2001). *Developing the curriculum. 5th ed.* Lungman: New York.

Ornos, P, Gonzaga, E., Bell-Esgra, C., Gomez, N., Tarinay, A., and Verde, S. (2008). *Facilitators of the learning process*. Metro Manila: Grandwater Publications.

Ornstein, A. & Hunkins, F. (2004). *Curriculum, foundations, principles, and issues*. New Jersey: Prentice-Hall, Inc.

Prescott, J., Wilson, S. E., & Wan, K. W. (2014). Pharmacy students' perceptions of natural science and mathematics subjects. *American journal of pharmaceutical education*, 78(6).

Rodger, S. and Tremblay, P. (2003). The effects of a peer mentoring program on academic success among first-year university Students. *The Canadian Journal of Higher Education Le revue canadienne d' enseignement superieur, 33 (3), 1-18.*

Romey, W. D. (1965). *Inquiry techniques for teaching science*. New Jersey: Prentice Hall

Santrock, J. (2004). *Educational psychology*. New York. McGraw-Hill, Inc.

Sejpal, K. (2013). Modular method of teaching. *International Journal for Research in Education, 2 (2), 169-171.*

Sevilla, C. G. et al. (1996). *Research methods, revised edition*. Manila

Siegel, S. and Casetellan, Jr. N. (1988). *Nonparametric statistics for behavioural sciences*. Singapore: McGraw-Hill Book Co.

Slavin, R. (2002). *Educational psychology: theory and practice*. New York: Allyn and Bacon

Talisayon, V. M. (1998). *Curriculum designing.* Diliman, Quezon City. UPISMED

Talisayon, V. M. (1983). *A feedback-based readability formula for science and mathematics curriculum materials.* UPNISMED Monograph No. 30

Taylor, J. (2004). *A technology-enhanced innovative approach to teaching general college chemistry*: Florida USA. University of South Florida.

UP Open University (1999). *Curriculum design and instruction for science education.* Diliman, Quezon City: UP Open University.

Udousoro, U. J. (2011). The Effects of gender and mathematics ability on academic performance of students in chemistry. *African Research Review, 5(4).*

Vega, V. & Prieto, N. (2012). *Facilitating Learning.* Mandaluyong: Books Atbp. Publishing Corporation.

Veggel, N. and Amory, J. (2014). The impact of math support on mathematics confidence and academic performance in a cohort oh HE animal science students. *Peer J Peer-Reviewed and Open Access Journal,* 7(2), *463-472*

APPENDICES

Appendix A. Face Content and Form Evaluation Tool for the Development of Facilitated Learning Modules

Development of Facilitated Learning Modules

Dear ____________________:

I have prepared seven facilitated learning modules on essential mathematical and statistical tools employed in introductory analytical chemistry. The facilitated learning modules aim to help students enhance their mathematical and statistical skills and to deepen their understanding of the analytical chemistry concepts. I prepared facilitated learning modules as supplementary learning materials which will be used in conjunction with facilitated learning instructions. However, the form and face content of these facilitated learning modules have to be evaluated by experts in chemistry education to ensure that the form and face content conform to the rules and standards governing writing learning modules.

In this respect, I would like to request you to evaluate the facilitated learning modules particularly their form and face content. Your valuable comments and suggestions are significant to the development of these learning modules. Further, your comments and suggestions would be incorporated in the final form and content of the facilitated learning modules to ensure that they are written as they should be to serve their purpose. Your involvement in this educational endeavor by sharing your expertise is highly appreciated.

Please write your comments and suggestions on the spaces provided below. Please feel free to use extra sheets should there be a need.

Comments and Suggestions:

Appendix B. Objectives and Content Evaluation Tool

Development of Facilitated Learning Modules

Dear ________________________:

I have prepared seven facilitated learning modules on essential and mathematical tools employed in introductory analytical chemistry. These facilitated learning modules aim to help students enhance their mathematical and statistical and to deepen their understanding of the analytical chemistry concepts. I prepared facilitated learning modules as supplementary learning materials which will be used in conjunction with facilitated learning instructions. The form and face content of these facilitated learning modules had already been evaluated by experts in chemistry education.

However, these facilitated learning modules' objectives and content have to be evaluated first before they can be used by the intended users. May I request you then to evaluate the modules by answering this questionnaire? Your honest and sincere comments in this activity is highly appreciated.

Directions: Please indicate the extent of your agreement or disagreement to the statements written below. You may encircle the number that serves as your answer. Your choices would be:

Strongly agree	4
Agree	3
Disagree	2
Strongly disagree	1

Statements 1-15 refer to the manner on how the objectives of the learning modules will be formulated.

Attainability	1	2	3	4
1. The objectives are formulated within the learning capabilities of the intended end-users.	1	2	3	4
2. The topics in each module can be covered within the allotted time indicated in the module.	1	2	3	4
3. The objectives of the learning modules are formulated based on the general objectives of the course syllabus				

4. The time element for realizing the objectives of the learning modules is based on the course syllabus time frame	1	2	3	4
5. The objectives are stated in a measurable, realistic, and time bounded manner	1	2	3	4
Clarity				
6. The objectives of the facilitated learning modules clearly state what the students must achieve.	1	2	3	4
7. The objectives are formulated using simple words which can easily be understood by the intended users.	1	2	3	4
8. The objectives are stated in terms of student learning outcomes.	1	2	3	4
9. Upon reading the objectives, the students will have an idea about the coverage of the learning module.	1	2	3	4
10. The objectives of the learning modules serve as instructions which are clear, unambiguous, and easy to follow.	1	2	3	4
Relevance				
11. The objectives serve as guide for the formation of instructional activities.	1	2	3	4
12. The objectives serve as an information disseminator about the expectations of the teachers on student performance.	1	2	3	4
13. The objectives will guide the teachers on what they ought to cover in the class.	1	2	3	4
14. The objectives will guide the students on what they ought to learn in this course.	1	2	3	4
15. The objectives serve as target statements that will guide the end-users about the standards and expectations of the course.	1	2	3	4

Statements 16-34 refer to the content of the learning modules.

Appropriateness

16. The concepts presented in these learning modules conform to the accepted principles in chemistry education.	1	2	3	4
17. The activities in the learning modules are appropriate in helping students understand the concepts and principles.	1	2	3	4
18. The contents are appropriate to meet the objectives of the facilitated learning modules.	1	2	3	4
19. The learning activities are designed to guide the students in realizing the objectives of the facilitated learning modules.	1	2	3	4
20. The contents of the learning modules are suitable to the understanding level of the students.	1	2	3	4

Appeal

21. The learning modules are expected to capture the interest of the reader	1	2	3	4
22. The approaches adopted by the writer in presenting the concepts and examples sustain the reader`s interest.	1	2	3	4
23. Graphics included in the learning modules are balanced and help in sustaining the interest of the reader.	1	2	3	4
24. In general, the facilitated learning modules are attractively packaged.	1	2	3	4
25. The learning modules have been presented in a technically appropriate manner.	1	2	3	4
26. The layout of the learning modules combines attractiveness with utility.	1	2	3	4

Innovativeness

27. The writer has developed a unique way of presenting the concepts and principles.	1	2	3	4
28. The solutions to learning exercises are presented in a distinct manner that students can easily understand.	1	2	3	4
29. The learning modules are carefully designed thus, showing novelty.	1	2	3	4
30. The facilitated learning modules exhibit originality.	1	2	3	4

Conformity to standards

31. The Minimum Learning Competencies for analytical chemistry as prescribed by the Commission on Higher Education are included in the facilitated learning modules.	1	2	3	4
32. The contents of the facilitated learning modules cover the important concepts and principles for chemistry instruction.	1	2	3	4
33. The tables and figures in these learning modules are appropriately presented for chemistry instruction.	1	2	3	4
34. The solutions to learning exercises in the facilitated learning modules are presented following the steps acceptable for chemistry instruction.	1	2	3	4

Appendix C. Romey's Student Involvement Index

Purpose: To determine the extent at which students have performed other activities while reading the Facilitated Learning Modules

Procedures:

1. Randomly select twenty pages of your module.
2. Starting with the first paragraph on each page, classify the first twenty five sentences according to the categories shown in the table.
3. For each page, from page 1 to page 20 (P_1 to P_{20} in the table), count the total number of sentence for each category.
4. Compute the Student Involvement Index as follows:

$$\text{Student Involvement Index} = \frac{\text{Total Number of Sentences in Category B}}{\text{Total Number of Sentences in Category A}}$$

Category	Number of Sentences					Total
	P_1	P_2	P_3	………	P_{20}	
A. 1. Facts 2. Stated conclusion 3. Definitions 4. Questions answered immediately						
Total for A						
B. 1. Questions requiring students to analyze data 2. Statement requiring student to formulate conclusion 3. Directions to students to perform and analyze some activity and solve problems						
Total for B						

$$\text{Student Involvement Index} = \frac{\text{Total for B}}{\text{Total for A}}$$

Appendix D. Fry Graph Readability Formula

Purposes:

1. To determine the grade level of the Facilitated Learning Modules; and
2. To determine whether the grade level of the Facilitated Learning Modules matches with the grade level of the intended users.

Procedures:

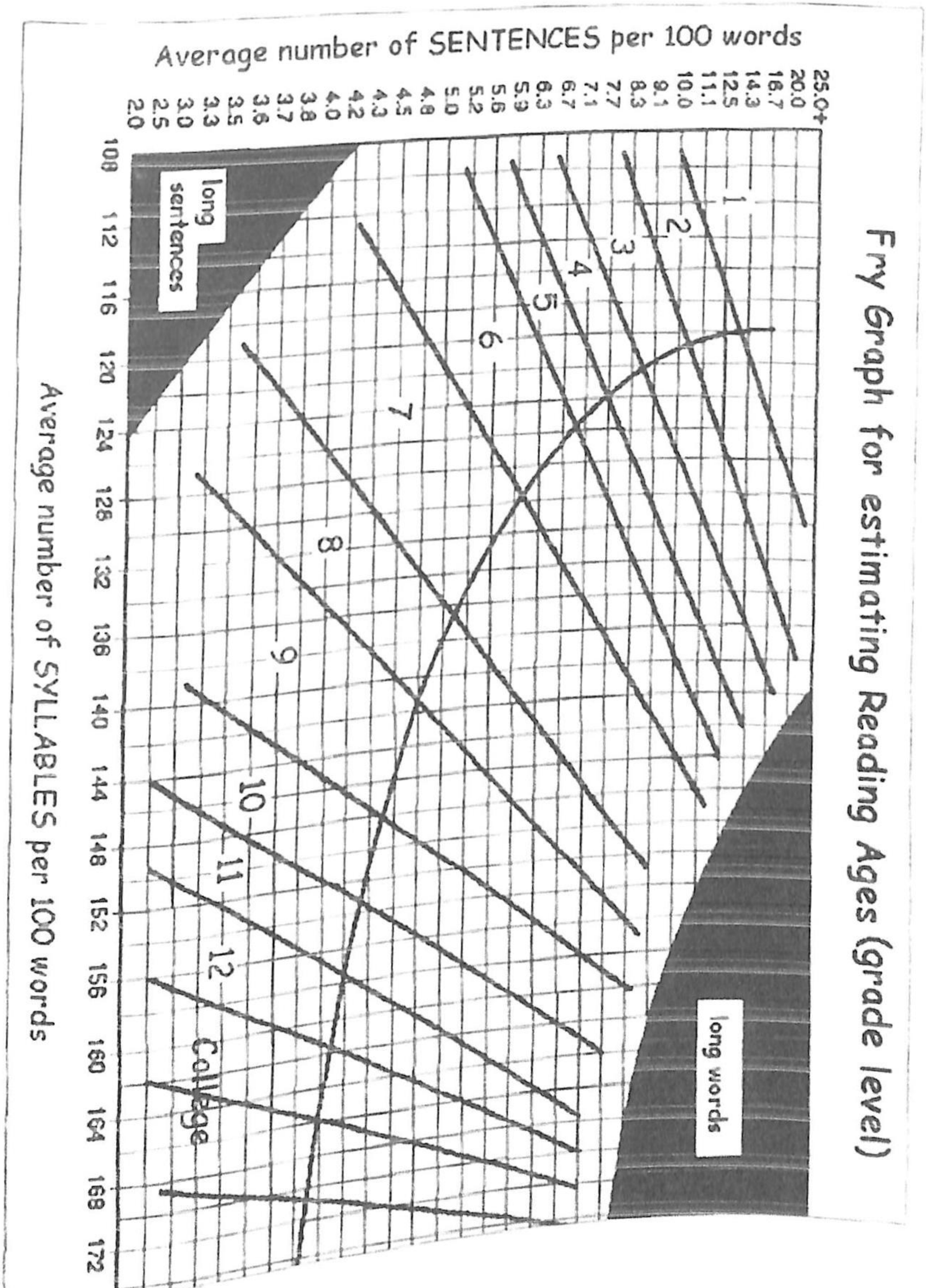
1. Skipping proper nouns, count 100 words in the first page, middle page and last page. If the first or middle page has less than 100 words, proceed to the next page. If the last page has less than 100 words, start counting in the previous page. Count as one word the article "a", the pronoun, "I", and contractions like "you're". Count the number of sentences in each of the three 100-word samples.

2. Count the number of syllables in each of the three 100-word samples. (Each numeral is a syllable. For example, 2010 is 4 syllables - - two-tou-sand-ten - - and one word.)

3. Compute the average number of sentences and the average number of syllables of the three samples.

	Number of Sentences	Number of Syllables
First page		
Middle page		
Last page		
Average		

4. Plot on the graph the point with the average number of sentences as y-coordinate and the average number of syllables as the x-coordinate. Read the approximate grade level of the area where the point lies. Subtract two grade levels. The grade levels in the readability graph are based on norms in the United States at the time the data were collected. The local norm is two grade levels lower.


Fry Graph for estimating Reading Ages (grade level)
Average number of SENTENCES per 100 words
25.0+
20.0
16.7
14.3
12.5
11.1
10.0
9.1
8.3
7.7
7.1
6.7
6.3
5.9
5.6
5.2
5.0
4.8
4.5
4.3
4.2
4.0
3.8
3.7
3.6
3.5
3.3
3.0
2.5
2.0
Average number of SYLLABLES per 100 words
108
112
116
120
124
128
132
136
140
144
148
152
156
160
164
168
172
long sentences
long words
1
2
3
4
5
6
7
8
9
10
11
12
College

Appendix E. Talisayon's Communication Index

Purpose: To determine whether the readability level of the Facilitated Learning Modules is acceptable for the intended users.

Procedures:

1. Identify ten students who have already taken the course. Reproduce ten copies of the moduleas guide for these students in performing the activity.

2. Request the students to read the module and list those words, figures and tables in the modules that they find unclear as they go through the modules.

3. Use the 100-word samples that you have considered in determining the readability of the modules. Form the listed unclear words, use only those found in these samples. Count the number of students who found a word in these samples unclear. Do these for all unclear words in the samples. The total number of words, Nx, is 300 words (3 samples x 100 words per sample). Also count the total number of students, Ns.

4. The communication index, CI, for words of the module:

$$CI = \frac{\text{Sum of (fX)}}{(Nr)(Nx)}$$

where:

X = number of readers indicating a given unclear word

f = number of times unclear word appears in the samples of words

Ns = total number of readers

Nr = total number of words in the samples

For example, five words, X_1, X_2, X_3, X_4, and X_5 are found unclear out of 300 words in the three samples. Suppose that X_1 appears twice and X_3 appears thrice in the samples. This makes the total number of unclear words, Nx, eight. Suppose further that the number of students who found these words unclear are $X_1 = 7$, $X_2 = 3$, $X_3 = 1$, $X_4 = 2$, and $X_5 = 10$. Then the CI is

$$CI = \frac{(2)(7)(1)+(3)(1)+(3)(1)(1)+(2)(1)+(10)(1)}{(300)(8)}$$

$$= 0.01$$

5. The range of acceptable values for CI is: $0 \leq CI \leq 0.01$. Hence, in the example, the CI has reached the maximum acceptable value of 0.01.

Appendix F. Sample Questions of the Pretest in Mathematics and Statistics

PRETEST ON MATHEMEMATICS AND STATISTICS FOR INTRODUCTORY ANALYTICAL CHEMISTRY

Sample Questions:

1. Which measure of central tendency is the most appropriate to use to describe the monthly income of the different families residing in Koronadal City?
   a. Mean b. Median c. Mode d. both A and C

2. Data were collected on the number of minutes spent in cooking a meal. The data are as follows: 8, 10, 15, 25, 30, 40, 12, 20, and 19. What is the range of this data?
   a. 24 b. 22 c. 32 d.48

3. Which of the following is an inexact number?
   a. the number of microseconds in a week
   b. the number of milliliters in a cubic meter of water
   c. the mass of a postage stamp
   d. the temperature of the loaf bread in the oven

4. The recommended adult dose of Elixophillin®, a drug used to treat asthma, is 6.00 mg/kg of body mass. Calculate the dose in milligrams for a 150.0 lb person with the correct number of significant figure. (1 kg = 2.205 lb)
   a. 68 b. 10200 c. 204 d. 408

5. Two alcohol solutions of different strengths have volumes of 40m³ containing 35% alcohol and 20 m³ contains 50% alcohol. If both mixtures are mixed together determine the percentage of alcohol in the combined mixture?
   a.40% b. 38% c. 39% d. 41%

6. What is the value $\frac{6a^2b^3}{9}$ of if a =2 and b = 3?
   a. 18 b. 24 c. 36 d. 72

Appendix G. Sample Questions of the Posttest on the Knowledge of Application of Mathematical and Statistical Tools and Knowledge of Introductory Analytical Chemistry

A. Sample Questions of Knowledge of Introductory Analytical Chemistry

1. This describes the nearness of an experimental value to the mean or to the true value.
   a. precision b. accuracy c. relative error d. deviation

2. Which of the following is **not** a unit of concentration?
   a. part per million b. g/L-min c. normal d. mol/L

3. Refer to the following thermochemical equation:

   2 C (g) + 2 D (g) ⇔ 3 E (g) + F (g; $\Delta H < 0$

   Predict the direction of the shift in equilibrium if the temperature is increased.

   a. forward b. backward
   c. no change d. forward then backward

B. Sample Questions of Knowledge of the Application of Mathematical and Statistical Tools

1. Sewage and industrial pollutants dumped into a body of water can reduce the dissolved oxygen concentration and adversely affect aquatic species. In one study, weekly readings are taken from the same location in a river over a two-month period.

Weak Number	1	2	3	4	5	6	7	8
Dissolved O_2, ppm	4.9	5.1	5.6	4.3	4.7	4.9	4.5	5.1

   Some scientists think that about 5.0 ppm is a dissolved O_2 level that is marginal for fish to live. (a) Conduct a statistical test to determine whether the mean dissolved O_2 concentration is less than 5.0 ppm at the 95% confidence level. State clearly the null and alternative hypotheses. (b) The week 3 measurement in the data set is suspected of being an outlier. Use the Q test to determine if the value can be rejected at the 95% confidence level.

2. (a) A 0.085 M solution of phenylacetic acid ($HC_8H_7O_2$) is found to have a pH of 2.68. Calculate the K_a value for this acid and the percent ionization. The acid-dissociation constant for benzoic acid ($HC_7H_5O_2$) is 6.3×10^{-5}. (b) Calculate the equilibrium concentrations of H_3O^+, $C_7H_5O_2^-$, and $HC_7H_5O_2$ in the solution if the initial concentration of $HC_7H_5O_2$ is 0.05 M.

Appendix H-1. Student Feedback Journal on the Conduct of Facilitated Learning Activities

Student Feedback Journal on the Conduct of Facilitated Learning Activities
(Experimental Group)

Dear ____________________:

I have prepared seven facilitated learning modules on essential mathematical and statistical tools employed in introductory analytical chemistry. The facilitated learning modules aim to help students enhance their mathematical and statistical skills and to deepen their understanding of the analytical chemistry concepts. I prepared facilitated learning modules as supplementary learning materials which were used in conjunction with facilitated learning instructions. Facilitated learning instruction includes peer mentoring, on-demand tutorials, and online group discussion and file sharing, which we adopted in our analytical chemistry class.

In this respect, I would like to request you to assess the conduct of the peer mentoring, the on-demand tutorial, and the online group discussion and file sharing. Rest assured that your answers shall only be used for this study. I thank you four time and cooperation for the success of this academic endeavor.

Please write your answers to the questions on the space provided. You may use additional sheet/s of paper if necessary. Please indicate whether you are a *mentor* or a *mentee*.

A) Peer Mentoring

1) As a mentor/ mentee, describe how the peer mentoring helped you address your difficulty in solving problems and in understanding concepts in analytical chemistry.

2) Please describe how the use of facilitated learning modules as supplementary learning materials helped the group in the conduct of peer mentoring.

Student Feedback Journal on the Conduct of Facilitated Learning Activities
(Experimental Group)

continued...

3) Please describe certain problem/s you encountered regarding the conduct of peer mentoring.

4) Would you recommend peer mentoring to be adopted for other chemistry classes? Why or why not?

B) On-demand Tutorial

1) Describe how on-demand tutorial helped you address your difficulty in solving problems and in understanding concepts in analytical chemistry.

2) Please describe how the use of facilitated learning modules as supplementary learning materials helped you in the conduct of on-demand tutorial.

3) Would you recommend on-demand tutorial to be adopted for other chemistry classes? Why or why not?

Student Feedback Journal on the Conduct of Facilitated Learning Activities
(Experimental Group)

continued...

C) Online Group Discussion and File Sharing

1) Describe how online group discussion and file sharing helped you address your difficulty in solving problems and in understanding concepts in analytical chemistry.

2) Please describe how the use of facilitated learning modules as supplementary learning materials helped you in the conduct of online group discussion and file sharing.

3) Would you recommend online group discussion and file sharing to be adopted for other chemistry classes? Why or why not?

Appendix H-2. Student Feedback Journal on the Conduct of Facilitated Learning Activities

Student Feedback Journal on the Conduct of Facilitated Learning Activities
(Control Group)

Dear ____________________:

Our analytical chemistry class adopted facilitated learning instruction this semester. Facilitated learning instruction includes peer mentoring, on-demand tutorials, and online group discussion and file sharing. This strategy was aimed to help you enhance your mathematical and statistical skills and to deepen their understanding of the analytical chemistry concepts.

In this respect, I would like to request you to assess the conduct of the peer mentoring, the on-demand tutorial, and the online group discussion and file sharing. Rest assured that your answers shall only be used for this study. I thank you four time and cooperation for the success of this academic endeavor.

Please write your answers to the questions on the space provided. You may use additional sheet/s of paper if necessary. Please indicate whether you are a *mentor* or a *mentee*.

A) Peer Mentoring

1) As a mentor/ mentee, describe how the peer mentoring helped you address your difficulty in solving problems and in understanding concepts in analytical chemistry.

2) Did you find textbook sufficient in the conduct of peer mentoring? Why or why not?

3) Please describe certain problem/s you encountered regarding the conduct of peer mentoring.

Student Feedback Journal on the Conduct of Facilitated Learning Activities (Control Group)

continued...

4) Would you recommend peer mentoring to be adopted for other chemistry classes? Why or why not?

B) On-demand Tutorial

1) Describe how on-demand tutorial helped you address your difficulty in solving problems and in understanding concepts in analytical chemistry.

2) Did you find textbooks sufficient in the conduct of on-demand tutorial? Why or why not?

3) Would you recommend on-demand tutorial to be adopted for other chemistry classes? Why or why not?

Student Feedback Journal on the Conduct of Facilitated Learning Activities
(Control Group)

continued...

C) Online Group Discussion and File Sharing

1) Describe how online group discussion and file sharing helped you address your difficulty in solving problems and in understanding concepts in analytical chemistry.

____

2) Did you find textbooks sufficient in the conduct of online group discussion and file sharing? Why or why not?

____

3) Would you recommend online group discussion and file sharing to be adopted for other chemistry classes? Why or why not?

____

Appendix I. Student Feedback Journal on the Use of Facilitated Learning Modules

Student Feedback Journal on the Use of Facilitated Learning Modules

Dear Student,

I have prepared several facilitated learning modules on essential mathematical and statistical tools employed in introductory analytical chemistry. The facilitated learning modules aim to help students enhance their mathematical and statistical skills and to deepen their understanding of the analytical chemistry concepts. I prepared facilitated learning modules as supplementary learning materials which were used in conjunction with facilitated learning instructions. Facilitated learning instruction includes peer mentoring, on-demand tutorials, and online group discussion and file sharing.

In this respect, I would like to request you to evaluate the use of facilitated learning modules as supplementary learning materials in conjunction with facilitated learning instruction. Please write your answers to the questions on the space provided. You may use additional sheet/s of paper if necessary. Please indicate whether you are a *mentor* or a *mentee*.

1) Please describe the facilitated learning modules' objectives in terms of attainability, clarity, and relevance.

2) Please describe the facilitated learning modules' contents in terms of appropriateness, innovativeness, appeal, and conformity to standards.

3) What do you think are the characteristic features of the facilitated learning modules that are useful in understanding the mathematical manipulations involved in solving analytical chemistry problem?

4) Please describe how the facilitated learning modules helped you in enhancing your mathematical and statistical skills in solving analytical chemistry problems and your understanding of introductory analytical chemistry.

Appendix J. Pretest and Posttest Scores of Control Group

Student	Pretest Scores	Posttest Scores		
		Application of Mathematical and Statistical Tools	Knowledge in Introductory Analytical Chemistry	Total
1	19	35	28	63
2	25	53	40	93
3	28	32	35	67
4	16	62	29	91
5	26	56	29	85
6	21	49	18	67
7	22	9	39	51
8	29	60	40	100
9	23	10	11	21
10	23	17	19	36
11	23	20	13	33
12	23	50	30	80
13	26	54	36	90
14	19	16	27	43
15	16	41	20	61
16	19	49	31	80
17	16	60	27	87
18	17	13	18	31
19	26	45	35	80
20	17	24	17	41
21	29	62	34	94
22	28	26	29	55
23	24	56	25	81
24	19	22	17	39
25	23	56	35	91
26	24	33	31	64
27	16	31	24	55
28	23	34	21	55
29	16	33	25	58
30	31	54	40	94
31	15	40	31	71
32	14	17	17	34
33	16	11	23	34
34	24	47	24	71
35	22	36	28	64
36	38	74	47	121
37	20	34	24	58
38	19	24	22	46
39	12	4	18	22
40	26	46	29	75
41	25	33	32	65
42	22	7	19	26
43	16	34	22	56
44	16	18	18	36
45	21	54	33	87
46	15	20	6	26
47	27	56	37	93
48	20	13	20	33
49	22	36	27	63

Appendix K. Pretest and Posttest Scores of Experimental Group

Student	Pretest Scores	Posttest Scores		
		Application of Mathematical and Statistical Tools	Knowledge in Introductory Analytical Chemistry	Total
1	16	19	17	36
2	17	36	20	56
3	23	40	24	64
4	19	68	36	104
5	18	31	22	53
6	20	27	28	55
7	17	36	30	66
8	26	48	35	83
9	14	22	21	43
10	25	72	31	103
11	20	60	39	99
12	18	23	22	45
13	18	40	29	69
14	30	48	39	87
15	21	61	30	91
16	19	55	35	90
17	24	28	22	50
18	21	37	29	66
19	22	29	30	59
20	26	67	35	102
21	25	54	29	83
22	10	33	22	55
23	22	36	24	59
24	11	39	34	73
25	16	53	34	87
26	15	24	10	34
27	17	37	19	56
28	25	45	42	87
29	16	41	27	68
30	21	58	37	95
31	23	29	22	51
32	18	35	31	66
33	20	29	34	63
34	19	16	25	41
35	15	31	26	57
36	31	72	39	111
37	27	38	35	73
38	19	63	27	90
39	28	59	33	92
40	21	46	38	84
41	18	19	14	33
42	21	54	26	80
43	18	30	25	55
44	19	23	22	45
45	26	25	25	50
46	18	43	31	74

Appendix L. Sample of Instructors' Ratings on the Evaluation of the Facilitated Learning Modules

Development of Facilitated Learning Modules

Dear ________________:

ave prepared seven facilitated learning modules on essential and mathematical tools employed in introductory analytical chemistry. These facilitated learning modules aim to help students enhance their mathematical and statistical and to deepen their understanding of the analytical chemistry concepts. I prepared facilitated learning modules as supplementary learning materials which will be used in conjunction with facilitated learning instructions. The form and face content of these facilitated learning modules had already been evaluated by experts in chemistry education.

However, these facilitated learning modules' objectives and content have to be evaluated first before they can be used by the intended users. May I request you then to evaluate the modules by answering this questionnaire? Your honest and sincere comments in this activity is highly appreciated

Directions: Please indicate the extent of your agreement or disagreement to the statements written below. You may encircle the number that serves as your answer. Your choices would be:

Strongly agree	4
Agree	3
Disagree	2
Strongly disagree	1

Statements 1-15 refer to the manner on how the objectives of the learning modules will be formulated.

Attainability				
1. The objectives are formulated within the learning capabilities of the intended end-users.	1	2	3	(4)
2. The topics in each module can be covered within the allotted time indicated in the module.	1	2	3	(4)
3. The objectives of the learning modules are formulated based on the general objectives of the course syllabus	1	2	3	(4)

4. The time element for realizing the objectives of the learning modules is based on the course syllabus time frame	1	2	3	4
5. The objectives are stated in a measurable, realistic, and time bounded manner	1	2	3	4

Clarity

6. The objectives of the facilitated learning modules clearly state what the students must achieve.	1	2	3	4
7. The objectives are formulated using simple words which can easily be understood by the intended users.	1	2	3	4
8. The objectives are stated in terms of student learning outcomes.	1	2	3	4
9. Upon reading the objectives, the students will have an idea about the coverage of the learning module.	1	2	3	4
10. The objectives of the learning modules serve as instructions which are clear, unambiguous, and easy to follow.	1	2	3	4

Relevance

11. The objectives serve as guide for the formation of instructional activities.	1	2	3	4
12. The objectives serve as an information disseminator about the expectations of the teachers on student performance	1	2	3	4
13. The objectives will guide the teachers on what they ought to cover in the class.	1	2	3	4
14. The objectives will guide the students on what they ought to learn in this course	1	2	3	4
15. The objectives serve as target statements that will guide the end-users about the standards and expectations of the course.	1	2	3	4

Statements 16-34 refer to the content of the learning modules.

Appropriateness

16. The concepts presented in these learning modules conform to the accepted principles in chemistry education.	1	2	3	4
17. The activities in the learning modules are appropriate in helping students understand the concepts and principles.	1	2	3	4
18. The contents are appropriate to meet the objectives of the facilitated learning modules.	1	2	3	4
19. The learning activities are designed to guide the students in realizing the objectives of the facilitated learning modules.	1	2	3	4
20. The contents of the learning modules are suitable to the understanding level of the students.	1	2	3	4

Appeal

21. The learning modules are expected to capture the interest of the reader	1	2	3	4
22. The approaches adopted by the writer in presenting the concepts and examples sustain the reader's interest.	1	2	3	4
23. Graphics included in the learning modules are balanced and help in sustaining the interest of the reader.	1	2	3	4
24. In general, the facilitated learning modules are attractively packaged.	1	2	3	4
25. The learning modules have been presented in a technically appropriate manner.	1	2	3	4
26. The layout of the learning modules combines attractiveness with utility.	1	2	3	4

Innovativeness

27. The writer has developed a unique way of presenting the concepts and principles.	1	2	3	4
28. The solutions to learning exercises are presented in a distinct manner that students can easily understand.	1	2	3	4

	1	2	3	4
29. The learning modules are carefully designed thus, showing novelty.	1	2	(3)	4
30. The facilitated learning modules exhibit originality.	1	2	(3)	4
Conformity to standards				
31. The Minimum Learning Competencies for analytical chemistry as prescribed by the Commission on Higher Education are included in the facilitated learning modules.	1	2	3	(4)
32. The contents of the facilitated learning modules cover the important concepts and principles for chemistry instruction.	1	2	3	(4)
33. The tables and figures in these learning modules are appropriately presented for chemistry instruction.	1	2	(3)	4
34. The solutions to learning exercises in the facilitated learning modules are presented following the steps acceptable for chemistry instruction.	1	2	3	(4)

Sample of Comments and Suggestions of Analytical Chemistry Instructors

(1)

Comments and suggestions:

The module writer emphasized the usefulness of statistics in the beginning paragraphs of Module I. I think citing the application of the topics in the daily activities of the students is important to motivate them to keep reading the modules.

(2)

The topics included are appropriate for the age of the intended users. The discussions are clearly presented that can easily be understood by the students. Also, the minimum learning competencies set by the CHED were met.

Appendix M. Average Scores in the Seven (7) Modules

Module	Control Group				Experimental Group			
	Application of Mathematical and Statistical Tools		Knowledge in Introductory Analytical Chemistry		Application of Mathematical and Statistical Tools		Knowledge in Introductory Analytical Chemistry	
	Total Points	Average Scores	Total Points	Average Scores	Total Points	Average Scores	Total Points	Average Scores
1	8	5.22	4	3.11	8	6.12	4	3.13
2	12	6.31	8	3.74	12	7.95	8	5.06
3	12	5.46	8	5.38	12	7.03	8	5.41
4	12	4.71	8	2.98	12	4.83	8	3.04
5	12	4.56	8	3.10	12	3.76	8	2.65
6	12	4.19	8	3.95	12	4.67	8	3.72
7	10	5.93	8	4.13	10	6.71	8	5.19

Appendix N. Excerpts from CMO No. 18, series 2007 (Learning Competencies in Analytical Chemistry)

15.3 ANALYTICAL CHEMISTRY

INTRODUCTION

Analytical Chemistry 1 and 2 are designed to be problem-driven and emphasize critical thinking. It should be supplemented with topics that are relevant to the practice of chemistry, as well as those that students confront in their lives.

OBJECTIVES OF SUBJECT AREA

The courses covered by the Analytical Chemistry subject area provide the basic methods and skills needed in the more advanced courses, as well as in industry. The overall objectives of the subject area include the following:

a. To acquire mastery of the principles and practice of quantitative chemical analysis;
b. To obtain a working knowledge of the applications of statistics in Analytical Chemistry; and
c. To gain an in-depth understanding of the applications of Analytical Chemistry in industry, agriculture, molecular biology, medical sciences, and others.

Appendix O. The Facilitated Learning Modules

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Facilitated Learning Modules on Mathematical and Statistical Tools in Introductory Analytical Chemistry

Chem 127 (Analytical Chemistry)

2nd Semester 2015 – 2016

Marzokie M. Mocsir

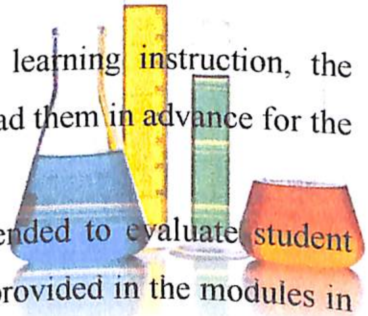
Teacher's Guide

This instructional material is formulated as supplemental learning materials in analytical chemistry. It primarily aims to make students understand the essential mathematical and statistical tools in solving problems in the subject. The learning modules explain exhaustively the mathematics and statistics encountered in solving problem for the students to understand the procedure and be able to solve the problems themselves.

It is recommended that teachers adopt the facilitated learning instruction as a classroom teaching approach. In this approach, the teacher must focus on developing students' skills; that is students must be involved in activities that require higher-order thinking – solving problem is an instance to it. The teacher must consider this supplemental learning material as an aid in simplifying the applications of mathematics and statistics as tools in analytical chemistry.

The following are recommended for teachers who will be using this instructional material:

1. The teacher must emphasize that the class will utilize the learning modules exclusively for learning purposes.
2. The teacher shall start the lecture using facilitated learning instruction in delivering the topic for the day. It must be noted that the discussion within the allotted time per day is not sufficient to tackle problem solving comprehensively. Moreover, the presentation of the procedures or solutions in textbooks are beyond the comprehension level of the students considering their limited background in mathematics and statistics. Hence, the modules must be used as essential supplemental learning materials.
3. For the successful implementation of the facilitated learning instruction, the teacher must give the learning modules to students to read them in advance for the smooth conduct of classroom activities.
4. Assignments, quizzes, reports and other activities intended to evaluate student performance can be developed based on the examples provided in the modules in



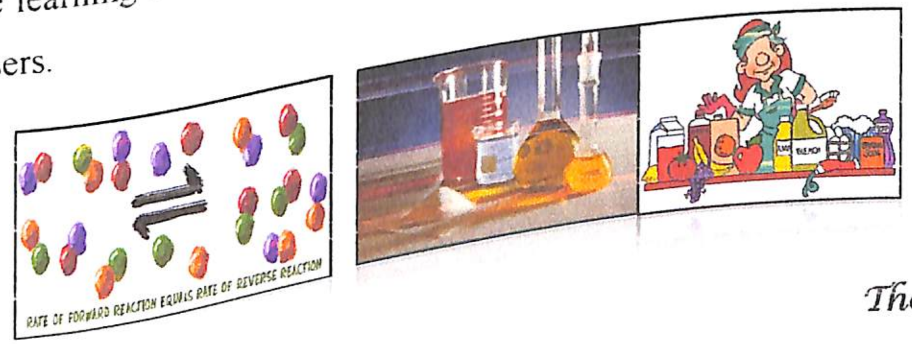
as far as mathematical and statistical applications are concerned. However, other items which the teacher believes would help develop students' critical thinking skills may also be included.

Foreword

Analytical chemistry is perceived as a difficult subject because it tackles not only chemical theories and principles but also the applications of chemical concepts utilizing mathematics and statistics. Medical technology students find the subject even more difficult because of their limited background in mathematics and statistics. It is in this premise that this supplemental learning material is formulated.

The sequence of modules are patterned on the sequence of topics in the syllabus of analytical chemistry existing at the Natural Sciences and Mathematics Department of Notre Dame of Marbel University. Modules on all topics requiring mathematic and statistics are formulated. References cited in the syllabus are revisited to find alternative and simplified mathematical procedures in solving problem in a manner that can easily be understood by students.

The development of the learning modules started with the assistance of chemistry education experts particularly on the forms and contents. The author also sought the assistance of teachers handling analytical chemistry to evaluate the learning modules in terms of their contents and objectives more specifically on how these modules would appear to capture the interest of the end users – the students. Former analytical chemistry students are requested to identify chemical or mathematical terms and procedures that they find difficult. These terms and procedures are revised in a manner that students can easily understand when reading the modules. Further, the author determined the grade level of the learning modules to ensure that the materials matches the grade level of the intended users.



The author

Table of Contents

MODULE 1
STATISTICAL TESTING FOR TREATMENT OF DATA I

Introduction

Let me begin my lecture by recalling some essential information you already knew about this topic. Let me ask you few questions before I start my discussions.

Why is experiment necessary to subjects like chemistry? What activities were carried out when you performed your experiment? What did you obtain when you performed your experiment? How did you manipulate the results of your experiment? What did you do then with these manipulated results?

You are all made aware that being an experimental science, chemistry involves laboratory activities designed to explain scientific theories. In your general chemistry laboratory, you did not only measure the value of the scientific property but you also gathered data as part of the experimentation. Perhaps the bigger challenge that you encountered was how you were going to manipulate or treat the data systematically in order to find the value of the property that was being measured.

Interestingly, statistics will teach you how to manipulate or treat experimental data systematically. As a scientific study, statistics is not only used in treating experimental data as it is also utilized extensively in almost all fields of disciplines. One common situation that every one of you might have already encountered is finding the simple mean or the average of the values. This is a situation that we usually experience not only in the laboratory particularly in treatment of data but also in every day activity.

This module covers the introductory concepts of statistics. The topics that I included in this module are pre-requisite to statistical testing and treatment of data. Some of these topics might have already been discussed in high school mathematics. But because of their extensive use in the statistical treatment of data in introductory analytic chemistry, it is necessary that we review these topics.

The last part of this module tackles essential mathematical tools in measurement. We will also review the rules and calculations involving significant figures and dimensional analysis. Although this is not part of the regular analytical chemistry course, its application is still useful in some topics in analytical chemistry.

Facilitated Learning Activity

PEER Mentoring

Because we are adopting facilitated learning instruction, you will perform *peer mentoring* as your learning activity while you are using this module. Peer mentoring is a group activity in which one of the members is designated as *mentor* and the rest of the group as *mentees*. The mentor will perform the role of a tutor or a teacher of the group. He/ She will act as leader of the group and will ensure that the group closely executes the activities in the module.

Here are the mechanics and guidelines of the peer mentoring activity:

(a) The mentor will introduce the topic to be tackled in the session.

(b) To start the session, the mentor will ask the mentees about possible problems or difficulties the group members encountered in the classroom when the teacher introduced the topic.

(c) The mentees will tell the mentor which specific topics are to be tackled for the session.

(d) The mentor starts the discussion of the topic to specifically address the problems or difficulties raised by the members. If the mentor is not so confident to impart the lesson to the mentees, he / she may ask other member of the group to act as mentor.

(e) The peer mentoring activity should maximize the use of this learning module as a supplemental learning material in the entire mentoring activity.

(f) The mentor should ensure that every member of the group is given the chance to ask, react, or suggest something pertaining to the topic during the course of the activity.

(g) The mentor may give the evaluation test and assign problem sets if such are necessary.

(h) The peer mentoring activity should be conducted during the period specified by the instructor. However, the group may be allowed to conduct the activity in their houses if longer time is needed to finish the session for the day.

(i) The mentoring activity should be conducted at least twice per week with at least 1.5 hours each session.

(j) The mentor is required to submit one narrative report at the end of the semester.

OBJECTIVES

After the end of the module, you should be able to:

- differentiate the three expressions of central value particularly on how these are computed and used appropriately to describe a set of data;

1. differentiate qualitatively between precision and accuracy;
2. compute absolute error, relative error, and percent error;
3. compute average deviation, standard deviations of the sample and the population, and the pooled standard deviation of the population;
4. differentiate between exact and inexact numbers;
5. report measured data accurately with the correct number of significant figures based on the accuracy of the instrument used;
6. report accurately the answers of performing various arithmetic operations with the correct number of significant figures; and
7. convert a given unit into the desired unit using dimensional analysis.

TIME FRAME: 4.5 hours; at least two mentoring sessions

CHECK-UP TEST

Before we proceed, let us first check your prior knowledge and skills on the topics included in this module. Please take the test below. For multiple-choice questions, just encircle the letter you think is the correct answer. Otherwise, provide the correct answer to the question. You have 30 minutes to do this.

1. This is the value that occurs with the highest frequency in a data set.
a. mean b. median
c. mode d.standard deviation

2. This is the value of the middle term in a data set that has been ranked in increasing order.
a. mean b. median
c. mode d. standard deviation

3. Find the mean, median, and mode for the following data set:4, 17, 9, 11, 26, 11, 13, 7, 22, and 11
a. mean = 15.1, median = 11, mode = 13
b. mean = 14.4,median = 18.5,mode = 11
c. mean = 12, median = 12,mode = 11
d. mean = 13.1,median = 11, mode = 11

4. Data were collected on the number of minutes spent in cooking a meal. The data are as follows: 8, 10, 15, 25, 30, 40, 12, 20, and 19. What is the range of this data?
a. 24 b. 22 c. 32 d.48

5. The more dispersed the data values in a particular data set are, the smaller the variance and standard deviation will be.
a. True b. False

6. Given the following data: 61.45, 61.53, and 61.32. If the accepted value for this data set is 61.71, what is the absolute error for the mean of the data set?

7. What is the percent relative error of the data set in item #6?

8. The following data is obtained for a sample with 9 measurements: 8.0, 2.0, 2.0, 7.0, 4.0, 6.0, 5.0, 3.0, and 4.0.Calculate the standard deviation for `this set.

9. The average weight of 8 people increases by 2.5 kg when a new person comes in place of one of them weighing 65 kg. What might be the weight of the new person?

10. A particular method for the determination of copper yields results that are low by 0.5 mg. What will be the percent relative error due to this source if the mass of the copper in a sample is 25 mg.

Check your answer against the KEY found at the end of this module.

How did you perform in the test? If your score is in the range 8-10, you are equipped to succeed in your study in this module. If you scored 6 or 7, you have the potential of doing far better. If you scored 4 or 5, you probably need to focus more on the reading materials and the mathematical procedure as we go along. But if your score is lower than 4, you need to review your past lessons of the subject. I advise you to retake the test until you get a score of 4 or better.

LESSON PROPER

Let me start my lecture by reviewing some fundamental concepts of statistics. You might have tackled this in your high-school mathematics or your previous algebra.

1.1 Central Value

Central value is expressed in three expressions and the use of each depends on how one wants to describe and interpret the data.

1.1.1 Arithmetic mean / Mean

The most common central value used by chemists is the *arithmetic mean*, $\bar{x}$, which is obtained by dividing the sum of the individual values by the number of values. Mathematically,

$$\bar{x} = \frac{x_1 + x_2 + x_3 + . \quad . \quad . + x_n}{n} = \frac{\sum x_i}{n}$$

where $x_1, x_2, x_3, \ldots, x_n$ are the individual values, n is the number of values, and $\sum x_i$ the sum of values of x.

1.1.2 Median

Another central value which is less commonly used is the *median*. It is the middle numerical value in a set of values.

Example 1-1

Find the median of the five values 20.4, 20.6, 20.1, 20.7, and 20.0.

Rules:

1) Rearrange the values from the lowest to the highest.
2) Identify the value that is physically located in the middle of the set of data.

20.0   20.1   <u>20.4</u>   20.6   20.7

When the set of data contains an even number of values, the median is the average of the two numerical values.

Example 1-2

Find the median of 20.4, 20.6, 20.1, and 20.7.

Rearranging,

20.1 20.4 20.6 20.7

middle numerical values = 20.4 and 20.6

The median is calculated as follows:

$$\text{median} = \frac{20.4 + 20.6}{2} = 20.5$$

1.1.3 Mode

The mode, which is not so common in analytical chemistry, of data is the value that is most frequently repeated in the data set.

Example 1-3

The mode of the data 20.2, 20.1, 20.0, 20.1, 20.4, 20.0, 20.1, and 20.7 is 20.1 because it appeared in the data the most frequent at three times.

Example 1-4

Calculate the mean and the median for each of the following sets of data:

Set A: 6.37, 6.33, 6.41, 6.80

Set B: 6.37, 6.33, 6.41, 6.93.

Solution

According to the definitions stated above, for data set A,

$$\bar{x} = \frac{6.37 + 6.33 + 6.41 + 6.80}{4} = \frac{25.91}{4} = 6.48$$

$$\text{median} = \frac{6.37 + 6.41}{2} = 6.39$$

For data set B,

$$\bar{x} = \frac{6.37 + 6.33 + 6.41 + 6.93}{4} = \frac{26.04}{4} = 6.51$$

$$\text{median} = \frac{6.37 + 6.41}{2} = 6.39$$

1.2 Precision and accuracy

The terms *precision* and *accuracy* are often used when dealing with the uncertainties of measured values. **Precision** is a measure of how closely individual measurements agree with one another while **accuracy** refers to how closely individual measurements agree with the correct, or "true," value. The dart analogy in Figure 1-1 illustrates the difference between these two concepts.

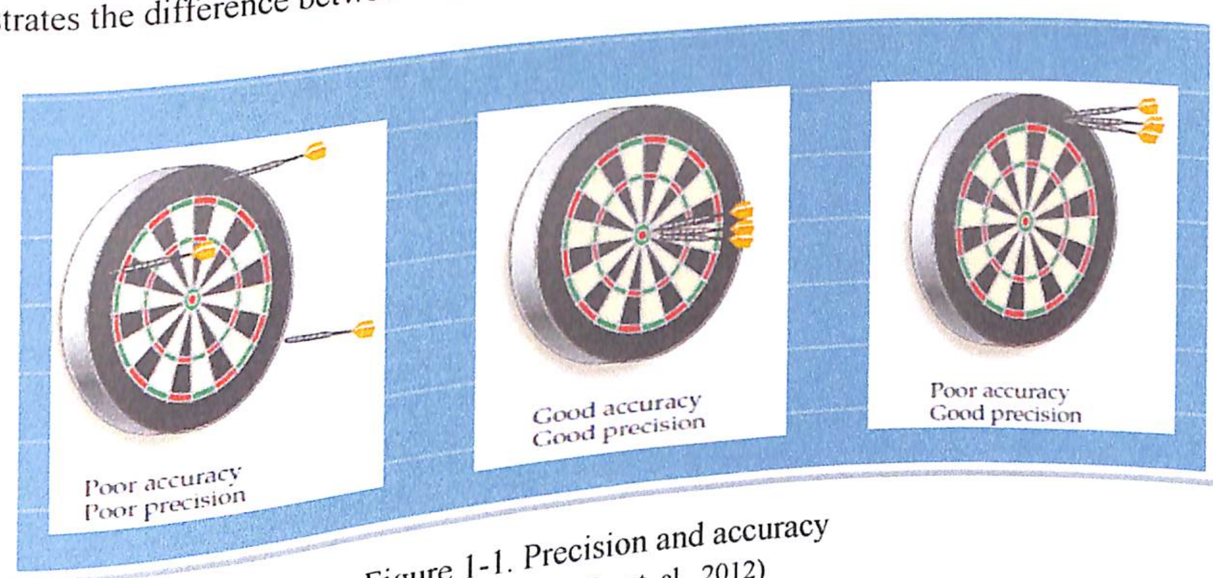


Figure 1-1. Precision and accuracy
(Source: Brown, T. L., et. al., 2012)

1.2.1 Expressions of accuracy

As defined, *accuracy* describes the nearness of an experimental value, x_i, or a mean, $\bar{x}$, to the true value, μ. It is expressed as error. The following are various expressions of error based on how it is computed.

Absolute error is calculated this way,

$$\text{error} = x_i - \mu \quad \text{or} \quad \bar{x} - \mu$$

Note: error carries the units of x_i, and μ.

Relative error is used when comparing errors at different quantities. It is calculated by dividing the absolute error by the true value as follows:

$$\text{relative error} = \frac{error}{\mu}$$

Relative error is often expressed by statisticians as pph or ppt, as defined below:

Parts per hundred (pph) or percent error is the relative error multiplied by 100. *Parts per thousand (ppt)* error is the relative error multiplied by 1000, and so on.

Notes from the author:

pph and ppt used as expressions of relative error should not be confused with or used interchangeably as the percent concentration (mass %, volume %, and mole %) and the ppt. Although the mathematical thought and the procedure of calculating them may be the same in some respect, percent concentration and ppt are some of the expressions of concentration.

Example 1-5

Calculate the absolute error, percent error, and parts per thousand error for the mean of the following data set.

x_i (mg)	8.33	8.29	8.28	8.34	8.36
μ (mg)	8.27				

Solution

To determine the error, you must calculated first the mean of the given data set:

$$\bar{x} = \frac{\sum x_i}{n} = \frac{8.33 + 8.29 + 8.28 + 8.34 + 8.36}{4} = \frac{41.60}{4} = 8.32$$

$$\text{error} = \bar{x} - \mu = 8.32 \text{ mg} - 8.27 \text{ mg} = 0.05 \text{ mg}$$

$$\% \text{ error} = \frac{error}{\mu} \text{ x } 100 = \frac{0.05\ mg}{8.27\ mg} \text{ x } 100 = 0.6$$

$$\text{ppt error} = \frac{error}{\mu} \text{ x } 1000 = \frac{0.05\ mg}{8.27\ mg} \text{ x } 1000 = 6$$

The *average error* is calculated like the average value or arithmetic mean except that the individual errors rather than the individual values are used.

1.2.2 Expressions of Precision

Precision, a term used often mistakenly used in place of accuracy, refers to the agreement between values in a set of data. The fact that the values of replicate measurements all agree well does not necessarily mean that they are close to the true value. There are several common ways to express the precision of data, as shown in the following:

1.2.2.1Average deviation (or mean deviation)

It is one of the methods of showing dispersion or way of ascertaining the deviation, taken *without regard to sign*, of the experimental value from the central value. The average deviation, $\bar{d}$, is found by summing the individual deviations and dividing by the number of measurements. Thus the average deviation from the mean is given by

$$\bar{d} = \frac{\sum | x_i - \bar{x} |}{n}$$

where $x_i =$ observation

$\bar{x} =$ mean of the observations

$n =$ number of observations

$| x_i - \bar{x} | =$ absolute value of the difference between an observation and the mean (inside the absolute value sign is always a positive number)

$\sum | x_i - \bar{x} | =$ sum of the absolute values of the differences between an observation and the mean

$\bar{d} =$ average deviation between the experimental values and the mean

Similar to accuracy, precision measurement such as average deviation can be expressed as an absolute error or as a relative error (% or pph, ppt, etc.)

1.2.2.2 Standard deviation of the sample

The standard deviation, s, or root-mean-square deviation as it is sometimes called, is the preferred measure of precision and is calculated from the equation

$$s = \sqrt{\frac{\sum(x_i - \bar{x})^2}{n - 1}}$$

where $x_i =$ observation

$\bar{x} =$ mean of the observations

$n =$ number of observations

$n - 1 =$ degree of freedom

$(x_i - \bar{x})^2 =$ square of the differences between an observation and the mean

$\Sigma(x_i - \bar{x})^2$ = sum of the squares of the differences between an observation and the mean

s = standard deviation or the measure of the spread of observations

The most common mistake made by students using this equation is they "square the sum of the deviations" rather than "sum the squares of the deviations". Look carefully at the following example to make sure that you learn to use the formula correctly.

Example 1-6

Quantitative analysis of student obtained the following results for the determination of isooctane in gasoline using Gas Chromatography.

Determination Number	Percent isooctane
1	3.83
2	3.97
3	3.94
4	3.88
5	3.94
6	3.90

Calculate the standard deviation from the mean.

Solution:

You can calculate the standard deviation of the given data set using the formula,

$$s = \sqrt{\frac{\Sigma(x_i - \bar{x})^2}{n-1}}.$$

The formula indicates that the mean is necessary. So you need to calculate first the mean.

$$\bar{x} = \frac{3.83 + 3.97 + 3.94 + 3.88 + 3.94 + 3.90}{6} = \frac{41.60}{4} = 3.91\%$$

x_i	$\lvert x_i - \bar{x} \rvert$	$(x_i - \bar{x})^2$
3.83	0.08	0.0064
3.97	0.06	0.0036
3.94	0.03	0.0009
3.88	0.03	0.0009
3.94	0.03	0.0009
3.90	0.01	0.0001
		$0.0128 = \sum(x_i - \bar{x})^2$

Substituting, you have

$$s = \sqrt{\frac{0.0128}{6 - 1}} = 0.051\%$$

Both average and standard deviations can also be expressed in relative terms to facilitate comparison between data sets:

$$\text{relative average deviation} = \frac{\bar{d}}{\bar{x}}$$

$$\text{relative standard deviation} = \frac{s}{\bar{x}}$$

Relative standard deviation (RSD) is also referred to as the *coefficient of variation*. Again, relative values can be expressed fractionally (as above), as parts per hundred or percent (multiplied by 100), as parts per thousand (multiplied by 1000), and so forth.

Range

The *range*, is the absolute difference between the largest and smallest values in the data set.

1.2.2.3 Pooled Standard Deviation

The equation for computing a pooled standard deviation from several sets of data takes the form. You use the formula given by Holler, F. and Crouch, S. (2014) to solve pooled standard deviation.

$$s_{pooled} = \sqrt{\frac{\sum_{i=1}^{N_1}(x_i - \bar{x}_1)^2 + \sum_{j=1}^{N_2}(x_j - \bar{x}_2)^2 + \sum_{k=1}^{N_3}(x_k - \bar{x}_3)^2 + \cdots}{N_1 + N_2 + N_3 + \cdots - N_t}}$$

where N_1 is the number of results in set 1, N_2 is the number in set 2, and so forth. The term N_t is the total number of data set pooled.

Now, I am going to demonstrate to you how to solve pooled standard deviation using the equation that I just mentioned. Consider the following example.

Example 1-7

Glucose levels are routinely monitored in patients suffering from diabetes. The glucose concentrations in a patient with mildly elevated glucose were determined at different months through a spectrophotometric analytical method. The patient was placed on a low sugar diet to reduce the glucose levels. The frequency of monitoring varies every month as shown below and the days of the month when monitoring is conducted are chosen randomly. The following results were obtained during a study to determine the effectiveness of the low-sugar diet. Calculate a pooled estimate of the standard deviation for the method.

Time	Glucose Concentration (mg/L)	Mean Glucose (mg/L)	Sum of Squares of Deviations	Standard Deviation from Mean
Month 1	1108, 1122, 1075, 1099 1115, 1083, 1100	1100.3	1687.43	16.8
Month 2	992, 975, 1022, 1001, 991	996.2	1182.80	17.2
Month 3	788, 805, 779, 822, 800	798.8	1086.80	16.5
Month 4	799, 745, 750, 774, 777, 800 758	771. 9	2950.86	22.2

Total number of measurements = 24

Total sum of squares = 6907.89

Solution

For the first month, the sum of squares in the next to the last was calculated as follows:

$$\text{Sum of squares} = (1108 - 1100.3)^2 + (1122 - 1100.3)^2 + (1075 - 1100.3)^2$$
$$+ (1099 - 1100.3)^2 + (1115 - 1100.3)^2 + (1083 - 1100.3)^2$$
$$+ (1100 - 1100.3)^2$$
$$= 1687.43$$

The other sums of squares were obtained similarly. The pooled standard deviation is then

$$s_{pooled} = \sqrt{\frac{6907.89}{24-4}} = 18.58 \text{ or } 19 \text{ mg/L}$$

Note that this pooled value is a better estimate of σ than any of the individual *s* values in the last column. Note also that one degree of freedom is lost for each of the four sets.

1.3. Reporting computed data

Another essential element of experimentation is how you report data that is consistent with the rules set in various standards. You look closely at the following topics that I am going to explain. Understand the rules and procedures that I emphasize.

A numerical result is worthless to users of the data unless they know something about its quality. Therefore, it is always essential to indicate your best estimate of the reliability of your data. According to Holler and Crouch (2014), a much less satisfactory but more common indicator of the quality of the data is significant figure convention.

1.3.1 Significant figures

We encounter significant figures when we deal with numbers obtained from measurements particularly when we need to report our data resulting from the experiment. The number of digits that we need to include in reporting the data depends on the accuracy of the instrument used in measurement. The following paragraphs illustrate how we can appropriately report a measured quantity.

Suppose you determine the mass of a coin on an analytical balance capable of measuring to the nearest 0.0001 g. You could report the mass as 4.8405 ± 0.0001 g. The notation ± (read "plus or minus") expresses the magnitude of the uncertainty of your measurement. In some scientific work we drop ± the notation with the understanding that *there is always some uncertainty in the last digit reported for any measured quantity.*

Figure 1-2 shows a thermometer with its liquid column between two scale marks. We can read the certain digits from the scale and estimate the uncertain one. Seeing that the liquid is between the 25 °C and 30 °C marks, we estimate the temperature to be 27 °C, being uncertain of the second digit of our measurement.

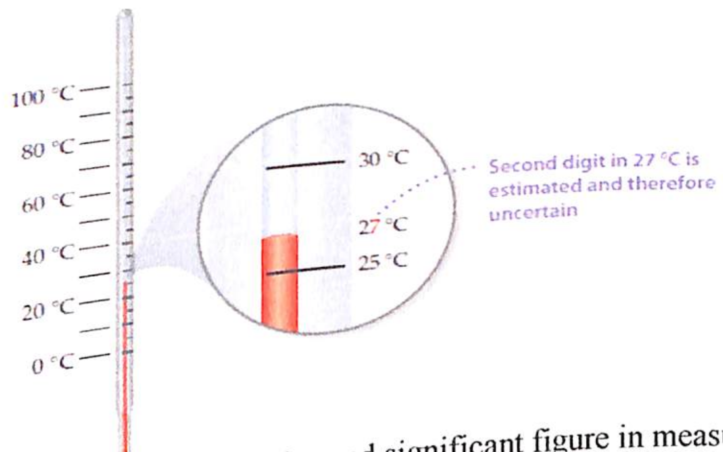


Figure 1-2. Uncertainties and significant figure in measurement

(Source: Brown, T. L., et. al., 2012)

All digits of a measured quantity, including the uncertain one, are called **significant figures**. A measured mass reported as 2.2 g has two significant figures, whereas one reported as 4.8405 g has five significant figures. The greater the number of significant figures, the greater the certainty implied for the measurement.

Example 1-8

A sample that has a mass of about 25 g is placed on a balance that has a precision of ± 0.001 g. How many significant figures should be reported for this measurement?

Answer: five, as in the measurement 24.995 g or 25.005 g, the uncertainty being in the third decimal place

Rules on counting the number of significant figures

1. All nonzero digits are significant. (significant figures in **bold**)

   423.444(6 sf)

2. Zeros between two significant figures are themselves significant.

   42,300045 (8 sf) **42,340.0025**(9 sf)

3. Zeros at the beginning of a number are never significant.

   000**42345.0** (6 sf) 0.000**48**(2 sf)

4. Zeros at the end of a number are significant if a decimal point is written in the number.

   0.0**500** g (3 sf) **5.0** cm (2 sf)

5. Zeros at the end of a number without a decimal point may or may not be significant. Exponential notation can be used to indicate whether end zeros are significant. For example, a mass of 20,700 mg can be written to show three, four, or five significant figures depending on how the measurement is obtained such as the accuracy of the instrument used:

   2.07×10^4 mg (three significant figures)

   2.070×10^4 mg (four significant figures)

   2.0700×10^4 mg (five significant figures)

(The exponential term 10^4 does not add to the number of significant figures.)

Example 1-9

How many significant figures are in each of the following measurements:

(a) 3.549 g,

(b) 4.5×10^{-3} m, (c) 0.00146 mL?

Answers: (a) four, (b) two, (c) three

1.4 Dimensional Analysis

The purpose of doing dimensional analysis is to get the desired unit out of a given unit. In doing so, the given quantity should be multiplied with a *conversion factor.* Conversion factor is ratio of two equal quantities expressed in different units. The unit of the quantity in the numerator is the unit desired and the unit in the denominator is similar to that of the given unit. Conversion tables found in textbooks and general references are used as conversion factors.

Here are some pointers that you need to follow in carrying out dimensional analysis.

What do you need on top? *(This is the desired unit in a single-step conversion.)*

What do you need at the bottom? *(This is the given unit in a single-step conversion.)*

What do you know? *(This refers to the conversion factor to be used that can be obtained from conversion tables.)*

How do you get there? *(This is the mathematical manipulation to show how the desired unit is obtained out of the given unit. Often, the desired unit cannot be obtained from the given unit by using only one conversion factor. This calls for the use of more than one conversion factor to get the desired unit.)*

Note: Aside from conversion tables, you may also obtain conversion factor forms the relationships of quantities given or cited in the situation or in the problem.

Example 1-10

An individual with a high cholesterol level has 232 mg cholesterol per 100.0 mL of his blood. How many grams of cholesterol are in his blood if he has a total blood volume of 5.2 L?

Solution

What are given: $232 \frac{mg\ cholesterol}{100.0\ mL}$; *5.2 L of blood ; 1000 mg = 1 g*

What is required: *grams (g) of cholesterol*

What I know: *1 L = 1000 mL, 1g = 1000mg*

What do I need on top: *grams (g)*

What do I need at the bottom: *none*

$$5.2\ \text{L blood} \times \frac{1000\ \text{mL}}{1\ \text{L}} \times \frac{232\ \text{mg}}{100.0\ \text{mL}} \times \frac{1\ \text{g}}{1000\ \text{mg}} = 12\ \text{g}$$

Note: In this example, only two (2) significant figures are included in the final answer since only multiplication and divisions are involved, in which the number of significant figure in the final answer must agree with the quantity with the least number of significant figure. In this case, 5.2 L has the lowest number of significant figures. Note further that exact numbers are not considered in counting number of significant figure because of their nature being exact. Exact numbers contain indefinite number of significant figure. Hence, 1 g, 1 L (with only one digit), 1000 mg, and 100 mL should not be considered because they exact numbers.

1.4.1 Exact and inexact numbers

There are two kinds of numbers that are encountered in scientific work: *exact numbers* are those whose values are known exactly while *inexact numbers* are those whose values have some uncertainty. Exact numbers have defined values or can result from counting objects. Inexact numbers are obtained from measurements whose uncertainties may have been caused by the inherent limitations of the equipment and by human differences.

Exact	**Inexact**
1000 g/ 1 kg	ruler measure
2.54 cm/ 1 in	temperature, volume or mass reading
12 in 1 dozen	etc.
any conversion factor	

Example 1-11

Indicate whether the number is exact or inexact: (a) the mass of the 32-oz can of coffee; (b) the volume of blood in the capillary tube; (c) the number of inches in a mile; (d) the average height of the students in the class; and (e) the number of pages in you book.

Answers: (a), (b), and (d) are inexact while (c) and (e) are exact.

Example 1-12

The volume of a van container used to deliver frozen fishes is 35.00m^3. What is the volume in liters?

Solution:

What is given: *35.00* m^3

What is required: *volume in liters (L)*

What you know: *1000 L = 1* m^3

What you need on top: *liters (L)*

What you need at the bottom: *none*

$$35.00\ m^3 \times \frac{1000\ L}{1\ m^3} = 35.00 \times 10^3$$

Example 1-13

The density of a certain substance is 1.945 $\times 10^3$ kg/m^3. What is its density in g/mL?

Solution

What is given: *density equal to 1.945 x 10³ kg/m³*

What is required: *density in g/mL*

What you know: 1000 g = 1 kg; 1000 mL = 1L; 1000 L = 1 m^3

What you need on top: *grams* (g)

What you need at the bottom: *mL*

$$1.945 \times 10^3 \frac{kg}{m^3} \times \frac{1000\ g}{1\ kg} \times \frac{1\ m^3}{1000\ L} \times \frac{1\ L}{1000\ mL} = 1.945 \frac{g}{mL}$$

1.5 Arithmetic Rules

Often, you will have to carry out arithmetic operations with measured quantities that are governed by significant figures. In doing so, it is easy to generate meaningless digits, especially with electronic calculators, and it is important that you learn to recognize and eliminate these digits.

1.5.1 Rounding Off

There are several different rules commonly used for discarding unwanted digits in a number. The following rule is the simplest and most common. If the digit to be discarded is 5 or greater, increase the retained preceding digit by 1. If it is less than 5, do not change the preceding digit. For example,

5.175 rounded off to three significant figures becomes 5.18.

7.009216 rounded off to three significant figures becomes 7.01.

1.082 rounded off to two significant figures becomes 1.1.

The rule is applied *one time* to the first digit only following the last retained digit. Under no circumstances should the rounding off be done sequentially. For example, 9.1547 should be rounded with three significant figures to 9.15 because 4 is less than 5. You should not round off the 7, making the number 9.155, and then round off the 5, making it 9.16.

1.5.2 Addition and subtraction

The result has the same number of decimal places as the measurement wit the fewest decimal places. When the result contains more than the correct number of significant figures, it must be rounded off.

Rules: Express all numbers with the same exponent and align all number with respect to the decimal point.

Round-off the answer according to the number of decimal places in the number with the fewest decimal places.

Example 1-14

Perform the following operations. Report the answer with the correct number of significant figures.

Solutions

(a)

$$\begin{array}{rl} 14.6481 & \text{(4 decimal places)} \\ +\ 17.347 & \text{(3 decimal places)} \\ +\ 44.31 & \text{(2 decimal places, least uncertain)} \\ \hline 76.3051 & \rightarrow \quad 76.31 \end{array}$$

When the numbers to be added or subtracted have exponents, they must be made to have the same exponent before the addition or subtraction is carried out. Consider the following example.

(b)

$$2.17 \times 10^{-3} \rightarrow 0.0217 \times 10^{-1}$$

$$3.163 \times 10^{-1} \rightarrow 3.163 \times 10^{-1}$$

$$2.76 \times 10^{-4} \rightarrow \underline{0.00276 \times 10^{-1}}$$

$$3.18746 \text{ X } 10^{-1} \rightarrow 3.187 \text{ X } 10^{-1}$$

1.5.3 Multiplication and division

The result contains the same number of significant figures as the measurement with the fewest significant figures. When the result contains more than the correct number of significant figures, it must be rounded off.

Example 1-15

Perform the following operations. Report the answer with the correct number of significant figures.

Solutions

(a) 3.26×10^{-5}

$\times$ $\underline{1.78}$

5.8028×10^{-5} → 5.80×10^{-5}

(b) 4.3179×10^{12}

$\times$ $\underline{3.6 \times 10^{-19}}$

1.554444×10^{-6} → 1.6×10^{-6}

(c) 34.60

$\times$ $\underline{2.46287}$

85.215302 → 85.22

Note that the power of 10 has no influence on the number of digits that should be retained.

Consider the following example to illustrate operations involving mixed operations (or composite operations)

Example 1-16

Compute the answer to the following expression using the correct number of significant figures. $\frac{18.1 \times 0.219}{2.7} + 12.045$

Solution

The result of the multiplication/division should contain two significant figures (same as the value 2.7). This rounded-off result is then added to 12.045, with the answer rounded off according to the rules of addition.

$$\frac{18.1 \times 0.219}{2.7} + 12.045$$

$\underline{1.4}68111\ldots + 12.045$ (Only the underlined digits, up to the tenths digit are significant of the first addend.)

$$1.468\ldots + 12.045 = 13.513 \rightarrow 13.5$$

Exercise: What is the answer, with the correct number of significant figures, to the following arithmetic expressions?

$$\frac{20.3 \times 0.1533}{104.228}$$

You can now assess yourselves if you understand the mathematical and statistical procedures that you just read. Consider the assignments given in the following page for your exercise to reinforce what you learned from my discussions.

ASSIGNMENT

1. An analysis of the city drinking water for total hardness produced the following results (in ppm $CaCO_3$): 228.3, 226.4, 226.9, 227.1, and 228.6. Calculate the following.

(a) mean (c) range (e) standard deviation

(b) median (d) average deviation

2. The following pH data were collected in the analysis of water from a certain country in Asia as part of an acid rain study: 4.17, 4.20, 4.19, 4.23, 4.22, 4.14, 4.20, and 4.15. Calculate the following:

(a) mean (c) percent average deviation (e) relative standard deviation

(b) median (d) standard deviation

3. If the true concentration of $CaCO_3$ in the drinking water described in Problem 1 is 225.9 ppm, calculate the absolute and parts per thousand error.

4. An alloy from National Bureau of Standards was analyzed for its chromium content and the following results were obtained: 2.61, 2.66, 2.61, 2.70, and 2.68% Cr. If the NBS certified value is 2.69% Cr, what is the absolute error? What is the percent error?

5. Analytical Chemistry student Carl Roger analyzed an ore sample for its copper content and obtained a mean of 4.67% Cu for three measurements. How many additional measurements must Carl make to obtain a mean that is five times more reliable?

6. Which of the following data sets has the best precision? Justify your answer by showing mathematical proof.

A	B	C
2.31	11.74	56.33
2.33	11.82	56.21
2.30	11.79	56.27
2.30	11.80	56.16

7. Analysis of several plant-food preparations for potassium ion yielded the following data:

Sample	Percent K^+
1	6.02, 6.04, 5.88, 6.06, 5.82
2	7.48, 7.47, 7.29
3	3.90, 3.96, 4.16, 3.96
4	4.48, 4.65, 4.68, 4.42
5	5.29, 5.13, 5.14, 5.28, 5.20

The preparations were randomly drawn from the same population.

(a) Find the mean and standard deviation s for each sample.

(b) Obtain the pooled value s_{pooled}.

(c) Why is s_{pooled} a better estimate of σ than the standard deviation from anyone sample?

8. Classify the following as exact or inexact number?

(a) the number of microseconds in a week

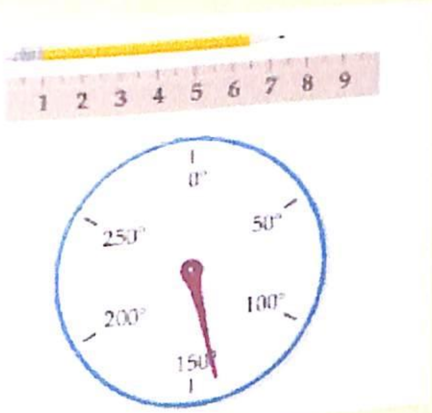
(b) the number of millilitres in a cubic meter of water

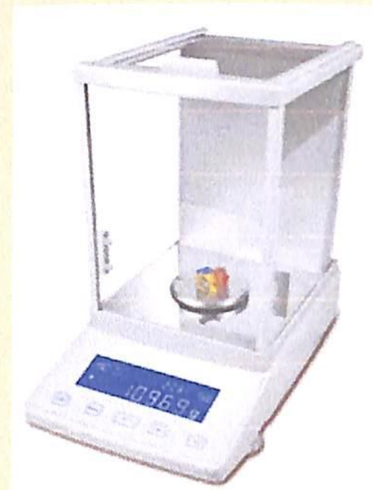
(c) the mass of a postage stamp

(d) the average mass of the students in the class

(e) the temperature of the loaf bread in the oven

9. (a) What is the length of the pencil in the following figures if the scale reads in centimeters? How many significant figures are in the measurement? (b) An oven thermometer with a circular scale reading degrees Fahrenheit is shown. What temperature does the scale indicate? How many significant figures are in the measurement? (c) The analytical balance shown can read up to 0.1 mg. Which number is uncertain in the reading? What place value is this?





For No. 9 (c)

For No. 9 (a) and (b)

10. Indicate the number of significant figures in each of the following measured quantities:

(a) 0.0234 cm^2 (b) 5.500 mm (c) 5.404×10^2 km

(d) 430.98 (e) 204.080

11. Carry out the following operations, and express the answer with the appropriate number of significant figures:

(a) 340.55 – (3216.6/2.6) (b) (5.03×10^{-4}) (3.8765)

(c) (0.0045 x 20.000.0) + (2813 x 12) (d) 863 x [1255 – (3.45 x 108)]

12. Perform the following conversions:

(a) 0.076 L to mL (b) 1.55 kg/m^3 to g/L (c) 5.850 lb/ft^3 to g/mL

13. (a) The recommended adult dose of Elixophillin®, a drug used to treat asthma, is 6 mg/kg of body mass. Calculate the dose in milligrams for a 150-lb person if 1 kg = 2.205 lb (b) A pound of coffee beans yields 50 cups of coffee (4 cups = 1 qt). How many millilitres of coffee can be obtained from 1g of coffee beans?

Key Answers for the Check-Up Test

1. C
2. B
3. D
4. C
5. B
6. – 0.28
7. – 0.45%
8. 2.1
9. 85
10. -2.0 %

What you learned

After going through this module, you learned how to compute and used appropriately the three expressions of central value in order to describe a set of data. You also learned the difference of accuracy and precision and how they are being expressed. After following the examples closely and solving the given assignments, you were able to compute average deviation, standard deviation of the sample and of the population or the pooled standard deviation.

In the later part of the module, you learned about the difference between exact and inexact numbers. You also learned that exact number is not governed by the rules on counting and operations involving significant figures because they have indefinite number of significant figures. You also learned how to report measured data accurately with the correct number of significant figures based on the accuracy of the instrument. Further, you now gained techniques in performing dimensional analysis in converting a given unit into a desired unit.

References

Brown, T. L., et al. (2012). *Chemistry the central science*. 12th ed. Illinois: Pearson Education, Inc.

Chang, R. (1994). *Chemistry*. 5th ed. New York: Brooks Publishing

Hargis, L.G. (1988). *Analytical chemistry principles and techniques*. New Jersey: Prentice-Hall, Inc.

Holler, F. J. and Crouch, S. R. (2014). *Skoog and West's fundamentals of analytical chemistry*. 9th ed. USA: Brooks/Cole CENGAGE Learning Inc.

Mann, P. S. (2011). *Introductory statistics*. New Jersey: John Wiley and Sons, Inc.

END OF MODULE 1

MODULE 3
WAYS OF EXPRESSING CONCENTRATIONS

Introduction

Most of the materials that we encounter in everyday life are mixtures. Many mixtures appear uniformly, thus they are called *homogeneous*. The air that we breathe is a solution of several gases. Brass is a solution of zinc and copper. The fluids that run through our bodies are solutions, carrying a great variety of essential nutrients, salts, and other materials.

Solutions which may be solid, liquid, or gaseous are made up of two or more components. The amount of the *component of interest* (or component in consideration) is referred to as concentration of the component in the solution. The concentration of solution can be expressed either qualitatively or quantitatively.

In your general chemistry laboratory, you often encountered reagents labelled as "*dil.*" for dilute and "*conc.*" for concentrated. These terms are used to describe a solution qualitatively. A solution with a relatively small concentration of solute is said to be *dilute*; one with a large concentration is said to be *concentrated*. Just as when you desire your coffee in the morning to have less or more coffee dissolved in it, would make a weak or a strong coffee based on your preference.

Qualitative expressions are not acceptable in analytical chemistry since they only provide a rough estimate of how much solute is being dissolved in the solution thus, not appropriate for calculation. In our study of analytical chemistry we only use quantitative expressions of concentrations as they indicate quantities of solute having numerical values thus, more appropriate for analytical calculations.

There are several ways to express concentration in quantitative terms, and we will examine some of these in this module. The contents of this module supplement the discussions presented in Chapter 4 of Skoog and West's Analytical Chemistry (9th ed.).

Facilitated Learning Activity

PEER Mentoring

Because we are adopting facilitated learning instruction, you will perform *peer mentoring* as your learning activity while you are using this module. Peer mentoring is a group activity in which one of the members is designated as *mentor* and the rest of the group as *mentees*. The mentor will perform the role of a tutor or a teacher of the group. He/ She will act as leader of the group and will ensure that the group closely executes the activities in the module.

Here are the mechanics and guidelines of the peer mentoring activity:

(a) The mentor will introduce the topic to be tackled in the session.

(b) To start the session, the mentor will ask the mentees about possible problems or difficulties the group members encountered in the classroom when the teacher introduced the topic.

(c) The mentees will tell the mentor which specific topics are to be tackled for the session.

(d) The mentor starts the discussion of the topic to specifically address the problems or difficulties raised by the members. If the mentor is not so confident to impart the lesson to the mentees, he / she may ask other member of the group to act as mentor.

(e) The peer mentoring activity should maximize the use of this learning module as a supplemental learning material in the entire mentoring activity.

(f) The mentor should ensure that every member of the group is given the chance to ask, react, or suggest something pertaining to the topic during the course of the activity.

(g) The mentor may give the evaluation test and assign problem sets if such are necessary.

(h) The peer mentoring activity should be conducted during the period specified by the instructor. However, the group may be allowed to conduct the activity in their houses if longer time is needed to finish the session for the day.

(i) The mentoring activity should be conducted at least twice per week with at least 1.5 hours each session.

(j) The mentor is required to submit one narrative report at the end of the semester.

OBJECTIVES

After the end of the module, you should be able to:

1. calculate the various expressions of concentration such as molarity, percent concentration, mole fraction, molality, ppm, ppb, and normality;
2. differentiate between density and specific gravity;
3. use density or specific gravity to convert a concentration expression into another expression;
4. calculate equivalent weight based on the different types of substance; and
5. calculate normality based from the equivalent weight of solute.

TIME FRAME: 4.5 hours; at least two mentoring sessions

CHECK-UP TEST

Before we proceed, let us first check your prior knowledge and skills on the topics included in this module. Please take the test below. Just encircle the letter you think is the correct answer.

1. Which of the following is not a solution?
   a. air   b. bronze   c. sea water   d. mayonnaise
2. This refers to the component in the solution that is present in the largest quantity?
   a. solute   b. solvent   c. specific gravity   d. solubility
3. Which expression of concentration that is expressed in mole of solute per kilogram of solvent?
   a. molarity   b. molality   c. normality   d. formality
4. The sum of all the mole fractions of components in a solution is equal to _____.
   a. 0.000   b. 100.0   c. 10.00   d. 1.000
5. Calculate the mass percentage of NaCl in a solution containing 1.50 g NaCl in 50.0 g of water.
   a. 2.91%   b. 3.00%   c. 33.3%   d. 97.1%
6. A commercial bleaching solution contains 3.62 mass % sodium hypochlorite, NaOCl. What is the mass of NaOCl containing 2500 g of bleaching solution?
   a. 40.3 g   b. 0.00456 g   c. 90.5 g   d. 165 g
7. Calculate the mole fraction of NaOCl in a solution that is 3.62 % NaOCl in water.
   a. 9.00×10^{-3} b. 6.00×10^{-3} c. 3.00×10^{-3} d. 1.00×10^{-3}
8. What is the molality of the solution made by dissolving 36.5 g of naphthalene ($C_{10}H_8$) in 425 g of toluene (C_7H_8)?
   a. 0.397 m   b. 1.65 m   c. 0.239 m   d.0.670 m
9. Which substance has 2 replaceable H^+?
   a. $NaHCO_3$ b. H_2CO_3 c. H_3PO_4 d. CH_3COOH
10. What is the equivalent weight of sodium hydroxide?
   a. 10   b. 15   c. 20   d. 40

Check your answer against the KEY found at the end of this module.

How did you perform in the test? If your score is in the range 8-10, you are equipped to succeed in your study in this module. If you scored 6 or 7, you have the potential of doing far better. If you scored 4 or 5, you probably need to focus more on the reading materials and the mathematical procedure as we go along. But if your score is lower than 4, you need to review your past lessons of the subject. I advise you to retake the test until you get a score of 4 or better.

LESSON PROPER

Let me begin my lecture discussing basic concepts about concentrations. Let me remind you that most parts of the module focus on the mathematical procedures in dealing with problems related to concentrations. You may now start reading the module.

3.1 Molar Concentration

The molar concentration of a solution is the number of moles, n_i, of the solute species that is contained in one liter of the solution. Molar concentration or molarity M, has the dimensions of **mol/L.** Molarity is also equal to the number of millimoles of a solute per milliliter of solution.

Molarity, M = (mol solute)/(L solution)

= (mmol solute)/(mL solution)

= n/V

Example 3-1

Calculate the molar concentration of ethanol in an aqueous solution that contains 2.30 g of C_2H_5OH (46.07 g/mol) in 3.50 L of solution.

Solution

moles of ethanol = amount of C_2H_5OH

$$= 2.30 \text{ g} \times \frac{1 \text{ mol}}{46.07 \text{ g}}$$

$$= 0.04992 \text{ mol } C_2H_5OH$$

$$\text{Molar concentration (M)} = \frac{\text{moles ethanol}}{\text{volume of solution}}$$

$$= \frac{0.04992 \text{ mol}}{3.50 \text{ L}}$$

$$= 0.0143 \frac{\text{mol}}{\text{L}} \quad \text{or} \quad 0.0143$$

3.1.1 Analytical Molarity

The analytical molarity of a solution gives the total number of moles of a solute in 1L of the solution (or total number of millimoles in 1 mL). A 1.0 M H_2SO_4 can be prepared by dissolving 1.0 mol or 98 g of H_2SO_4 in water and diluting to exactly 1.0 L.

3.1.2 Equilibrium Molarity

The equilibrium molarity or species molarity expresses the molar concentration of a particular species in a solution at equilibrium. The equilibrium molarity of H_2SO_4 in a solution with an analytical concentration of 1.0 M is 0.0 M because H_2SO_4 is entirely dissociated, there are no H_2SO_4 in molecular form as such in this solution.

Example 3-2

Calculate the analytical and equilibrium molar concentrations of the solute species in an aqueous solution that contains 285 mg of trichloroacetic acid, Cl_3CCOOH (163.4 g/mol) in 10.0 mL. Assume that trichloroacetic acid (HA) is 73% ionized in water.

Solution

$$\text{amount of HA} = 285 \text{ mg HA} \times \frac{1 \text{ g HA}}{1000 \text{ mg HA}} \times \frac{1 \text{ mol HA}}{163.4 \text{ g HA}} = 1.744 \times 10^{-3} \text{ mol HA}$$

$$\text{molar analytical concentration} = \frac{1.744 \times 10^{-3} \text{ mol}}{10 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}}$$

$$= 0.174 \frac{\text{mol}}{\text{L}} \text{ or } 0.174 \text{ M}$$

73% ionized in water means that 73% of HA in the original amount has been ionized or dissociated into its component ions, H^+ and A^-. Further, only 27% (or 100 – 73) of the HA remains as HA in its molecular form or undissociated form. The ionization reaction is represented by the following equation. Note that double-arrow sign represents a reversible reaction which indicates reaction in which the concentrations of all the species (reactants and products are in equilibrium).

$$HA \leftrightharpoons H^+ + A^-$$

Hence, the equilibrium concentrations are as follows:

Concentration of HA, or the concentration of HA in undissociated form at equilibrium is,

$$[HA] = 0.174\text{ M} \times (0.27) = 0.174\text{M} \times 0.27\text{ M} = 0.047\text{ M}$$

Note: The [ ] sign represents a molar concentration.

Concentration of H^+, or the concentration of hydrogen ion produced upon ionization,

$$[H^+] = 0.174\text{ M} \times 0.73$$

$$= 0.127\text{ M}$$

Since in the balanced chemical equation, for every mole of hydrogen ion formed, equal mole of A^- is also formed. Hence,

$$[H^+] = [A^-] = 0.127\text{ M}$$

3.1.3 Dilution

Dilution is a process of decreasing the concentration of the solution by adding certain amount of solvent in the solution. While the volume is increased as a result of addition of solvent, the number of moles of solute originally present in the solution remains the same. Thus,

moles of solute before dilution = moles of solute after dilution

Note that the number of moles of solute can be obtained by multiplying the molarity (mol/L or mmol/mL) of the solution by its volume (L or mL). This means that,

$$M_1V_1 = M_2V_2$$

where M_1 = molarity before dilution V_1 = volume before dilution

M_2 = molarity after dilution V_2 = molarity after dilution

The original solution which is to be diluted is usually called the *stock* solution and the amount to be diluted is withdrawn using a pipet. This volume of solution is transferred into a container whose volume is known and is marked such as the volumetric flasks. The volume of the volumetric flask to be used is the volume of the desired solution or must be the volume of the solution after dilution.

Example 3-3

(a) Calculate the molarity of the solution that is obtained by diluting 25.0 mL of 0.100 M HCl into 100.0 mL solution. (b) How many liters of 0.250 M of NaOH is needed to obtain a 500.0 mL of 0.100 M NaOH solution.

Solution

(a)

$$M_1V_1 = M_2V_2$$

$$(0.100\ \text{mmol/mL})\ (25.0\ \text{mL}) = M_2\ (100.0\ \text{mL})$$

$$M_2 = \frac{(0.100\ \text{mmol/mL})\ (25.0\ \text{mL})}{(100.0\ \text{mL})}$$

$$= 0.0250\ \text{M}$$

(b)

$$M_1V_1 = M_2V_2$$

$$(0.250\ \text{mol/L})\ V_2 = (0.100\ \text{mol/L})\ (0.5000\ \text{L})$$

$$V_2 = \frac{(0.100\ \text{mol/mL})\ (0.5000\ \text{mL})}{(0.250\ \text{mol/L})}$$

$$= 0.200\ \text{L}$$

3.2 Percent concentration

Concentration can be expressed in terms of percent (parts per hundred). Percent composition can be expressed in three different methods:

Mass percent (m/m) = (mass of solute)/(mass of solution) x 100 %

Volume percent (v/v) = (volume solute)/(volume solution) x 100%

Mass/Volume percent (m/v) = (mass of solute, g)/(volume solution, mL) x 100%

Example 3-4

(a) Calculate the mass percentage of Na_2SO_4 in a solution containing 11.7 g Na_2SO_4 in 443 g of water. (b) What is the mass percentage of iodine (I_2) in a solution containing 0.045 mol I_2 in 115 g CCl_4?

Solution

(a) mass % of Na_2SO_4 = $\frac{\text{mass of } Na_2SO_4}{\text{total mass of the solution}} \times 100$

$= \frac{\text{mass of } Na_2SO_4}{\text{mass of } Na_2SO_4 + \text{mass of } H_2O} \times 100$

$= \frac{11.7\text{ g } Na_2SO_4}{11.7\text{ g } Na_2SO_4 + 443\text{ g } H_2O} \times 100$

= 2.57 %

(b) mass % I_2 $= \frac{\text{mass of } I_2}{\text{total mass of the solution}} \times 100$

$= \frac{\text{mass of } I_2}{\text{mass of } I_2 + \text{mass of } CCl_4} \times 100$

$= \frac{0.045\text{ mol } I_2 \times \frac{253.80\text{ g } I_2}{1\text{ mol } I_2}}{115\text{ g } CCl_4} \times 100$

= 9.9 %

3.3 Parts per million (ppm) and parts per billion (ppb)

For very dilute solutions, ***parts per million*** (ppm) is a convenient way to express concentration.

$$C_{ppm} = \frac{\text{mass of solute}}{\text{mass of the solution}} \times 10^6$$

where, C_{ppm} is the concentration in parts per million.

For even more dilute solution ***parts per billion*** (ppb) is used

$$C_{ppb} = \frac{\text{mass of solute}}{\text{mass of the solution}} \times 10^9$$

Example 3-5

(a) Seawater contains 0.0079 g Sr^{2+} per kilogram of water. What is the concentration of Sr^{2+} measured in ppm? **(b)** What is the molarity of K^+ in a solution that contains 63.3 ppm of $K_3Fe(CN)_6$ whose molar mass is 329.3 g/mol)?

Solution

$$\text{(a) ppm } Sr^{2+} = \frac{\text{mass of } Sr^{2+}}{\text{mass of the solution}} \times 10^6$$

$$= \frac{\text{mass in g of } Sr^{2+}}{\text{mass in g of } Sr^{2+} + \text{ mass in g of } H_2O} \times 10^6$$

$$= \frac{0.0079 \text{ g } Sr^{2+}}{0.0079 \text{ g of } Sr^{2+} + 1000 \text{ g } H_2O} \times 10^6$$

$$= 7.9 \text{ ppm}$$

(b) **Note**: Concentration in ppm can be assumed to be equal to mg solute per liter solution if the solvent used is water. This is because the density of water is approximately equal to 1 g/mL or 1L of water has an approximate mass of 1 kg. Thus,

$$63.3 \text{ ppm } K_3Fe(CN)_6 = 63.3 \frac{\text{mg } K_3Fe(CN)_6}{\text{L solution}}$$

So that, molar concentration of $K_3Fe(CN)_6$

$$\text{Molarity of } K_3Fe(CN)_6 = 63.3 \frac{\text{mg } K_3Fe(CN)_6}{\text{L solution}} \times \frac{1 \text{ g } K_3Fe(CN)_6}{1000 \text{ mg } K_3Fe(CN)_6} \times \frac{1 \text{ mol } K_3Fe(CN)_6}{329.3 \text{ g } K_3Fe(CN)_6}$$

$$= 1.922 \times 10^{-4} \frac{\text{mol } K_3Fe(CN)_6}{\text{L soln}} \text{ or } 1.922 \times 10^{-4} \text{ M } K_3Fe(CN)_6$$

$$\text{Molarity of } K^+ = 1.922 \times 10^{-4} \frac{\text{mol } K_3Fe(CN)_6}{\text{L soln}} \times \frac{3 \text{ mol } K^+}{\text{mol } K_3Fe(CN)_6}$$

$$= 5.77 \times 10^{-4} \frac{\text{mol } K^+}{\text{L soln}} \text{ or } 5.77 \times 10^{-4} \text{ M } K^+$$

3.4 Mole Fraction

Mole fraction of a solute is defined mathematically as the ratio of the mole of the solute and the total moles of the solution or mixture. Mole fraction of solute *i* is represented by x_i, as is written as follows:

$$x_i = \frac{\text{mole of solute } i}{\text{total mole of the solution}}$$

Mole fraction may also be reported as mole percent if the value of the mole fraction is multiplied by 100. Mole fraction is dimensionless or unitless.

$$\text{mole percent} = \frac{\text{mole of solute } i}{\text{total mole of the solution}} \times 100$$

Moreover, the sum of all the mole fractions of components of the mixture is 1.00.

Mathematically,

$$x_1 + x_2 + x_3 + \ldots + x_n = 1.00$$

Example 3-6

A solution is made containing 7.5 g CH_3OH in 245 g H_2O. Calculate the mole fractions of (a) CH_3OH and (b) H_2O

Solution

(a) $$x_{CH_3OH} = \frac{\text{mole of } CH_3OH}{\text{mole of } CH_3OH + \text{mole of } H_2O}$$

$$= \frac{7.5\text{ g }CH_3OH \times \frac{1\text{ mol }CH_3OH}{32\ 05\text{ g }CH_3OH}}{7.5\text{ g }CH_3OH \times \frac{1\text{ mol }CH_3OH}{32\ 05\text{ g }CH_3OH} + 245\text{ g }H_2O \times \frac{1\text{ mol }H_2O}{18.02\text{ g }H_2O}}$$

$$= 0.017$$

(b) Since there are only two components present in the solution, the sum of the mole fractions of methanol and water is equal to 1.00. Hence the mole fraction of water in the solution is,

$$x_{H2O} = 1.000 - x_{CH_3OH}$$
$$= 1.000 - 0.017$$
$$= 0.983$$

3.5 p-Functions

Analysts frequently express the concentration of a species in terms of its **p-function**, or **p-value**. The p-value is the negative logarithm (to the base 10) of the molar concentration of that species. Thus, for the species X,

$$pX = -\log [X]$$

As shown by the following examples, p-values offer the advantage of allowing concentrations that vary over ten or more orders of magnitude to be expressed in terms of small positive numbers.

Example 3-7

Calculate the p-value for each ion in a solution that is 2.00 x 10^{-3} M in NaCl and 5.4x 10^{-4} M in HCl.

Solution

$$pH = -\log [H^+] = -\log (5.4 \times 10^{-4}) = 3.27$$

To obtain pNa, we write

$$pNa = -\log[Na^+] = -\log(2.00 \times 10^{-3}) = 2.699$$

The total Cl^- concentration is given by the sum of the concentrations of the two solutes:

$$[Cl^-] = 2.00 \times 10^{-3}\ M + 5.4 \times 10^{-4}\ M$$

$$[Cl^-] = 2.00 \times 10^{-3}\ M + 0.54 \times 10^{-3}\ M$$

$$[Cl^-] = 2.54 \times 10^{-3}\ M$$

$$p[Cl] = -\log(2.54 \times 10^{-3})$$

$$= 2.595$$

3.6 Density and Specific Gravity of Solutions

3.6.1 Density

The density of a substance is its mass per unit volume. Density is expressed in units of kg/L or g/mL.

3.6.2 Specific Gravity

Specific gravity is the ratio of its mass to the mass of an equal volume of water at 4°C. Specific gravity is dimensionless.

TABLE 4-3
Specific Gravities of Commercial Concentrated Acids and Bases

Reagent	Concentration, % (w/w)	Specific Gravity
Acetic acid	99.7	1.05
Ammonia	29.0	0.90
Hydrochloric acid	37.2	1.19
Hydrofluoric acid	49.5	1.15
Nitric acid	70.5	1.42
Perchloric acid	71.0	1.67
Phosphoric acid	86.0	1.71
Sulfuric acid	96.5	1.84

Source: Holler, F. J. and Crouch, S.R (2012)

Example 3-8

Calculate the molar concentration of HNO_3 (63.0 g/mol) in a solution that has a specific gravity of 1.42 and is 70% HNO_3 (w/w).

Solution

Note that the specific gravity of the solution is 1.42. This indicates that the density of the solution is 1.42 g solution / mL solution.

$$\frac{1.42 \text{ g solution}}{\text{mL solution}} = \frac{1420 \text{ g solution}}{1000 \text{ mL solution}} = \frac{1420 \text{ g solution}}{1 \text{ L solution}}$$

$$\text{Molarity} = \frac{\text{mol } HNO_3}{\text{L solution}} = \frac{1420 \text{ g solution}}{\text{L solution}} \times \frac{70 \text{ g } HNO_3}{100 \text{ g solution}} \times \frac{1 \text{ mol } HNO_3}{63.0 \text{ g } HNO_3}$$

$$= 15.8 \frac{\text{mol } HNO_3}{\text{L solution}} \text{ or } 15.8 \text{ M}$$

3.7 Molality, m

Molality is defined as the number of moles of solute per kg of solution.

$$m = \frac{\text{mol solute}}{\text{kg of solvent}} \qquad \text{unit: } 1 \frac{\text{mol}}{\text{kg}} = 1 \text{ molal}$$

Because both moles and mass do not change with temperature, molality (unlike molarity) is *not* temperature dependent.

The following diagram illustrates how to convert molarity into molality and vice versa. Common to both expressions is the number of moles of solute which is located in the numerator. The mass of solvent is necessary to calculate the molality. This can be obtained by subtracting the mass of solute from the mass of solution. The mass of the solution may be obtained from the given density of the solution. That means if we know the density of the solution, we can calculate the molality from the molarity, and vice versa

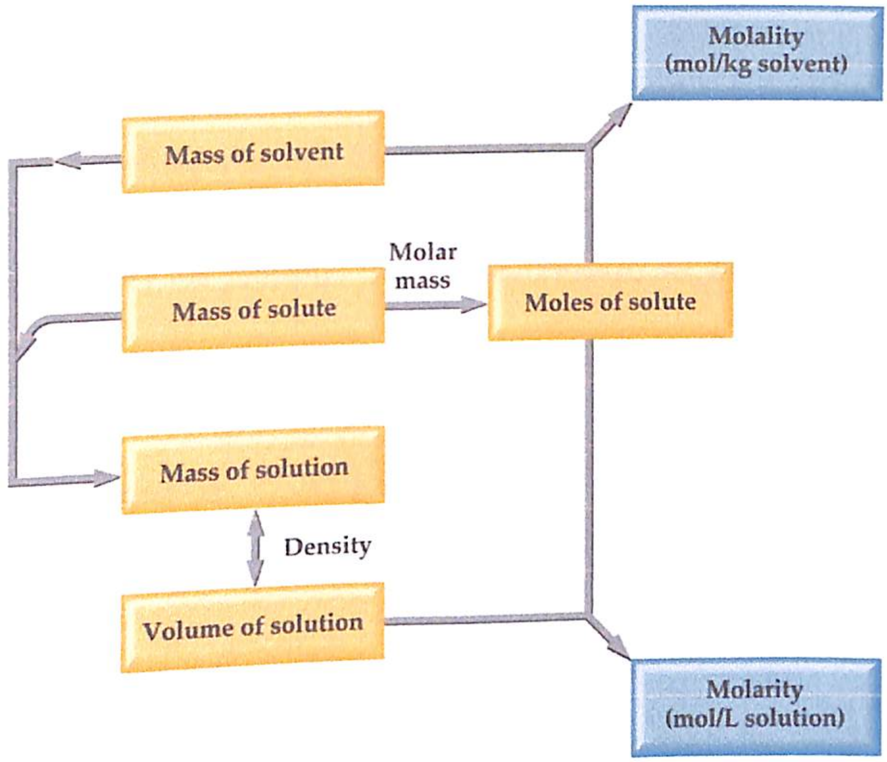


Figure 3-1 Changing molarity to molality and vice versa

(Source: Brown, T. L., et al., 2012)

Example 3-9

A solution is made by dissolving 4.35 g glucose ($C_6H_{12}O_6$) in 25.0 mL of water. Calculate the molality of glucose in the solution.

Solution

$$m = \frac{\text{mol solute}}{\text{kg of solvent}} = \frac{\text{mol } C_6H_{12}O_6}{\text{kg of } H_2O}$$

$$= \frac{4.35 \text{ g } C_6H_{12}O_6 \times \frac{1 \text{ mol } C_6H_{12}O_6}{180.18 \text{ g } C_6H_{12}O_6}}{25.0 \text{ mL } H_2O \times \frac{1.00 \text{ g } H_2O}{1.00 \text{ mL } H_2O} \times \frac{1.00 \text{ kg } H_2O}{1000 \text{ g } H_2O}}$$

$$= 0.966 \ \frac{\text{mol } C_6H_{12}O_6}{\text{kg of } H_2O} \quad \text{or} \quad 0.966 \text{ m (molal)}$$

Example 3-10

Ascorbic acid, (vitamin C, $C_6H_8O_6$) is a water-soluble vitamin. A solution containing 85 g of ascorbic acid dissolved in 210 g of water has a density of 1.22 g/mL at 55 °C. Calculate (a) the mass percentage; (b) the mole fraction of ascorbic acid; (c) the molality; and (d) the molarity of ascorbic acid in this solution.

Solution

mass of the solution = 85 g ascorbic acid + 210 g water

= 295 g solution

(a) percent ascorbic acid $= \frac{\text{mass of ascorbic cid}}{\text{mass of soltuon}} \times 100$

$= \frac{\text{85 g ascorbic acid}}{\text{295 g solution}} \times 100$

= 28.8 %

percent water $= \frac{\text{mass of water}}{\text{mass of soltuon}} \times 100$

$= \frac{\text{210 g water}}{\text{295 g solution}} \times 100 = 71.2\ \%$

(b) $x_{C_6H_8O_6} = \frac{\text{mole of } C_6H_8O_6}{\text{mole of } C_6H_8O_6 + \text{mole of } H_2O}$

$$= \frac{85\text{ g } C_6H_8O_6 \times \frac{1\text{ mol } C_6H_8O_6}{176.14\text{ g } C_6H_8O_6}}{85\text{ g } CH_3OH \times \frac{1\text{ mol } C_6H_8O_6}{176.14\text{ g } C_6H_8O_6} + 210\text{ g } H_2O \times \frac{1\text{ mol } H_2O}{18.02\text{ g } H_2O}}$$

= 0.040

(c) molality $= \frac{\text{mol ascorbic cid}}{\text{kg solution}} \times 100$

$$= \frac{\text{85 g ascorbic acid} \times \frac{\text{1 mol ascorbic acid}}{\text{176.14 g ascorbic acid}}}{\text{295 g solution} \times \frac{\text{1 kg solution}}{\text{1000 g solution}}}$$

$$= 1.64 \frac{\text{mol ascorbic acid}}{\text{kg solution}} \quad \text{or} \quad 1.64\ \text{M}$$

(d) molarity $= \frac{\text{mol ascorbic acid}}{\text{L solution}}$

volume of solution $= \frac{\text{mass of the solution}}{\text{density of the solution}} = \frac{295\ \text{g solution}}{\frac{1.22\ \text{g solution}}{\text{mL solution}}}$

$= 241.8\ \text{mL solution} \quad \text{or } 0.241\ \text{L solution}$

molarity $= \frac{85\ \text{g ascorbic acid} \times \frac{1\ \text{mol ascorbic acid}}{176.14\ \text{g ascorbic acid}}}{0.241\ \text{L solution}}$

$= 2.00 \frac{\text{mol ascorbic acid}}{\text{L solution}} \quad \text{or} \quad 2.00\ \text{M}$

3.8 Normality, N

Normality is defined as the number of equivalence of solute per liter of solution. Equivalence of solute is expressed as the ratio of the mass (g) of solute and its equivalent weight (EW with units expressed in g/eq). Equivalent weight of the solute is expressed as the ratio of its formula weight (FW) or molar mass and the value of constant ***a*** whose units are eq/mol and depends on the kind of solute in consideration. Hence, calculation of equivalent weight of solute depends on the kind of solute. Putting these into mathematical equations to check the consistency of units, we have,

$$N = \frac{\text{equivalence of solute}}{\text{liter of solution}} = \frac{\text{eq}}{\text{L}}$$

$$\text{Equivalence (eq) of solute} = \frac{\text{mass of solute}}{\text{EW of solute}} = \frac{\text{g}}{\frac{\text{g}}{\text{eq}}}$$

$$\text{EW of solute} = \frac{\text{formula weight or molar mass of solute}}{\text{constant a}}$$

$$= \frac{\frac{\text{g}}{\text{mol}}}{\frac{\text{eq}}{\text{mol}}} = \frac{\text{g}}{\text{eq}}$$

$$\text{Normality, N} = \frac{\text{g solute x constant } a}{\text{FW}_{\text{solute}}\text{x L solution}} = \frac{\text{g solute}}{\text{EW solute x L solution}}$$

$$\text{units: } \frac{\text{g solute} \cdot \frac{\text{eq solte}}{\text{mol solute}}}{\frac{\text{g solute}}{\text{mol solute}} \text{ x L solution}} = \frac{\text{eq solute}}{\text{L solution}}$$

Note: Formula weight is the weight of one formula unit of the substance. It has the same numerical value, but different units, as the molar mass (g/mol). It has units similar to atomic weight.

Evaluation of the constant a (eq/mol) and equivalent weight (g/eq)

(a) ***a*** of an acid = number of replaceable H^+ in the acid

Equivalent weight of acid solute

$$EW_{acid} = \frac{\text{Formula weight or molar mass of acid}}{\text{Number of replaceable } H^+} = \frac{\frac{g}{mol}}{\frac{eq}{mol}} = \frac{g}{eq}$$

Example 3-11

Calculate the equivalent weights and normalities of 24.5 g of H_2SO_4 and 73.0 g of HCl. One (1) liter of both solutions were prepared.

Solution

$$EW_{H2SO4} = \frac{FW_{H2SO4}}{\text{Number of replaceable } H^+} = \frac{98\frac{g}{mol}}{2\frac{eq}{mol}} = 49 \text{ g/eq}$$

$$N = \frac{24.5 \text{ g } H_2SO_4}{49\frac{g}{eq} \text{ x 1 L solution}} = 0.50\frac{eq}{L} \text{ or } 0.50 \text{ N}$$

and

$$EW_{HCl} = \frac{FW_{HCl}}{\text{Number of replaceable } H^+} = \frac{36.5\frac{g}{mol}}{1\frac{eq}{mol}} = 36.5 \text{ g/eq}$$

$$N = \frac{73.0 \text{ g HCl}}{36.5\frac{g}{eq} \text{ x 1 L solution}} = 2.00\frac{eq}{L} \text{ or } 2.00 \text{ N}$$

(b) ***a*** of a base = number of replaceable OH^- in the acid

Equivalent weight of base solute

$$EW_{base} = \frac{\text{Formula weight or molar mass of base}}{\text{Number of replaceable } OH^-} = \frac{\frac{g}{mol}}{\frac{eq}{mol}} = \frac{g}{eq}$$

Example 3-12

Calculate the equivalent weights and normalities of 10.0 g of NaOH dissolved to form 2.00 L solution and 7.40 g of $Ca(OH)_2$ dissolved to form 5.00 L solution.

Solution

$$EW_{NaOH} = \frac{FW_{NaOH}}{\text{Number of replaceable } H^+} = \frac{40\frac{g}{mol}}{1\frac{eq}{mol}} = 40 \text{ g/eq}$$

$$N = \frac{10.0 \text{ g NaOH}}{40\frac{g}{eq} \times 2.00 \text{ L solution}} = 0.125\frac{eq}{L} \text{ or } 0.125 \text{ N}$$

and

$$EW_{Ca(OH)2} = \frac{FW_{Ca(OH)2}}{\text{Number of replaceable } OH^-} = \frac{74\frac{g}{mol}}{2\frac{eq}{mol}} = 37 \text{ g/eq}$$

$$N = \frac{7.40 \text{ g Ca(OH)2}}{37\frac{g}{eq} \times 5.00 \text{ L solution}} = 0.0400\frac{eq}{L} \text{ or } 0.0400 \text{ N}$$

(c) ***a*** of a salt = total number of positive or negative charge

Equivalent weight of salt solute

$$EW_{salt} = \frac{\text{Formula weight or molar mass of salt}}{\text{total number of positive or negative charge}}$$

$$= \frac{\frac{g}{mol}}{\frac{eq}{mol}} = \frac{g}{eq}$$

Example 3-13

Calculate the equivalent weights and normalities of 29.25 g of NaCl dissolved in 1.50 L solution and 15.8 g of $CaCl_2$ dissolved in 500 mL solution.

Solution

$$EW_{NaCl} = \frac{FW_{NaCl}}{\text{toatal number of positive or negative charge}} = \frac{58.5\ \frac{g}{mol}}{1\ \frac{eq}{mol}}$$

$= 58.5$ g/eq

$$N = \frac{29.25\ g\ NaCl}{58.5\ \frac{g}{eq} \times 1.50\ L\ solution} = 0.333\ \frac{eq}{L} \quad or \quad 0.333\ N$$

and

$$EW_{CaCl2} = \frac{FW_{CaCl2}}{\text{total umber of positive or negative charge}} = \frac{95\ \frac{g}{mol}}{2\ \frac{eq}{mol}}$$

$= 47.5$ g/eq

$$N = \frac{15.8\ g\ CaCl2}{47.5\ \frac{g}{eq} \times 0.500\ L\ solution} = 0.665\ \frac{eq}{L} \quad or \quad 0.665\ N$$

(d) ***a*** of solute in a redox reaction

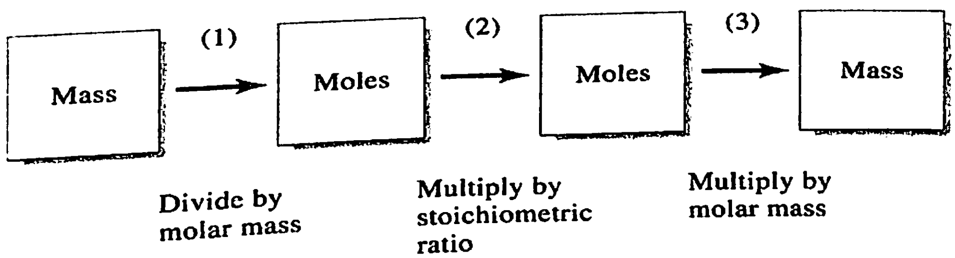
a is the number of electrons/s gained or lost in the reaction. To determine ***a***in a redox reaction, it is helpful that the exact chemical equation is known.

3.8 Chemical Stoichiometry

The stoichiometry of a reaction is the relationship among the number of moles of reactants and products as shown by a balanced equation. A balanced chemical equation is a statement of the combining ratios or stoichiometry in units of moles among the reacting substances and their products.

Steps in doing chemical stoichiometry

- Transformation of the known mass of a substance in grams to a corresponding number of moles
- Multiplication by a factor that accounts for the stoichiometry
- Reconversion of the data in moles back to the SI units called for in the answer



Source: Holler, F. J. and Crouch, S. R. (2014)

Example 3-14

(a) What mass of $AgNO_3$ (169.9 g/mol) is needed to convert 2.33 g of Na_2CO_3 (106.0 g/mol) to Ag_2CO_3? (b) What mass of Ag_2CO_3 (275.7 g/mol) will be formed? The reaction is given as follows:

Solution:

(a) $$Na_2CO_{3(aq)} + 2\,AgNO_{3(aq)} \rightarrow Ag_2CO_{3(s)} + 2NaNO_{3(aq)}$$

$$2.33\ \text{g}\ Na_2CO_3 \times \frac{1\ \text{mol}\ Na_2CO_3}{106.0\ \text{g}} \times \frac{2\ \text{mol}\ AgNO_3}{1\ \text{mol}\ Na_2CO_3} \times \frac{169.9\ \text{g}\ AgNO_3}{1\ \text{mol}\ AgNO_3}$$

$$= 7.47\ \text{g}\ AgNO_3$$

(b) From the balanced equation,

moles of Ag_2CO_3 = moles of Na_2CO_3 = 0.02198mol

$$= 0.02198 \text{ mol } AgCO_3 \times \frac{275.7 \text{ g } Ag_2CO_3}{1 \text{ mol } Ag_2CO_3}$$

$$= 6.06 \text{ g } Ag_2CO_3$$

ASSIGNMENT

Solve the following problems using the mathematical procedures discussed in this module.

1. Calculate the analytical and equilibrium molar concentrations of the solute species in an aqueous solution that contains 250.0 mg of acetic acid, CH_3COOH (60.06 g/mol) in 15.0 mL. Assume that acetic acid (HA) is 82% ionized in water.

2. Commercial concentrated aqueous ammonia is 28% NH_3 by mass and has a density of 0.90 g/mL. What is the molarity of the solution?

3. Calculate the molarity of the following aqueous solutions: (a) 10.5 g $Mg(NO_3)_2$ in 250.0 mL of solution; (b) 22.4 g $Li.ClO_4.3H_2O$ in 125 mL of solution; and (c) 25.0 mL of 3.50 mL HNO_3 diluted to 0.250 L.

4. (a) Calculate the mass percentage of bromine (Br_2) in a solution containing 0.0667 mol Br_2dissolved in 250 g CCl_4. (b) An ore contains 5.95 g of silver per metric ton (1 MT = 1000kg) of ore.

5. A solution is made containing 25.5 g phenol (C_6H_5OH) in 495 g ethanol (CH_3CH_2OH). Calculate (a) the mole fraction of phenol; (b) the mass percent of phenol; and (c) the molality of phenol.

6. A sulfuric acid solution containing 571.6 g of H_2SO_4 per liter of solution has a density of 1.329 g/cm^3. Calculate the (a) mass percentage of sulfuric acid and water in the solution; (b) the mole fractions of the components; (c) the molality; and (d) the molarity of H_2SO_4 in this solution.

7. The density of acetonitrile (CH_3CN) is 0.786 g/mL, and the density of methanol (CH_3OH) is 0.791 g/mL. A solution is made by dissolving 15.0 mL CH_3OH in 90.0 mL CH_3CN. (a) What is the mole fraction of ethanol in the solution? (b) What is the molality of the solution? (c) Assuming that the volumes are additive, what is the molarity of CH_3OH in the solution?

Key Answers for the Check-Up Test

1. D
2. B
3. B
4. D
5. A
6. C
7. A
8. D
9. B
10. D

What you learned

After going through this module, you were able to calculate the various expressions of concentration such as molarity, mole fraction, molality, ppm, ppb, and normality. Moreover you also learned to differentiate density and specific gravity and you were able to use them in converting concentration into another concentration expression. Lastly, you were able to calculate equivalent weight based on the different types of substances and calculate normality based from the equivalent weight.

References

Brown, T. L., et al. (2012). *Chemistry the central science.* 12th ed. Illinois: Pearson Education, Inc.

Chang, R. (1994). *Chemistry.* 5th ed. New York: Brooks Publishing

Hargis, L.G. (1988). *Analytical chemistry principles and techniques.* New Jersey: Prentice-Hall, Inc.

Holler, F. J. and Crouch, S. R. (2014). *Skoog and West's fundamentals of analytical chemistry.* 9th ed. USA: Brooks/Cole CENGAGE Learning Inc.

END OF MODULE 3