# Engineering Mathematics Self-Learning Modules: Independent Learning for Engineering Freshmen

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## 1. Introduction

Independent learning is not a method of instruction. It is a human act. Despite the very comprehensive learning materials provided the learner; the well-thought lesson plans prepared by the teacher and the well-designed class schedules, not a single person nor institution has complete control of the learning process. Not even the bell can signal the start and end of learning.

Learning absolutely resides in the learner himself. The learner has the ultimate and supreme capability to gain and apply knowledge for his personal welfare and his society's progress. The challenged posed by this fact to engineering educators is to provide a learning situation where the learner may discover his potentials and utilize them to the fullest in order to obtain, comprehend and practice the knowledge required of future engineering professionals.

The Engineering Sciences Department of the Faculty of Engineering of the University of Santo Tomas in Manila, Philippines, has introduced modular instruction in two Mathematics courses during the second semester of the school year 1998-1999. Printed learning modules of Plane Trigonometry and Solid Geometry were developed to allow its Engineering Freshmen to learn these courses at their own pace.

The authors of this paper were tasked to prepare the learning materials of the courses; to design and implement the program of activities for both the learners and the teacher; and to conduct a research on the feasibility of this novel project for continuous implementation and the possible adoption of other courses in the Faculty of Engineering. The authors perceived the project as a tough act considering that learning with instructional modules is a novel concept in tertiary education and in Engineering Mathematics courses at that.

## 2. Independent Learning: Then and Now

Oxford University in England is credited as the first institution to develop techniques of independent study[1]. This was the tutorial system, described as "Oxford's most important contribution to educational practice" in the Handbook to the University of Oxford, provided a "morals" tutor to selected young citizens who would govern and direct society in the future. The finest education was provided to these students and tutors instructed them on good manners and on exercising control over financial matters. Reforms were introduced and a second tutor was added - the "academics" tutor.

In the United States, Harvard University was the first to introduce the elective systems. The

pacesetter, however, was Swarthmore College in Philadelphia. The first honors program was developed for students who showed independence and responsibility in their academic work.[2]

Information and Communications Technology (ICT) has changed the world we live in. ICT has found its place in almost all aspects of life: in government, in business and industry, in professional organizations and in learning institutions. ICT requires individuals capable of independent action and self-direction. This demands a shift in the role of teachers from being a transmitter of knowledge toward a responder controlled by the student; from being the initiator-developer to being a contributor-reactor; and from being a programmer-director toward being a co-designer-assister[3]. There is a need to introduce learner-centered activities to harness his potentials to the fullest. The use of ICT in the development of inter-active self-learning materials has made learning more fun and exciting.

## 3. Self-Learning Mathematics Modules at the UST Faculty of Engineering

The UST Faculty of Engineering recognizes the breakthroughs in ICT. The teaching staff is encouraged to design and create a learning environment that will maximize the use of the technology and effect maximum learning of the students. Integration of ICT will allow for self-paced learning and self-directed learning.

Independent learning will initially be introduced at the Faculty of Engineering through printed learning modules. If indeed the printed learning modules provide better learning, then these materials will serve as the framework in developing inter-active learning modules for possible distance learning courses.

The module writers were given a full semester to prepare the learning materials. A 9-unit teaching load incentive was given and a 2-day seminar-workshop on Module Writing was provided.

### 3.1 The Learning Modules

Two types of learning modules were designed. The Expository type defines the concepts of a learning unit. This type of module writing provides the students with descriptions, discussions, and definitions of terms related to the concepts discussed in the learning unit. Derivations of formulas are explicitly provided. All modules of Plane Trigonometry utilized the Expository type.

The Exploratory type provides the learner with guided questions that lead him to the definitions of the concepts of the learning unit. The learner experiences deriving mathematical formulas by himself through self-discovery activities. All but two learning units of the modules on Solid Geometry made use of the Exploratory type.

Each module consists of the following sections:

1. Cover Page – which states the learning unit
2. Overview – which discusses the concepts to be learned and, for most units, practical applications of these concepts.

3. General Objectives – which states the general learning outcomes.
4. Pre-requisites – which presents the concepts previously learned are needed in the learning

unit for facility in handling the activities and better comprehension.

5. How-to-Use this Module – which lists the instructions in carrying out the activities provided in the module.
6. Pre-Test – which serves as a diagnostic examination to determine if the learner has sufficient knowledge of the learning unit.
7. Key to Pre-Test – which provides the answers to the questions in the Pre-Test. The result may qualify the learner to bypass the learning unit on hand and proceed to the next.
8. The Lessons
    a. Specific Objectives – which states the specific learning outcomes.
    b. Discussion – which introduces the learner to the concepts of the unit.
    c. Illustrative Examples – which demonstrates the solution of relevant problems.
    d. Practice Exercises – which lists the problems the learner has to solve. Answers are provided for comparison.
9. Post-Test – which assesses if indeed learning has taken place.
10. Key to Post-Test – which provides the answers to the questions in the Post-Test. The result will direct the learner to either proceed to the next module or go through the same module another time.

3.2 Modular Instruction

The authors share the same view with educational innovators that any innovation introduced in the conduct of a learning program should integrate the best of traditional strategies. Thus, the authors opted for a once-a-week session with the learner for queries. The following activities were carried out:

1. Orientation
   The philosophy that absolute learning resides in the individual was emphasized. Self-recognition and self-esteem are acquired through independent study. Values like resourcefulness, teamwork, creativity and discipline are inculcated in the learning program. Schedules were announced with regard to the submission of Unit Assignments, the administration of the Unit Examinations and the Comprehensive Examination. The computation of the Final Grade was explained.

2. Unit Assignments
   At the start of every learning unit, related exercises were provided. The solutions were to be submitted at a designated time before the administration of the Unit Examination. The students were provided ample time to work on every unit assignment. They were encouraged to form study groups to analyze, discuss and solve amongst themselves the assigned tasks.

3. Examinations
   The Unit Examination was provided after one or two learning units. There were five (5) Unit Examinations scheduled in the Solid Geometry course. These were on Review of Plane Geometry and Polyhedral Angles, Prisms, Cylinders, Pyramids, and Cones. There was no Unit Examination administered for the learning unit on Spheres. Exercises related to Spheres were integrated in the Comprehensive Examination.

   Six (6) Unit Examinations were defined in the Plane Trigonometry course. These were on

the Trigonometric Functions of Acute Angles and Solution of Right Triangles, Trigonometric Functions of Any Angle, Solution of Oblique Triangles, Trigonometric Formulas and Identities, Graphs of Trigonometric Functions and Inverse Trigonometric Functions and Identities, and Trigonometric Equations. Exercises related to the learning unit on Complex Numbers were integrated in the Comprehensive Examination.
All Unit Examinations were one-hour examinations. They were administered in the classroom.

A Comprehensive Examination covering all learning units was administered at the end of the semester. This covered all the learning units of the instructional modules. The Comprehensive Examination was a two-hour examination.

The Final Grade of a student in the modular class was computed with the following components:

20% - Average of Unit Assignments
30% - Comprehensive Examination
50% - Average of Unit Examinations

Twelve classes were privileged to experience modular instruction. Six classes were assigned to handle the learning modules of Plane Trigonometry and the other six classes were given the modules of Solid Geometry. Modular training was given only to students with no failing grades in the previous semester. No class handled both modules.

Students enrolled in the modular class and the traditional chalk-and-board class took the same examinations with the exception of the Mid-term Examination provided to the traditional class. In Solid Geometry, the mid-term exam was the Unit Examination of Cylinders with additional exercises about the previous learning units. In Plane Trigonometry, the mid-term exam was the Unit Examination on Trigonometric Formulas and Identities with additional exercises about the previous learning units.

The Final Grade of a student in the traditional classes was the average of the sum of the results obtained in every Unit Examination and twice the sum of the mid-term and comprehensive examinations.

Table 1 shows the comparison of students' performance in the two Mathematics courses in both traditional and modular classes.

*Table 1. Comparison of Students' Performance*

| **TRIGONOMETRY** | MODULE | *PERCENTAGE* | LECTURE | *PERCENTAGE* |
|---|---|---|---|---|
| Passed | 173 | 68 | 216 | 56 |
| Failed | 81 | 32 | 170 | 44 |
| Total | 254 | 100 | 386 | 100 |
| | | | | |
| **GEOMETRY** | | | | |
| Passed | 213 | 86 | 329 | 89 |
| Failed | 24 | 14 | 47 | 11 |
| Total | 247 | 100 | 375 | 100 |

Chi square test provided a computed value of 9.489664 for Plane Trigonometry. There was a highly significant difference between the students' performance in the modular and traditional classes. Students in the modular classes performed better than those who were enrolled in the lecture classes.

In Solid Geometry, the computed value was 0.799627. This indicated that there was no difference in the performance of a student whether he was enrolled in the modular or traditional class.

The comparison did not end here. The authors followed the performances of the students enrolled in both modular and lecture classes in the first semester of the following school year in Differential Calculus with Analytic Geometry. Lectures were delivered in all Calculus classes.
Table 2 shows the comparison of the students' performance in the second year.

*Table 2. Comparison of Students' Performance in Differential Calculus*

| **TRIGONOMETRY** | MODULE | *PERCENTAGE* | LECTURE | *PERCENTAGE* |
|---|---|---|---|---|
| Passed | 159 | 93 | 175 | 81 |
| Failed | 12 | 7 | 41 | 19 |
| Total | 171 | 100 | 216 | 100 |
| | | | | |
| **GEOMETRY** | | | | |
| Passed | 151 | 82 | 265 | 71 |
| Failed | 32 | 18 | 44 | 29 |
| Total | 183 | 100 | 309 | 100 |

Chi square test provided a computed value of 11.55811 for Plane Trigonometry indicating a highly significant difference between the students' performance who were enrolled in the modular classes and in the traditional classes during the previous semester. Students coming from the modular classes performed better than those who were enrolled in the lecture classes.

In Solid Geometry, the computed value was 0.927671. This indicated that there was no difference in the performance of a student previously enrolled in a modular class or in a traditional class.

A survey among the students enrolled in modular classes was conducted and the following observations were made:

1. The learner became aware of his capacity to learn by himself.
2. Self-confidence was developed.
3. Learner became resourceful and creative in the solution of problems.
4. Teamwork was promoted.
5. Fear of and apprehension about self-learning were overcome.
6. There was willingness to go through modular instruction again.

It is worthwhile to note that most of the students preferred to learn a course with the combination of both modules and lectures. A study undertaken in the US in Chemistry classes showed the same observation[4]. There are learning units that are best learned through modules and there are subject matters that need the further explanation of the teacher.

## 4. Conclusion

Modular training provides a good avenue for students to develop in them self-pride. When a student passes a course utilizing self-learning modules, greater self-confidence is developed in him. However, there are some concerns the authors would like to raise.

1. It is better that students know upon enrollment if a course is to be conducted through lectures or modules. Most students are not conditioned to learn by making use of self-learning modules.
2. Enrollment to modular classes must be voluntary. Fear and anxiety contributes to poor performance of the students.
3. Learning modules must be independent of required textbooks. If not, additional financial burden is imposed on the students.
4. Lectures must also be provided but only on lessons that will require the need for such. During the 1999 Summer Session, the authors provided minimal lectures in their classes with better results.
5. Other courses may initially opt for a combination of lecturing in some learning units and providing modules in the other units. The authors introduced a learning module on Partial Fractions in College Algebra and most of the students were able to perform the exercises correctly.
6. Extra care must be observed when writing modules especially with the solutions and answers to the illustrative examples and practice exercises. Any error present in the module will lead to confusion and may result to lack of interest on the part of the learner. Credibility of the author is highly at stake.

There is one area that has become a matter of concern to peers at the ES Department. They worry that evaluating and marking Unit Assignments is an exercise in futility because of the high probability of students merely copying someone else's work. The authors contend that while it is true that duplication of solutions is not far-fetched, the activity freely provided the learner the opportunity to interact and brainstorm with other learners. The free exchange of ideas was encouraged and the authors left it to the learner whether he becomes an active participant in the learning process or an "empty bucket" always waiting for the "rain to drop". On judgment day, the learner would be working all by himself and that is when he would recognize the value of experiential learning and confront the dilemma that passive learning brings.

Modular training should not be taken as the sole means of individualizing instruction. There are other ways by which personalized learning may take place. ICT has made possible learning anytime and anywhere. Web-based courses are designed to enhance learning. Distance learning requires the development of courses for online users. Thus, the administrators and faculty members are encouraged to develop and introduce innovations in the teaching-learning process. It is their responsibility to provide a learning environment that should make the student feel that learning should not necessarily be structured, formatted and restricted. While there are certain standards the learning institution has set, the student should be allowed to pursue further studies by guiding him to resources the teacher may not be able to supply due to some constraints; by introducing relevant and current information which are not covered in the course syllabus; by letting him think ahead of the time; and by imbibing the impact to society of all knowledge he

acquired.

We must all look forward to the student who *lives* by what he *learns* from school.

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