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Learning Undergraduate Mathematics in a Discovery-Enriched Approach

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Abstract**—**Students often adopt routine practicing as learning strategy for mathematics. The reason is they are often bound and trained to solving conventional-typed questions in Mathematics in high school. This will be problematic if students further consolidate this practice in university. Therefore, the Department of Mathematics emphasized and integrated the Discovery-enriched approach in the undergraduate curriculum. This paper presents the details of implementing the Discovery-enriched Curriculum by providing adequate platform for project-learning, expertise for guidance and internship opportunities for students majoring in Mathematics. The Department also provided project-learning opportunities to mathematics courses targeted for students majoring in other science or engineering disciplines. The outcome is promising: the research ability and problem solving skills of students are enhanced.

Keywords**—**Discovery-enriched curriculum, higher education, mathematics education, project learning.

I. Introduction

THOUGH applying mathematics knowledge in solving problem-based questions is highly emphasized; mathematics teachers often find it hard to set sensible mathematics projects / case studies in high school. Since tackling conventional-typed questions are still the major emphasis in high-school curriculum in Hong Kong, students are often bound and trained to solving conventional-typed questions. This will be problematic if students solely adopt routine practicing as a learning strategy in university. Therefore, the Department of Mathematics, City University of Hong Kong (CityU), emphasized and integrated the Discovery-enriched approach in the teaching of undergraduate students. Through the implementation of the Discovery-enriched Curriculum (DEC), it is hoped that all students have an encouraging platform to make an original discovery while studying at CityU so that they learn what it means to create new knowledge, communicate it, curate it, and cultivate it to benefit society [1]. To be specific, we adopted project-approach learning in several courses in the undergraduate curriculum for students majoring in Mathematics.

The academic year 2012/13 is the first academic year for all universities in Hong Kong to transit from three-year undergraduate curriculum to four-year undergraduate curriculum. First year students are admitted to the College of Science and Engineering and study fundamental courses in Science, Mathematics, Languages and Gateway Education. They opt for their majors by the end of their first year's studies. The following illustrates the implementation of the Discovery-enriched Curriculum (DEC) throughout the new four-year undergraduate programme in Mathematics Major, namely, the Bachelor of Science (Honours) in Computing Mathematics.

II. First Year Curriculum: Interdisciplinary Research as one of the Electives for Gateway Education

To get accord with the goal of DEC in enabling students to make their original discovery, the course GE1319 Interdisciplinary Research for Smart Professionals is designed and first launched in the academic year 2012/13 by the College of Science and Engineering. This is one of the elective courses for first year students in fulfilling the requirement of gateway education. The course aims to broaden first year students' exposure in research by providing them with opportunities in performing research on projects which are outside their normal disciplines of study, under the supervision of faculty members who are expertise in specific fields. By arranging a series of mass lectures, it also allows students to get familiar with the inter-disciplinary research basis and culture. The course provides essential learning opportunities for students to gain the skills for building up knowledge outside their own discipline, and to experience the process of creating own knowledge. Such skills are essential for smart professionals in the knowledge-based society [2], [3].

Table I illustrates the schedule of GE1319 in semester A 2012/13. A series of five lectures are conducted weekly at the beginning of the course. It is hoped that students acquire a general understanding on the attitude of performing scientific research and appreciate the basis and importance of interdisciplinary undergraduate research. They will also be equipped with research skills by attending training class on MATLAB conducted by faculties of the Department of Mathematics. Students in a group of three are then assigned to different advisors and start performing projects of various topics. They are required to give presentations at the end of the semester. The performances on both projects and presentations

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form the core part of the assessment of this course.

Throughout the course, students are required to discuss their assigned readings on interdisciplinary research with the supervisor in a regular basis. Some available projects in semester A 2012/13 are 'The calculation of π by some numerical methods', 'The beauty of fractal geometry' and 'Pitfalls of Numerical Computations'.

TABLE I
SCHEDULE OF GE1319 INTERDISCIPLINARY RESEARCH FOR SMART PROFESSIONALS

(a)

Week	Duration	Lecture Title	Remark
2	1 hour	'What is scientific research?'	To be conducted by faculty from the College of Science and Engineering
3	1 hour	'Ethical issues on scientific research'	To be conducted by faculty from the College of Liberal Arts and Social Sciences
4	1 hour	'The interdisciplinary nature of scientific research'	To be conducted by faculty from the College of Science and Engineering
5	1 hour	'Business opportunities and social implications on scientific research'	To be conducted by faculty from the College of Business
6	1 hour	'Legal issues on scientific research'	To be conducted by faculty from the School of Law

(b)

Week	Duration	Activities	Remark
3-7	2 hours per week	A tutorial on MATLAB	To be conducted by faculty from the Department of Mathematics
8-13	9 hours in total	Project team supervision	To be supervised by faculties from the Department of Mathematics
8-13	2 hours per week	Tutorials	To be conducted by teaching staff from the Department of Mathematics
14	3 hours	Group presentations	To be evaluated by faculties from the Department of Mathematics

For instance, students who perform the project 'The calculation of π by some numerical methods' will be introduced the methods of estimating π by Archimedes, Chinese Mathematician Liu Hui, Zhu Chongzhi and by generating random points and considering the ratio of the points inside an inscribed circle with radius r to the points inside the square with sides $2r$ by Monte Carlo method (with the use of MATLAB). They are encouraged to explore more methods of estimating π historically and to appreciate and make comparison on different methods.

III. CURRICULUM IN MATHEMATICS MAJOR

The curriculum of the Department of Mathematics is tailor-made to meet the growing demand for expertise in educational, industrial and financial sectors. Students have much flexibility to opt for elective courses in mathematics, internships, exchange studies and industrial placements as well as to declare for minor [4]. To enhance students' attitude and ability in applying mathematics knowledge to interdisciplinary research, the courses adopt discovery-enriched approach. The following highlights the practice of DEC throughout the programme.

A. MA4533 Applied Mathematics Laboratory

This six-week elective course is offered in every semester (semester A, semester B and summer semester). It aims to develop students' problem-based learning and team work ability, presentation skill and report writing ability. Students in a group of three are required to tackle problems related to applied mathematics. They are supervised by eminent professors who are visiting professors of the Department of Mathematics with expertise in related field. Students meet the supervisor on a regular basis (normally once a week) to report on the literatures reviewed, methodology and problems encountered in tackling the problem [5]. They are required to make presentations and their performance is assessed by faculties of the Department of Mathematics.

The course has been welcomed by students majoring in mathematics who are at their second or third year of studies in the Mathematics Major. A student can register for the course repeatedly, provided that different projects are being performed by the student. Some topics performed in previous semesters are 'Monte Carlo Method', 'Binomial Models in Finance' and 'Option pricing and implied volatility'. They are all topics that beyond the scope of mathematics learnt for students who registered for this course. Selected projects of high quality will be showcased in the Student Project Exhibition, an annual event of CityU held at the end of each academic year that attracts the participation of high school students and representatives from industrial sectors.

B. MA4530 Final Year Project

This is a whole-yearly course offered annually to final year students majoring in mathematics. It gives the student ample opportunity to demonstrate innovative abilities and initiative in his/her independent treatment of problems, and develops the ability to integrate and apply knowledge and analytical skills to practical situations. The course also serves to give students practice in clear and concise written and spoken communication of the results of an investigation [6].

Students in their final year of studies are highly encouraged to register in this course. Each individual is assigned with more

demanding research-based problems under the guidance of a faculty in the Department of Mathematics. Students meet the supervisor on a regular basis to report on the literatures reviewed, methodology and problems encountered in tackling the problem. They give presentations, write report and their performance is evaluated by faculties of the Department of Mathematics.

From past experience, students who would like to pursue postgraduate studies in mathematics or mathematics-related disciplines were particularly eager to register for this course, hoping that they can gain hands-on experience on performing research, acquire more knowledge on specific topics for their future postgraduate studies and to establish an attitude of performing research. Some topics performed in past years are 'Queueing System', 'Numerical Solution of Differential Eigenvalue Problems with the Tau Method', 'Markov Chain Approximation on Financial Bubbles', 'Periodic Solutions of Strongly Nonlinear Oscillators' and 'Numerical Simulation for Solitons in Optical Fibers'. Selected projects of high quality will also be showcased in the Student Project Exhibition.

C. MA4540 Modeling and Case Studies

This course provides students with the necessary skills to apply mathematical modeling techniques in a range of physical problems. It develops students' problem-based learning and team work ability, presentation skill and report writing ability [7].

TABLE II
SCHEDULE OF MA4540 MODELLING AND CASE STUDIES

Week	Duration	Activities	Remark
2-8	3 hours per week	Lecture on the basics of mathematical modeling and the techniques	To be conducted by teaching staff / faculty from the Department of Mathematics
8-13	At least 3 hours per week	Project team supervision	To be supervised by faculties from the Department of Mathematics
14	3 hours	Group Presentations	To be evaluated by course teachers of MA4540

Table II illustrates the schedule of MA4540. Students attend seven lectures on the basics of formulating mathematics model in tackling a given problem and the techniques of mathematics modeling in the first half of the semester. They form a group of three in week 8 and are given several project topics. They are free to select project topics interested and are then guided by project advisors who are expertise in the related field towards the completion of the project. Students are required to give presentations at the end of the semester. The performance of the projects and the group presentations constitute the core part of the assessment in this course.

Project such as 'Harvesting Strategy on a Fishery Model with Birth Pulse', 'Circular Restricted Three Body Problem' and 'University Timetable Scheduling' were performed in the past few years. Selected projects will also be showcased in the Student Project Exhibition.

The courses MA4533, MA4530 and MA4540 have been offered for several years and have been welcome by students. The performance of most students was very satisfactory, as commented by their supervisors and the panel members.

D. Internship and Industrial Placement Schemes

Students from the Department of Mathematics have many opportunities in joining the internship schemes offered by the Co-operative Education Centre of CityU. Through the internship schemes, students learn to apply their classroom learning to real life and at the same time improve their problem solving and interpersonal skills. They gain solid work experience and become better equipped for work. The placement training covers a wide spectrum of work areas, all being relevant to students' major studies [8].

Every year, nearly 20% of mathematics-major students participated in the internship scheme and gained experience in government sector and enterprises such as Hong Kong Observatory, Towngas, DHL, etc. There are also one-year placement positions from Hong Kong and Shanghai Banking Corporation for students who have completed their second year of studies in the Mathematics Major.

E. Exchange Opportunities and Participation in Mathematical Contest in Modeling at the National Level

Due to the flexibility of the curriculum, many students from the Department of Mathematics are well qualified and opt for exchange studies and have the occasion to study in overseas universities for one semester during their second or third years' studies in the Mathematics Major. The scheme is very popular to students, especially to those who would like to pursue further studies after graduation. Students widened their horizon by participating in the exchange studies.

The Department of Mathematics strongly encouraged students to take the opportunity on applying their mathematics knowledge and analytical skills by actively participating in contests on mathematical modeling. Students are informed of upcoming events in advance. Students who participant in contests at the national level will normally be assigned with experienced advisors. The performance of students has been outstanding in past years. In particular, a team of five students from the Department of Mathematics participated in the China Undergraduate Mathematical Contest in Modeling 2011 and two of them obtained First Prize at the national level.

IV. CONCLUSION

The outcome of Discovery-enriched Curriculum is promising. Students welcomed the means of delivery of knowledge in a project-learning approach. Their problem-solving skills are enhanced and their interest in performing research and enquiry-learning are cultivated. Their research skills are built and are better prepared for further studies. In recent years, over 25% of the students in each cohort pursue Master or Doctoral Studies in Pure or Applied

Mathematics after graduating from the bachelor degree in Computing Mathematics.

The Department of Mathematics will closely monitor the implementation of DEC in existing courses and to broaden its coverage to more courses in the curriculum by launching more project-learning opportunities in a wider spectrum of courses. The department will continue to encourage more participation to contests on mathematical modeling and provide necessary support to students.

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