Maritime Mathematics Course Renovation in Maritime Training Programs in New Zealand

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Abstract— **Maritime Mathematics is a fundamental part of Maritime Training Programs, as it is deeply involved in maritime affairs, e.g. ship stability and navigation are the problems that can be solved by computing using mathematics. Standards of Training, Certification and Watchkeeping (STCW) requires the trainees to be assessed and deemed competent in maritime mathematics, a New Zealand Qualifications Authority (NZQA) Level 3 course with 15 credits is to assess for competency in maritime mathematics in the following six topics: Algebra, Mensuration, Graphs, Calculus, Geometry, Trigonometry. Until end of 2021, the program specific regulations allow open entry for domestic students and no mathematics access criteria for international students. This means that the students start their maritime mathematics class at varying levels of proficiency. However, all learning outcomes in six maritime mathematics topics must be achieved for a student to be deemed competent by completion of their training programs. A study is conducted to identify the gaps caused by the open entry policy, based on observation of interaction of teaching and learning with results in course final exam, to analyze the weakness of the current teaching contents and start Maritime Mathematics course renovation in maritime training programs in New Zealand. This study has contributions to Programme Change Application, which has been approved by NZQA at end of 2021, that Applicants must meet the following criteria for admission into the programme Applicants with no seagoing experience: 14 credits in either Mathematics (calculus, algebra or equivalent) and/or Physics. As the programme Applicants with seagoing experience still have no mathematics access criteria, this study has led to the production of a new Industry-oriented teaching strategy to the course development in 2022. And a formative test at the time of student enrolment to identify this group of students. thus, a pre-course session will be offered to the group of students who are lack of Mathematics foundation. Further study is to follow and enhance Maritime Mathematics course renovation in New Zealand.**

Keywords— Maritime Mathematics, Course Renovation, Maritime Training Programs

I. INTRODUCTION

New Zealand Diploma in Nautical Science program is classified in subject area of Engineering and Related Technologies in New Zealand Qualification Framework by New Zealand Qualifications Authority (NZQA) [1]. Mathematics as a science and marine activity follow each other throughout history, Stanivuk and the team [2] stated that Modern maritime affairs require an understanding of their formation and implementation, as well as the application of exact mathematical science in such a progressive and demanding technological progress of electronic and IT devices, such as those used on board ships.

Whilst Qi and his team [3] had been undertaking on-going research of applying mathematics knowledge to industry orientated problems in classroom teaching, Akakpo [4] recommended that the supply of good classroom examples and maritime case studies from different application areas is a key factor for the development of attractive and inspiring educational modules in both applied and industrial mathematics used in the maritime industry. Especially in the courses on mathematical modelling are needed a flow of fresh problems to maintain an intellectual urge.

A New Zealand Qualifications Authority (NZQA) approved program New Zealand Diploma in Nautical Science (Level 6) [5] is to provide the maritime industry with people who have the skills and knowledge required by the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) to work as Officer of the Watch (Deck) on foreign-going ships. Graduates will be able to work directly under the Chief Mate or Master and have a very high level of responsibility for the safety of the vessel. The Officer of the Watch will be expected to operate unsupervised for extended periods in sole charge of complex and unpredictable vessel operations.

This qualification is for seafarers training to become officers in charge of a navigational watch on ships of 500 GT or more operating in unlimited waters but is also open to suitably qualified new entrants to the maritime industry.

Whilst the STCW requires the trainees to be assessed and deemed competent in maritime mathematics, A NZQA Level 3 course with 15 credits is to assess for competency in maritime mathematics in the following six topics:

1, Algebra. This will include the manipulation of algebraic expressions, the algebraic expression of problems, and the solution of algebraic problems.

2, Mensuration. This will include calculating perimeter, area, surface area and volumes of various shapes.

3, Graphs. This will include the sketching of graphs in accordance with given relationships, the description of features of the graphs, the reporting of data in graphical form, and the reporting of conclusions obtained from graphical data.

4, Calculus. This will include the differentiation of polynomial functions to obtain derivatives in accordance with calculus principles, and the anti-differentiation of polynomial functions to obtain anti derivatives in accordance with calculus principles.

5, Geometry., the expression of problems which allow solution by geometric properties, and the solution of problems by applying geometric properties.

6, Trigonometry. This will include the expression and solving of problems using plane trigonometry.

Until end of 2021, the program specific regulations allow open entry for domestic students and no mathematics access criteria for international students. This means that the students start their maritime mathematics class at varying levels of

proficiency. However, all learning outcomes in six maritime mathematics topics must be achieved for a student to be deemed competent by completion of their training programs. This study was conducted to identify the gaps caused by the open entry policy, based on observation of interaction of teaching and learning with results in course final exam, to analyse the weakness of the current teaching contents and start Maritime Mathematics course renovation in maritime training programs in New Zealand. This study had contributions to Programme Change Application, which has been approved by NZQA at end of 2021, that Applicants must meet the following criteria for admission into the programme Applicants with no seagoing experience: 14 credits in either Mathematics (calculus, algebra or equivalent) and/or Physics. As the programme Applicants with seagoing experience still have no mathematics access criteria. This paper presents the study which has led to the production of a new Industry-oriented teaching strategy to the course development in 2022. The further study is based on experiment of a program development including a formative test at the time of student enrolment to identify this group of students, a pre-course session will be offered to the group of students who are lack of Mathematics foundation.

II. Course Descriptor of Industry-oriented Teaching Strategy of Maritime Mathematics

Maritime Mathematics (15 credits of 300 credits for the diploma program) is aimed to solve problems using applied mathematics in the maritime environment.

This course extends over a period of 4 weeks in total of 150 hours study time. The main structure of the course is stated below.

With this course students are able to: manipulate algebraic expressions and use algebraic methods and mensuration to solve problems, sketch and describe graphs, apply calculus, solve problems using geometry and solve problems using trigonometry to manipulate algebraic expressions and use algebraic methods and mensuration to solve problems, sketch and describe graphs, apply calculus, solve problems using geometry and solve problems using trigonometry.

III. Assessment Design of Maritime Mathematics

As shown in Table 1, the teaching plan consists of teaching sessions of Algebra, Mensuration (including Arithmetic), Graphs, Calculus, Geometry, and Trigonometry. Other sessions are also provided: An Introduction session, 7 sessions of Extra tutorial and 3 sessions for Mock Exam.

Assessment weighting is showed in Table 1. Graphs and Calculus are combined.

TABLE 1 ASSESSMENT WEIGHTING

Topic	Teaching sessions 1.67 hour/session	Assessment weighting
Algebra	17	20%
Mensuration (Arithmetic)	7	10%
Geometry	6	15%
Graphs	6	35%
Calculus	7	
Trigonometry	10	20%
others	11	

IV. Industry-oriented Teaching Contents

The teaching contents are to provide exercise to solve the issues in marine applications e.g.

- A crew rows 7 miles downstream and back in 200 minutes. If the river runs at 2 knots, what is the boat's speed in still water?.
- A forestay 12 meters long is made fast to the foremast at a point 8 metres above deck with the other end fast on deck forward of the mast. An anchor light is hung on the forestay 5 meters above deck. Find the horizontal distance between the mast and the anchor light measured along the deck.
- A lightship A is 12 NM due West of a point of land B. From A, a vessel C is observed 14.5 NM off and at the same time the vessel C bears 230° (T) from B. Find the bearing of the lightship A from the vessel C.

V. Result of Final Exam and Analysis

The final exam has a result as shown in Fig. 1. The horizonal scale indicates marks and the vertical scale indicates the number of individual students. The scale of 100% indicates a full mark while the pass line is 50% of the maximum mark. The pass rate of this exam is 65%, while 72% of the passed students received a low-pass between 50% and 59% of the full mark.

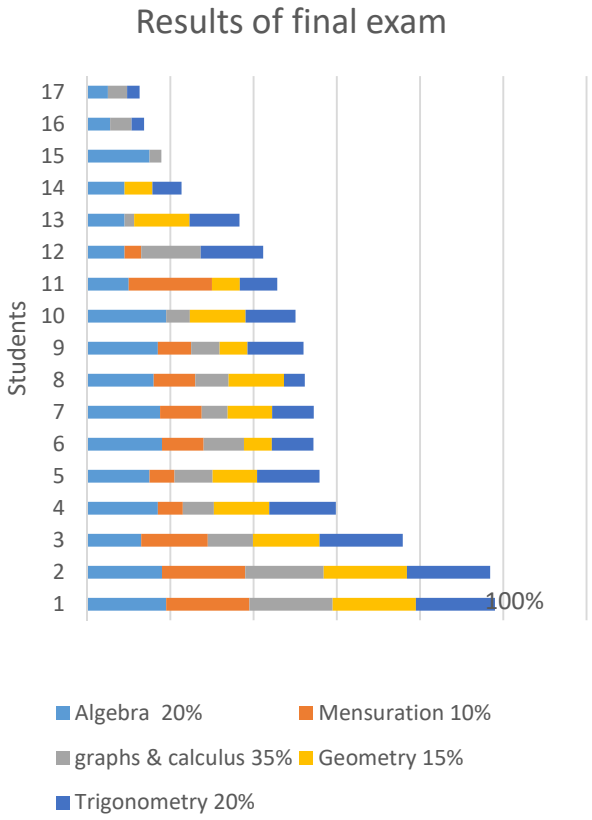

Fig. 1. Results of final exam with assessment weighting

Results as shown in Fig. 2 to 6, the vertical scale indicates marks in 100% and the horizonal scale indicates the number of individual students.

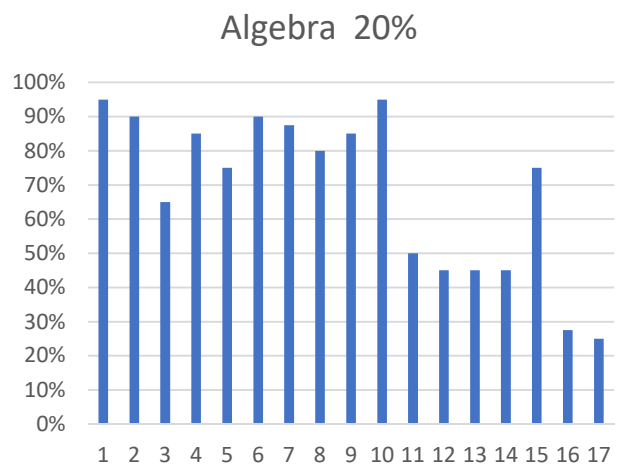

Fig. 2. Algebra results

Fig. 2 shows that result of Algebra has 71% pass rate, no zero marks.

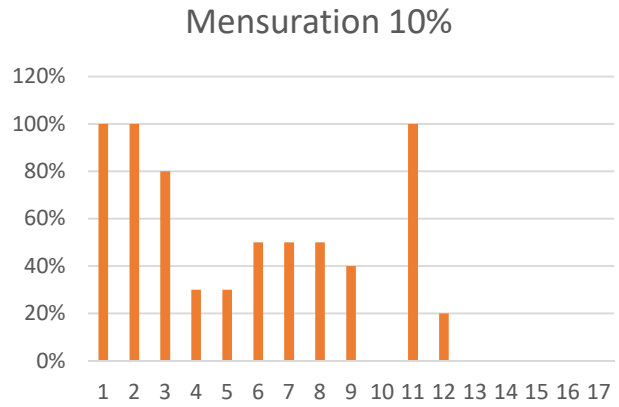

Fig. 3. Mensuration results

Fig. 3 shows that result of Mensuration has 41% pass rate, 6 students have zero marks out of 17 students.

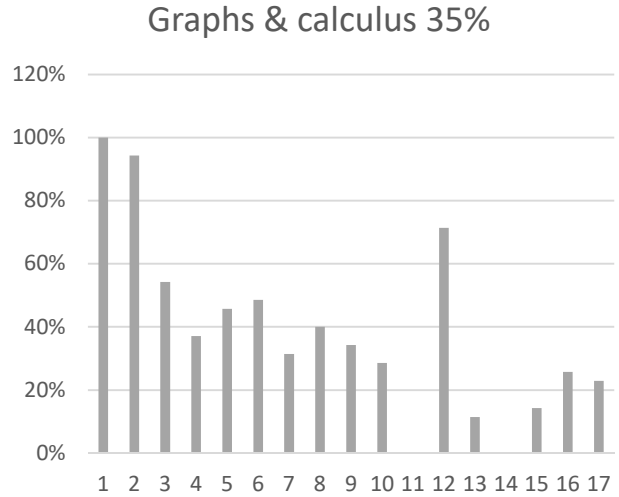

Fig. 4. Graphs & calculus results

Fig. 4 shows that result of Graphs & Calculus has 24% pass rate, 2 students have zero marks out of 17 students.

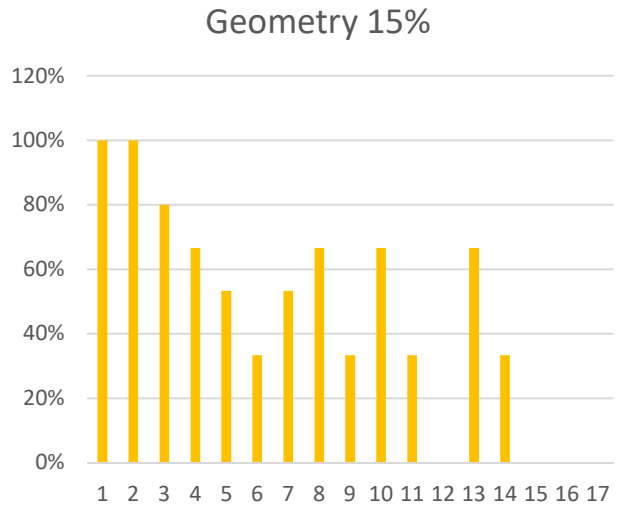

Fig. 5. Geometry results

Fig. 5 shows that result of Geometry has 53% pass rate, 4 students have zero marks out of 17 students.

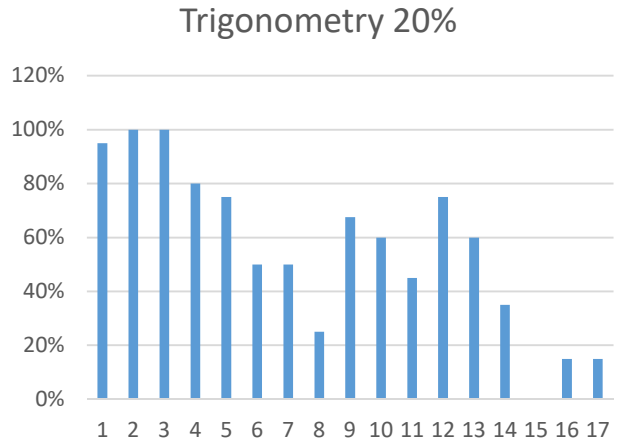

Fig. 6. Trigonometry results

Fig. 6 shows that result of Trigonometry has 65% pass rate, a student has a zero mark out of 17 students.

In summary, results as shown that, Algebra has 71% pass rate, Mensuration 41%, Graphs & Calculus 24%, Geometry 53%, Trigonometry 65% as shown in Table 2.

TABLE 2 PASS RATE AND ZERO MARKS IN SUBJECTS

Topic	Pass rate	Zero marks
Algebra	71%	0%
Mensuration	41%	24%
Geometry	53%	24%
Graphs/calculus	24%	12%
Trigonometry	65%	7%

From Fig. 2 to Fig. 6 have shown in details to the individuals, whose background of foundation will be

identified for further research. A summary as shown in Table 2, Algebra has the highest pass rate and the Graphs & Calculus has lowest pass rate, while Mensuration and Geometry received 24% zero marks.

There are 24% zero marks in Mensuration, 24% zero marks in Geometry, 12% zero marks in Graphs & Calculus, 7% zero marks in Trigonometry.

Further analyses, 6 students have zero marks, while a student has zero marks in 3 of 5 teaching sessions, 2 students have zero marks in 2 of 5 teaching sessions and other 3 students have zero marks in 1 of 5 teaching sessions. All of these students are in the fail grade.

Most of zero marks were caused by no attempts to answer during the exam time, and no observations to identify of time issues, in fact, some of those students handed in their exam papers with no answers to those questions in exam paper.

VI. Conclusion and Futher Research

In this case study, it was concluding that program specific regulations of New Zealand Diploma in Nautical Science are allowing open entry for domestic students, has vary impact of six topics: Algebra, Mensuration, Graphs, Calculus, Geometry, Trigonometry, and most of the students have low-pass, while a large group of student failed with zero marks in some of the six topics.

Though Industry-oriented teaching contents were included in topics which are clearly linked to the students' practical areas, to provide exercise to solve the issues in marine applications, large group of students were failed due to lack of maths foundation.

Programme Change Application has been approved by NZQA at end of 2021, that Applicants must meet the following criteria for admission into the programme Applicants with no seagoing experience: 14 credits in either Mathematics (calculus, algebra or equivalent) and/or Physics. However, the programme Applicants with seagoing experience have no mathematics access criteria.

A two-hour pre-test is introduced prior to Maritime Mathematics. The degree of difficulty of the questions will be approximately comparable to National Certificate of Educational Achievement (NCEA) Level 2 maths.

The maths topics included in the assessment will be taken from the following topic areas as shown in Table 3.

TABLE 3 THE MATHS TOPICS INCLUDED IN THE ASSESSMENT

Arithmetic	Manipulation of Powers, roots, Ratio & proportion, variation, logs to different bases
Algebra	Addition, subtraction, factorization, transposition and evaluation of formulae, simultaneous equations
Graphs	Plotting graphs from data Determining equation to straight line graphs
Measurement of Angles and Trigonometric Relationships	Complementary and supplementary angles Pythagoras Theorum
Geometry	Construction of perpendiculars Bisecting lines and angles Construction of triangles Similar triangles
Solution of Triangles	Sine rule Cosine rule Equilateral and isosceles triangles
Mensuration of Areas	Parallelogram Triangles polygons Circles. Sectors
Mensuration of Volumes and Masses	Volume, density Volumes of prisms, pyramids and spheres

A Pre-Maths course is required prior to Maritime Mathematics for students failed in pre-test.

This course will extend over a period of 1 week. The aim to this course is to re-introduce Maths and thinking methods as preparation for the main examination courses.

Teaching Structure: A flexible approach will be employed depending on progress and starting level of the students. Emphasis is on principles and ideas rather than on total coverage of syllabus. The use of demonstrations and the relating of topics to real life workplace situations will be carried out where possible. Mathematics will involve the ability to manipulate expressions and use basic mathematical skills to solve simple problems. Course Topics of Mathematics covers Algebra, Mensuration, Graphs, Trigonometry.

This is an on-going research project. Next step is an industry survey to be conducted to determine the aspects of the current maths course most needed in Maritime industry. This project is led to the production of an Industry-oriented teaching strategy [3] to the course development in 2022/2023.

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