NUI MAYNOOTH

Ollscoil na hÉireann Má Nuad

The Role of Mathematics in Engineering Practice and in the Formation of Engineers

Volume 2 of 2

Eileen Goold

B. E., M.Eng.

Thesis Submitted for the Award of Doctor of Philosophy

National University of Ireland Maynooth

Department of Design Innovation

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Head of Department: Dr. Frank Devitt

Supervisor: Dr. Frank Devitt

TABLE OF CONTENTS

LIST OF FIGURES

Page number

LIST OF TABLES

Page number

APPENDIX 1: SURVEY QUESTIONNAIRE

Survey on Mathematics Used by Engineers

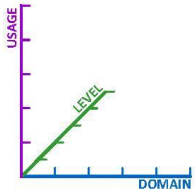
Department of Design and Innovation, NUI Maynooth

This survey is part of NUI Maynooth's research into the role mathematics plays in the working life of engineers. We anticipate the outcome of this study will contribute to enhancing the structure and content of engineering education, particularly in regard to mathematics quantity, level and conceptual approach.
For further information, please feel free to contact Eileen Goold at eileen.goold@nuim.ie, (m) 086 179 8175.

Your participation in this survey is important and is much appreciated. All contributions are confidential. The results will be published in early 2012.

INSTRUCTIONS

Please refer to support document, Survey INFO, attached. In this survey, we ask for comments on your professional usage of mathematics, with reference to **3 dimensions**, as follows:



DOMAIN There are 5 (topics) domains ...
Statistics and Probability; Geometry and Trigonometry; Number; Algebra; Functions

LEVEL There are 5 (academic progression) levels ...
Junior secondary; Intermediate secondary; Senior secondary; Engineering; B.A. / BSc.

USAGE There are 5 usage types ...
Reproducing; Connecting; Mathematising; Thinking; Engaging

THE WHOLE SURVEY IS CONTAINED IN PAGES 2– 10. Completion time is 30 minutes approx.

PART A (p2) First, we request some brief biographical details.

PART B (p3-7) We ask for your separate entries for each mathematics domain, in each case for the first 3 usage types (reproducing, connecting, mathematising).

PART C (p8-10) The two remaining usage types (thinking, engaging) are entered separately.

Please note the specific completion instructions at the beginning of each PART. *Completion instructions are always in blue italics.*

The 5 USAGE types are defined in the support document attached, **"Survey INFO."**
Information on mathematics TOPICs at the various LEVELs and examples of different USAGE types are also included in this support document. It may be useful to open this supplementary document alongside the survey document for ease of reference.

PART A - BIOGRAPHICAL DETAILS

***Instructions**: Select your responses from the options available in the radio buttons or dropdown menus.*

A.01	Your gender	Male ○	Female ○
A.02	Do you have a Chartered Engineer status or equivalent? (i.e. level 8 engineering degree, e.g. B.Eng., + four years relevant professional experience)	Yes ○	No ○
A.03	Your engineering discipline?	Please select one of ...	
	Other discipline? *Please state*		
A.04	Your engineering role?	Please select one of ...	
	Other role? *Please state*		
A.05	Your company?	Please select one of ...	
	Multinational company?	Yes ○	No ○
A.06	Your current position?	Please select one of ...	
A.07	Your Leaving Cert maths level and grade?	Please select one of	Please select one of
	Year of Leaving Cert? *Please state*		
A.08	Do you agree that you could perform satisfactorily in your current job <u>without</u> higher level Leaving Cert Maths?	Please select one of ...	
A.09	Did you enjoy maths in secondary school?	Please select one of ...	

A.10 Only a minority of students sit higher level Leaving Cert maths and many of those subsequently choose not to stay with numerate studies. How, in your view, could young people's affective engagement (e.g. enjoyment) with maths be improved?

PART B (i) - STATISTICS & PROBABILITY

B.10 QUESTION:

To what extent have you used Statistics & Probability in your work in the last 6 months?

INSTRUCTIONS:
Select your response from the options presented in EACH of the dropdown menus to indicate your usage of Probability & Statistics at each LEVEL and for each USAGE type. Usage types are mutually independent.

*For guidance, definitions and sample topics in Probability & Statistics, at various levels and usage types are provided in the support document attached, "**Survey INFO**."*

You should make an entry in ALL (yellow) answer boxes.

STATISTICS & PROBABILITY

USAGE TYPE		*e.g. facts or applying routine algorithms* Type 1 usage **Reproducing**	*e.g. use of different tools & problem solving strategies* Type 2 usage **Connecting**	*e.g. interpreting & developing models, translating into real world solutions* Type 3 usage **Mathematising**
SUBJECT LEVEL				
Junior – secondary		Please select one of ...	Please select one of ...	Please select one of ...
Intermediate – secondary		Please select one of ...	Please select one of ...	Please select one of ...
Senior – secondary		Please select one of ...	Please select one of ...	Please select one of ...
Engineering		Please select one of ...	Please select one of ...	Please select one of ...
B.A. / B.Sc.		Please select one of ...	Please select one of ...	Please select one of ...

PART B (ii) - GEOMETRY & TRIGONOMETRY

B.20 QUESTION:

To what extent have you used Geometry & Trigonometry in your work in the last 6 months?

INSTRUCTIONS:
Select your response from the options presented in EACH of the dropdown menus to indicate your usage of Geometry & Trigonometry at each LEVEL and for each USAGE type. Usage types are mutually independent.

*For guidance, definitions and sample topics in Geometry & Trigonometry, at various levels and usage types, are provided in the support document attached, "**Survey INFO.**"*

You should make an entry in ALL (yellow) answer boxes.

GEOMETRY & TRIGONOMETRY

USAGE TYPE		*e.g. facts or applying routine algorithms* Type 1 usage **Reproducing**	*e.g. use of different tools & problem solving strategies* Type 2 usage **Connecting**	*e.g. interpreting & developing models, translating into real world solutions* Type 3 usage **Mathematising**
SUBJECT LEVEL				
Junior – secondary		Please select one of ...	Please select one of ...	Please select one of ...
Intermediate – secondary		Please select one of ...	Please select one of ...	Please select one of ...
Senior – secondary		Please select one of ...	Please select one of ...	Please select one of ...
Engineering		Please select one of ...	Please select one of ...	Please select one of ...
B.A. / B.Sc.		Please select one of ...	Please select one of ...	Please select one of ...

PART B (iii) - NUMBER

B.30 QUESTION:

To what extent have you used Number in your work in the last 6 months?

INSTRUCTIONS:

Select your response from the options presented in EACH of the dropdown menus to indicate your usage of Number at each LEVEL and for each USAGE type. Usage types are mutually independent.

*For guidance, definitions and sample topics in Number, at various levels and usage types, are provided in the support document attached, "**Survey INFO.**"*

You should make an entry in ALL (yellow) answer boxes.

NUMBER

USAGE TYPE		*e.g. facts or applying routine algorithms* Type 1 usage **Reproducing**	*e.g. use of different tools & problem solving strategies* Type 2 usage **Connecting**	*e.g. interpreting & developing models, translating into real world solutions* Type 3 usage **Mathematising**
SUBJECT LEVEL				
Junior – secondary		Please select one of ...	Please select one of ...	Please select one of ...
Intermediate – secondary		Please select one of ...	Please select one of ...	Please select one of ...
Senior – secondary		Please select one of ...	Please select one of ...	Please select one of ...
Engineering		Please select one of ...	Please select one of ...	Please select one of ...
B.A. / B.Sc.		Please select one of ...	Please select one of ...	Please select one of ...

PART B (iv) - ALGEBRA

B.40 QUESTION:

To what extent have you used Algebra in your work in the last 6 months?

INSTRUCTIONS:
Select your response from the options presented in EACH of the dropdown menus to indicate your usage of Algebra at each LEVEL and for each USAGE type. Usage types are mutually independent.

*For guidance, definitions and sample topics in Algebra, at various levels and usage types, are provided in the support document attached, "**Survey INFO.**"*

You should make an entry in ALL (yellow) answer boxes.

ALGEBRA

USAGE TYPE		*e.g. facts or applying routine algorithms* Type 1 usage **Reproducing**	*e.g. use of different tools & problem solving strategies* Type 2 usage **Connecting**	*e.g. interpreting & developing models, translating into real world solutions* Type 3 usage **Mathematising**
SUBJECT LEVEL				
Junior – secondary		Please select one of ...	Please select one of ...	Please select one of ...
Intermediate – secondary		Please select one of ...	Please select one of ...	Please select one of ...
Senior – secondary		Please select one of ...	Please select one of ...	Please select one of ...
Engineering		Please select one of ...	Please select one of ...	Please select one of ...
B.A. / B.Sc.		Please select one of ...	Please select one of ...	Please select one of ...

PART B (v) - FUNCTIONS

B.50 QUESTION:

To what extent have you used Functions in your work in the last 6 months?

INSTRUCTIONS:
Select your response from the options presented in EACH of the dropdown menus to indicate your usage of Functions at each LEVEL and for each USAGE type. Usage types are mutually independent.

*For guidance, definitions and sample topics in Functions, at various levels and usage types, are provided in the support document attached, "**Survey INFO.**"*

You should make an entry in ALL (yellow) answer boxes.

FUNCTIONS

USAGE TYPE		*e.g. facts or applying routine algorithms* Type 1 usage **Reproducing**	*e.g. use of different tools & problem solving strategies* Type 2 usage **Connecting**	*e.g. interpreting & developing models, translating into real world solutions* Type 3 usage **Mathematising**
SUBJECT LEVEL				
Junior – secondary		Please select one of ...	Please select one of ...	Please select one of ...
Intermediate – secondary		Please select one of ...	Please select one of ...	Please select one of ...
Senior – secondary		Please select one of ...	Please select one of ...	Please select one of ...
Engineering		Please select one of ...	Please select one of ...	Please select one of ...
B.A. / B.Sc.		Please select one of ...	Please select one of ...	Please select one of ...

PART C (i) - THINKING USAGE (Type 4)

C.11 QUESTION:

To what extent, with or without direct application of mathematics, did your mathematics training (with its associated modes of thinking and analysis) directly influence your approach to your work?

INSTRUCTIONS:
Select your response from the options presented in EACH of the dropdown menus to indicate your thinking usage of maths in the last 6 months, within 2 years of graduating and within 10 years of graduating.

*For guidance, definition and examples of THINKING USAGE are provided in the support document attached, "**Survey INFO.**"*

You should make an entry in ALL (yellow) answer boxes that represent your career.

THINKING USAGE

USAGE TYPE		*e.g. reasoning, logical techniques problem solving strategies, sense of solution etc.* Type 4 usage **Thinking**
WHEN		
in the last 6 months		Please select one of ...
within 2 years of graduating		Please select one of ...
within 3-5 years after graduating		Please select one of ...
within 6-10 years after graduating		Please select one of ...
greater than 10 years after graduating		Please select one of ...

C.12 QUESTION:

What modes of thinking, resulting from your maths education, influence your work performance?

PART C (ii) - ENGAGING USAGE (Type 5)

C.21 QUESTION:

With regard to your work in the last 6 months, to what degree.....

INSTRUCTIONS:
Select your response from the options presented in EACH of the dropdown menus to indicate your affective usage of maths in the last 6 months and state why in EACH of the corresponding text fields.

*For guidance, definition and examples of ENGAGING USAGE are provided in the support document attached, "**Survey INFO.**"*

You should make an entry in ALL (yellow) answer boxes.

ENGAGING USAGE

USAGE TYPE		*e.g. motivation, attitudes, beliefs, emotions, value, confidence and self-efficacy* Type 5 usage **Engaging**
QUESTION		
...was a specifically mathematical approach necessary?		Please select one of ...
Why?		
...did you actively seek a mathematical approach?		Please select one of ...
Why?		
....did you enjoy using mathematics?		Please select one of ...
Why?		
...did you feel confident dealing with mathematics?		Please select one of ...
Why?		
...did you have a negative experience when using mathematics?		Please select one of ...
Why?		

PART C (iii) - ENGAGING USAGE (Type 5)

C.31 QUESTION:

What events, experiences, aptitudes or other factors within and outside of school contributed to your interest in and learning of mathematics?

FACTORS WITHIN SCHOOL		
...primary school		
...secondary – Years 1 & 2		
...secondary – Junior Cert		
...secondary – Leaving Cert		
FACTORS OUTSIDE SCHOOL		
... primary school years		
... secondary – Years 1 & 2		
...secondary – Junior Cert		
...secondary – Leaving Cert		

C.32 QUESTION:

To what degree did your feelings about mathematics impact your choice of engineering as a career?

Please select one of ...

C.33 ADDITIONAL COMMENTS:

Would you like to make any additional comments?

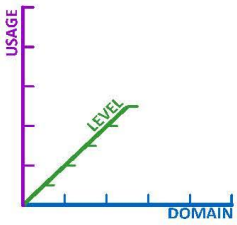
RETURNING YOUR COMPLETED SURVEY:

***INSTRUCTIONS**: Many thanks for completing the survey. To return your completed questionnaire, please select the **SUBMIT FORM** option at the top right hand corner of your screen and follow the prompts. If you experience any difficulty, please contact Eileen Goold at eileen.goold@nuim.ie or at 086-1798175. Your participation is very much appreciated.*

APPENDIX 2: SURVEY SUPPORT DOCUMENT

Survey INFO
Survey on Mathematics Used by Engineers
Department of Design and Innovation, NUI Maynooth

In this survey, we ask for comments on your professional usage of mathematics, with reference to **3 dimensions**, as follows:



DOMAIN There are 5 (topics) domains ...
Statistics and Probability; Geometry and Trigonometry; Number; Algebra; Functions

In this support document you will find information on TOPICs at the various LEVELs:

LEVEL There are 5 (academic progression) levels ...
Junior secondary; Intermediate secondary; Senior secondary; Engineering; B.A. / BSc.

Mathematics topics for each of these levels, is included in the domain pages 4 - 8.

USAGE There are 5 usage types ...
Reproducing; Connecting; Mathematising; Thinking; Engaging

Examples and definitions of the 5 USAGE types are in pages 2 and 3

Further examples of Type 1, Type 2 and Type 3 USAGE types are also included:

USAGE TYPES - examples

EXAMPLE: In a street comprising of 30 houses on the north side and 10 houses on the south side, 12 north side houses have no water supply and 8 south side houses have no water supply.

(a) What percentage of the north side houses has no water supply?
ANSWER: $(12 \div 30) \cdot 100\ \% = 40\%$ (Answer involves percentage calculation procedure)
– Type 1 REPRODUCING procedures, concepts, definitions

(b) What is the probability that an arbitrary house is in the south side and has no water supply?
ANSWER: $(10 \div 40) \cdot (8 \div 10) = 0.2$. (Answer involves connecting concepts in "Statistics and Probability" with "Number" and choosing a strategy to solve the problem)
– Type 2 CONNECTING and integrating for problem solving

(c) If the houses are divided into arbitrary groups of 2 houses for inspection purposes, would you expect at least 1 house in each group not to have a water supply?
ANSWER: – probability of arbitrary group of 2 houses with one only not having a water supply is the probability of first house not having a water supply and the second house having a water supply or the second house not having a water supply and the first house having a water supply. Probability of only one house not having a water supply in:
... 1^{st} group of houses is $P_1 = (20 \div 40) \cdot (20 \div 39) + (20 \div 40) \cdot (20 \div 39) = 0.5128$
... 2^{nd} group of houses is $P_2 = (19 \div 38) \cdot (19 \div 37) + (19 \div 38) \cdot (19 \div 37) = 0.5135$
... 18^{th} group of houses is $P_{18} = (3 \div 6) \cdot (3 \div 5) + (3 \div 6) \cdot (3 \div 5) = 0.6$; $P_{19} = 0.666667$; $P_{20} = 1$
... each group of 2 houses for total of 40 houses is $P_{Total} = P_1 \cdot P_2 \cdot P_3 \cdot P_4 \cdots P_{20}$
Approximate answer is $(\frac{1}{2})^{17} = 0.0000076$ significantly < 0.5 thus no expectation
(Answer involves mathematising the problem, developing a strategy and presenting mathematical arguments e.g. in this example, solution is derived by taking a fixed reference point (e.g. probability of 2 houses having only one without water), extrapolating to make other data tentatively known by reasonable assumption, establishing boundary of validity and confirming that the data (extrapolated data) transcends the boundary by virtue of reasonable assumptions.)
– Type 3 MATHEMATISING - mathematical thinking, generalisation and insight

(d) How might the water distribution manager convince a reluctant government to increase the budget for water system maintenance? ANSWER: - by
(i) looking for a rigorous, supportable, clear statement of justification – costs v. benefits
(ii) decomposing the problem into addressable elements (e.g. what are the... age profile of piping, likelihood of weather events of varying gravity, likely volumes of pipe leakage under various weather conditions, likelihood of water treatment plant failure?)
(iii) identifying evidence-based (i.e. provable) answers for each problem element, where available or by looking for patterns and analogues to justify estimated answers where evidence data is lacking
(iv) integrating the elemental solutions into a total solution and presenting this in a clear, simple tabular presentation, e.g. showing the number of household-days of water interruption per year (with, say, > 50% probability), for each of 0%, 10%, 20%, ... increase in maintenance budget and so allowing the budget giver to choose the budget level and consequences simultaneously.
(Mathematical training inclines the manager to use modes of thinking learned and practised in the solution of mathematical problems. The manager seeks out clarity or simplicity, supported by rigour and presents a clear and simple solution that is defensible if queried)
– Type 4 THINKING - contribution of mathematics training to modes of thinking

(e) Motivation and confidence to engage with mathematics (e.g. positive or negative emotional feelings when presented with mathematics problems or when an opportunity to 'mathematise' a problem arises.)
– Type 5 ENGAGING – emotional relationships with mathematics

USAGE TYPES - EXAMPLES

USAGE TYPES - definitions

Type 1 **REPRODUCING procedures, concepts, definitions**

Usage of mathematics through knowledge of facts and concepts, recalling mathematical properties, performing routine procedures, applying standard algorithms and operating with mathematics symbols and formulae. Users require knowledge of facts, concepts, definitions and routine procedures that have been memorized and previously practiced.

Example: Use Pythagoras' theorem to compute the length of the unknown side of a right angled triangle. (Answer involves applying Pythagoras' theorem)

Type 2 **CONNECTING and integrating for problem solving**

Usage of mathematics by making connections within and between different mathematics topics and integrating information in order to solve problems, where there is a choice of strategies and mathematical tools. Users have to choose their own strategies and mathematical tools, and make connections between the different domains in mathematics.

Example: Would a ladder of length 6 meters, when placed against a house wall and 1 m from the bottom of the wall, reach windows which are 5 metres from the ground? (Answer involves connecting concepts in "Geometry and Trigonometry" and "Number" and choosing strategy to solve problem)

Type 3 **MATHEMATISING - mathematical thinking, generalisation and insight**

Usage of mathematics by extracting the mathematics embedded in a situation and using mathematics to develop models and strategies; making mathematical arguments, proofs and generalizations to solve the problem; analysing; interpreting and translating mathematical models into real world solutions. Users have to recognise and extract the mathematics embedded in situations, develop new strategies and models, give arguments and proofs and implement solutions.

Example: A group of men cycle at speeds ranging from 10 to 20 km/hour due east for one hour and then due south for a further hour, another group of men cycle at speeds of 20 to 30 km/hour due south for 1 hour and then due east. Everyone starts at the same time and place. If after 2 hours of cycling everyone decides to cycle directly home, would you expect the fastest cyclist to get home first? (Answer involves mathematising the problem and presenting mathematical arguments e.g. in this example by taking a fixed reference point (e.g. how long does it take the fastest cyclist to get home), extrapolating to make other data known by reasonable assumption (e.g. how long it takes any cyclist to get home) and confirming the answer, in this example each cyclist takes √2 hours to get home)

Type 4 **THINKING - contribution of mathematics training to modes of thinking**

Usage of mathematical modes of thinking learned and practised through mathematics, e.g. methods of analysis and reasoning, logical rigour, problem solving strategies (e.g. problem decomposition and solution re-integration), recognition of patterns, use of analogy, and a sense of what the solution to a problem might be.

Example: Applying principles of rigour, logical deduction or induction, as well as clear limiting conditions to any area of decision making e.g. investment decisions, replacing an old car with new, national election voting strategy, developing national health strategy, etc.)

Type 5 **ENGAGING – emotional relationships with mathematics**

Motivation and persistence to take or engage with a mathematical approach to a problem as a result of one's attitudes, beliefs, emotions, goals, sense of value, interest, confidence and self-efficacy.

Example: Choosing to model a problem mathematically in preference to alternative; believing that mathematical analysis and modelling will yield insight, rigor and beneficial outputs. These attitudes apply whether the actual mathematical manipulation is carried out by oneself or by another.

USAGE TYPES - DEFINITIONS

APPENDIX 1(a) Sample topics – Statistics and Probability

Junior – secondary

Number of possible outcomes for multiple events; Probability scale; Probability of equally likely outcomes; Different types of data; Data collection methodologies; Displaying data using bar charts, line plots, pie charts, histograms and stem and leaf plots etc. ; Calculate mean, median, mode and range for different data sources; Analysing data and shape of data distribution

Intermediate – secondary

Counting: Number of ways of selecting r objects from n distinct objects;
Concepts of Probability: Venn diagrams; AND/OR and mutually exclusive rules Outcomes of Random Processes: Probability of 1st success on the nth Bernoulli trial); Statistical Reasoning: Bivariate data types;
Finding Collecting and Organising Data: Types of statistical studies e.g. sample, surveys and designed experiments;
Representing Data Graphically and Numerically: Stem and leaf plots; Distribution of data; Concepts of symmetry and skewness; Relationship between variables using Scatterplots; Correlation; Standard deviation
Analysing, Interpreting and Drawing Inferences from Data: Interpret a histogram; Empirical rule (3σ)

Senior – secondary

Counting: Number of ways of arranging r objects from n distinct objects
Concepts of Probability: Addition and multiplication rules for AND/OR probabilities and conditional probability; Mutually exclusive events
Outcomes of Random Processes: Bernoulli trials; Normal distribution tables
Finding, Collecting and Organising Data: Requirements of statistical sample and control groups; Biases; Limitations; Ethical issues
Representing Data Graphically and Numerically: Centre; Spread; Correlation coefficient; Outliers; Percentiles;
Analysing, Interpreting and Drawing Inferences from Data: Null and alternative hypothesis; Margin of error

Engineering

Probability & Statistics: Probability theory and data presentation; Set theory; Conditional probability; Bayes theorem; Law of Total Probability; Probability mass function; Binomial and Poisson Distributions; Queuing theory, Chebychev's inequality; Gaussian, Gamma and Weibull distributions; Modelling times to failure; Central limit theorem; Confidence interval estimation; Hypothesis testing; Chi-squared test; Linear Regression; Correlation/ causation; prediction intervals

B.A. / BSc.

Probability: Discrete random variables - Bernoulli, Binomial, Poisson, geometric and hypergeometric; Marginal and conditional distributions; Covariance and correlation; Central Limit theorem; F and chi-squared distributions
Linear Models 1: Multiple regression models; Least-squares estimation;
Multivariate normal distribution; Hypothesis testing and confidence intervals;
Analysis of variance R2; F-tests; Regression diagnostics; Cook's distance
Applied Probability: Markov chains; Queuing models; Limiting probabilities;
Reliability models; Monte-Carlo simulation of random variables
Statistical Inference: Methods of moments and maximum likelihood; Bias and mean square error of estimators; Cramer-Rao lower bound; Rao-Blackwell Theorem; Testing hypotheses- Neymann Pearson; Likelihood ratio tests; Bayesian estimation; Bayes rule
Linear Models 2: Weighted least squares; Box-Cox method; Collinearity and variance inflation factors; Cross-validation; Durbin-Watson test
Categorical Data Analysis: Two way contingency tables; Chi-squared test;
Fisher's exact test; Cochran-Mantel-Haenszel methods

STATISTICS & PROBABILITY TOPICS

APPENDIX 1(b) Sample topics – Geometry and Trigonometry

Junior – secondary

Synthetic Geometry Concepts: e.g. similar triangles, parallel lines, tangent to a circle, collinear points, vertically-opposite angles, perpendicular lines, isosceles triangle, equilateral triangle, right-angled triangle, diameter, chord, arc, sector, circumference of a circle, disc, centre of a circle.
Axioms/Theorems/Corollaries/Constructions: e.g. Axiom 5: [Axiom of Parallels] Given any line l and a point P, there is exactly one line through P that is parallel to l;
e.g. Theorem 14: [Theorem of Pythagoras] In a right-angled triangle the square of the hypotenuse is the sum of the squares of the other two sides; e.g. Corollary 3: Each angle in a semi-circle is a right angle; e.g. Construction 6: Division of a line segment into 2 or 3 equal segments, without measuring it.
Transformation Geometry: Translations, central symmetry and axial symmetry
Co-ordinate Geometry: Equation of a line.
Trigonometry: Right-angled triangles; Trigonometric ratios – $\sin\theta$, $\cos\theta$ and $\tan\theta$

Intermediate – secondary

Synthetic Geometry: e.g. Theorem 10. The diagonals of a parallelogram bisect one another; e.g. Corollary 6. If two circles share a common tangent line at one point, then the two centres and that point are collinear.
Co-ordinate Geometry: Area of triangles; Slopes of lines; Equation of a circle with centre (0,0); Intersection of line and circle
Trigonometry: Sine and cosine functions; Area of sector of circle

Senior – secondary

Synthetic Geometry: Tangent to a circle; Centroid of a triangle, Orthocentre of a triangle; Theorem 12: Let Δ ABC be a triangle. If a line l is parallel to BC and cuts [AB] in the ratio s : t, then it also cuts [AC] in the same ratio. Prove Pythagoras' theorem
Co-ordinate Geometry: Perpendicular distance from a point to a line; Divide line segment in the ratio m:n; Equation of circle with centre (-g,-f)
Trigonometry: Graph of trigonometric functions e.g. $a\sin(n\theta)$; Trigonometric equations e.g. $\sin(n\theta) = 0$; Trigonometric formulae e.g. $\sin(A+B) = \sin A \cos B + \cos A \sin B$

Engineering

Vectors: Vectors in n-Space; Orthogonality of vectors; Vector equation of a line/plane in 3-space; Vector equation of a curve in parametric form in 2 and 3 space; Arc length; Unit tangent; Unit principal normal vectors; Curvature

B.A. / BSc.

Differential Geometry: Surfaces: Shape operator; Gaussian and mean curvatures; Minimal surfaces; geodesics
Fractal Geometry: Minkowski /Hausdorff dimension; Sharkovsky's theorem

GEOMETRY & TRIGONOMETRY TOPICS

APPENDIX 1(c) Sample topics – Number

Junior - secondary

Number Systems: Arithmetic operations including laws of addition, subtraction multiplication and division for natural numbers N and integers Z, including use of brackets

Indices: rules for indices e.g. $a^p a^q = a^{p+q}$; notation of $a^{(1/2)}$; arithmetic involving numbers in index form; express numbers in form $a \times 10^n$

Applied Arithmetic: Problems involving %, profit or loss, discount, compound interest up to 3 years, income tax

Applied Measure: Surface area and Volume of rectangular solids and cylinders; Units of measure and time

Sets: Notation; Elements; Rules; Operations of intersection, union, difference and compliment

Intermediate – secondary

Number Systems: Complex numbers, Argand diagram, Modulus, Sum to n terms of an arithmetic series

Indices: Roots of indices e.g. $a^{m/n} = \sqrt[n]{a^m}$ $m,n \in Z$ $n \neq 0$, $a > 0$

Arithmetic: Calculations involving formula e.g. compound interest

Length, Area and Volume: e.g. triangle, parallelogram, trapezium, sector of disc, rectangular block, cylinder, right cone, right prism sphere, hemisphere etc.

Senior – secondary

Number Systems: Complex conjugates, Geometric sequences and series, inequalities e.g. $n! \geq 2^n$; factorisation; limits of sequences $\lim_{n \to \infty} n/(n+1)$; Finite and infinite geometric series; Recurring decimals

Indices: Rules of logarithms e.g. $\log_a (x/y) = \log_a x - \log_a y$

Arithmetic: present value of repayments and investments

Engineering

Computation and Simulation: e.g.MatLab

B.A. / BSc.

Groups: Orbit Stabilizer theorem; Sylow's theorem; Soluble groups; Nilpotent groups; Free groups; Central series of a finite group

Number Theory: Brounkner's Algorithm; Pell's equation; Liouville's theorem; Quadratic reciprocity law; Jacobi symbol; Chebyshev's theorem

NUMBER TOPICS

APPENDIX 1(d) Sample topics – Algebra

Junior - secondary

Generating Arithmetic Expressions from Repeating Patterns: Arithmetic expressions for terms in a sequence

Representing Situations With Tables, Diagrams and Graphs: Tables, Diagrams and Graphs as tools for representing and analysing linear and quadratic patterns and relations

Finding Formulae: Written formula from which data is derived

Expressions: Add and subtract algebraic expressions of forms such as:

$\frac{ax+b}{c} \pm \frac{dx+e}{f}$ where a, b, c, d, e, f $\in$ Z.

Factorise expressions such as $a^2x^2 - b^2y^2$ where a, b $\in$ N

Equations and Inequalities: Solve quadratic equations of the form

$ax^2 + bx + c = 0$ where a, b, c $\in$ Q, x $\in$ R

Solve linear inequalities of the form

$g(x) \leq k$, where $g(x) = ax + b$, a $\in$ N and b, k $\in$ Z

Intermediate - secondary

Manipulation of Formulae: Solutions of $f(x) = ax^2 + bx + c$, where a, b, c $\in$ Q; Solutions to simultaneous linear equations with two unknowns; Solutions to one linear and one quadratic equation with two unknowns

Inequalities: Solutions to $g(x) \leq k$, $g(x) \geq k$, where $g(x) = ax + b$ and a, b, k $\in$ Q

Complex Numbers: Express non-zero positive rational numbers in the form $a \times 10^n$, where n $\in$ Z and $1 \leq a < 10$

Senior – secondary

Manipulation of Formulae: Addition, subtraction, multiplication and division, of polynomials and rational algebraic functions; Factor Theorem for polynomials; Solutions to simultaneous linear equations with three unknowns; Solutions to cubic equations with at least one integer root; Solutions to one linear and one quadratic equations with two unknowns

Inequalities: Solutions to inequalities (quadratic equations)

Complex Numbers: Conjugate Root Theorem; De Moivre's Theorem

Engineering

Matrices: Matrix algebra; Solve linear system of equations using Gaussian elimination; Eigenvalues and eigenvectors; Laplace Transform

B.A. / B.Sc.

Point Set Topology: Topological spaces; Fundamental Group; Homeomorphic spaces

Galois Theory: Steinitz Theorem; Galois groups of polynomials and field extensions; Frobenius map; Fundamental theorem of Galois theory; Solubility of polynomials

ALGEBRA TOPICS

APPENDIX 1(e) Sample topics – Functions

Junior – secondary

Functions: Function notation f(x) = , f: , x → , and y =

Graphing functions: Graph of f (x) = $ax^2+bx + c$ and g(x) = ax + b, where a ∈N; b,c∈Z; x ∈R; use graphical methods to find approximate solutions where f(x) = g(x); Graph solution sets on the number line for linear inequalities

Intermediate - secondary

Functions: Graph of functions of the form, where a,b,c ∈Z, x∈R and ab^x where a∈N, b, x ∈R; Use graphical methods to approximate solutions to f(x) = 0, f(x) = k and f(x) = g(x), where f(x) and g(x) are of the above form

Calculus: First and second derivatives of linear, quadratic and cubic functions by rule; Apply differentiation to rates of change and maxima and minima

Senior - secondary

Functions: Graphs of functions of the form f(x) = $ax^2+bx + c$, where a,b,c ∈ Q, x∈R; Logarithmic functions, Exponential functions; Trigonometric functions; Inverse of function

Calculus: Derivatives of polynomial, exponential, trigonometric, logarithmic functions; Derivative of sums, differences, products, quotients and composition of functions; Integration of functions, Integration to find average value or area of plane bounded by polynomial and exponential curves

Engineering

Calculus: Differentiate and integrate polynomials, exponential, trigonometric and hyperbolic functions; McLaurin and Taylor series; Simpson's rule; First and second order differential equations

Differential Equations and Transform Methods: Solutions to linear second-order differential equations; Dirac delta function; Laplace transform of integrals; Convolution theorem; Fourier series; Fourier transform; Z-transform

Complex Analysis and Vector Calculus: Curl of a vector field; Maxwell's equations; Cauchy-Riemann equations; Cauchy's Integral theorem; Laurent Series; Residue theorem

Unconstrained Optimisation: Fibonacci search; DSC algorithm; Conjugate Gradient Algorithm; Hessian-based Gradient; Gauss-Newton algorithm

B.A. / B.Sc.

Complex Analysis: Residue theorem; Schwarz' Lemma, Arzela-Ascoli and Montel theorems; Riemann mapping theorem; Gamma function; Riemann zeta function
Prime number theorem

Real Analysis: Hahn-Banach theorem; Open mapping theorem; Closed graph theorem
Uniform Boundedness Principle; Hilbert Spaces

FUNCTIONS TOPICS

USAGE – TYPE 1

Type 1 Usage **REPRODUCING procedures, concepts, definitions**
This type relates to usage of maths topics through knowledge of facts and concepts, recalling mathematical properties, performing routine procedures, applying standard algorithms and operating with maths symbols and formulae.

Sample Type 1 mathematics usage (for illustration only)

1. *Four people are chosen at random, if one is a female, what percentage are males? (Statistics and Probability @ Secondary – junior level)*

2. *Below is data collected from 12 adults when asked to state their annual income and the number of years they spent in full-time education. Construct a scatter plot to display this data.*

Years of education	*11*	*12*	*13*	*13*	*14*	*15*	*16*	*16*	*17*	*17*	*17*	*19*
Income /€1,000	*28*	*30*	*35*	*43*	*55*	*38*	*45*	*38*	*55*	*60*	*30*	*58*

(Statistics and Probability @ Secondary - senior level)

3. *State Pythagoras' Theorem (Geometry and Trigonometry @ Secondary – junior level)*

4. *What is the area of a triangle ABC in which |AB| = 6 cm, |CB| = 10 cm and |<ABC| =50°? (Geometry and Trigonometry @ Secondary - intermediate level)*

5. *What is the scalar product of the vectors (4, 2, 1) and (2, 4, 1)? (Geometry and Trigonometry @ Engineering level)*

6. *The difference between the square root of a number and 4% of the same number is 6, what is the number? (Number @ Secondary - junior level)*

7. *What is the value of $(57.6 + 80.44) / (1.3 \times 10^4)$? (Number @ Secondary - intermediate level)*

8. *If the population of Ireland is 4 million and is increasing at 2.5% per annum, what will the population be in 100 years time? (Number @ Secondary- senior level)*

9. *What is Sylow's Theorem? (Number @ B.A / B.Sc. level)*

10. *What is the solution for x in the equation $3x - 2 = 7$? (Algebra @ Secondary – junior level)*

11. *What is a topological space? (Algebra @ B.A / B.Sc. level)*

12. *Graph the function $x^2 + 3x - 2$ in the domain $-5 \leq x \leq 5$ (Functions @ Secondary- junior level)*

13. *What is $\int(\sin 2x + e^{4x})\,dx$? (Functions @ Secondary - Senior level)*

14. *Calculate the r.m.s. value of the current, $i(t) = 20\,e^{-t}$ $0 \leq t \leq 10$ with period = 10 seconds, over a complete period. (Functions @ Engineering level)*

15. *State the Residue Theorem (Functions @ B.A / B.Sc. level)*

USAGE TYPE 1 -FURTHER EXAMPLES

USAGE – TYPE 2

Type 2 Usage **CONNECTING and integrating for problem solving**
This type relates to usage of maths topics by making connections within and between different mathematics topics and integrating information in order to solve problems where there is a choice of strategies and mathematical tools.

Sample Type 2 mathematics usage (for illustration only)

1. *Below is data collected from 12 adults when asked to state their annual income and the number of years they spent in full-time education. What is the correlation between the variables?*

Years of education	*11*	*12*	*13*	*13*	*14*	*15*	*16*	*16*	*17*	*17*	*17*	*19*
Income /€1,000	*28*	*30*	*35*	*43*	*55*	*38*	*45*	*38*	*55*	*60*	*30*	*58*

(Statistics and Probability @ Secondary – senior level)

2. *Mary used a photocopying machine to make a copy of a 10 X 10 cm^2 drawing, reducing the size to 60% and then increasing that copy by 140%. What was the resultant size of the copy?*
(Number @ Secondary – junior level)

3. *A sum of €P was invested at r% per annum compound interest. The interest for the first year was €220. The interest for the second year was €228.80. How much interest would accrue over 5 years? (Number @ Secondary – intermediate level)*

4. *What is the derived series of the dihedral group of order 12? (Number @ B.A / B.Sc. level)*

5. *When the sphere of (volume 36 πcm^3) is fully immersed in a cylinder of water, the level of the water rises by 2.25 cm. What is the radius of the cylinder? (Geometry and Trigonometry @ Secondary – intermediate level)*

6. *What is the oscillating plane of α(s) = { a cos (s/c), a sin s/c, b (s/c) } where $c^2 = a^2 = b^2$? (Geometry and Trigonometry @ B.A / B.Sc. level)*

7. *A vehicle starts from rest and its velocity is measured every second for 6 seconds, with the following results. What distance does it travel in 6 seconds?*

Time t (s)	*0*	*1*	*2*	*3*	*4*	*5*	*6*
Velocity v (m/s)	*0*	*1.2*	*2.4*	*3.7*	*5.2*	*6.0*	*9.2*

(Functions @ Secondary - senior level)

8. *At time t = 0, a projectile is launched from the point (0,0,0) and follows a trajectory given by the curve r(t) = (1 – cos t)i + t j + sin tk . What is the distance travelled by the projectile before crashing into the ground? (Functions @ Engineering level)*

9. *Two envelope stuffing machines, working together can stuff a batch of envelopes in 2 hours. Working separately it will take the second machine 1 hour longer than the first machine to stuff a batch of envelopes. How long would it take each machine to stuff a batch of envelopes by themselves? (Algebra @ Secondary – senior level)*

10. *If a force of F(N) is applied to a mass of m(kg) that is retarded by a spring of spring constant k (N m^{-1}) and a damper of damping coefficient c (N s m^{-1}), its motion is described by the following differential equation: M (d^2y/dx + c (dy/dx) + ky) = F, where y is the displacement of the mass at time t. Derive the state space representation of this model ?*
(Algebra @ Engineering level)

USAGE TYPE 2 - FURTHER EXAMPLES

USAGE – TYPE 3

Type 3 MATHEMATISING - mathematical thinking, generalization and insight
This level relates to usage of mathematics topics by extracting the mathematics embedded in a situation and using mathematics to develop models and strategies; making mathematical arguments, proofs and generalisations to solve the problem; analysing; interpreting and translating mathematical models into real world solutions.

Sample Type 3 mathematics usage (for illustration only)

1. *A lobby that is 14 metres long and 6 metres wide has four options for floor covering: 1. Carpet (4 metres wide) @ €24 per square metre; 2. Mat (3 metres wide) @ €25 per square metre; 3. Vinyl (5 metres wide) @ €22 per square metre; and 4. Tiles (500 mm x 500 mm) @ €1 each. Which floor covering would you recommend? (Algebra @ Secondary – junior level)*

2. *A shed is 4m long and 2m wide. A concrete path of constant width is laid all the way around the shed. If the area of the path is 9.5m ^{2}, what is the width of the path? (Algebra @ Secondary – intermediate level)*

3. *Is the polynomial g: = x^5 -7x + 1 with integer coefficients solvable? (Algebra @ B.A / B.Sc. level)*

4. *A tablecloth is required for a small round coffee table, height 60 cm, diameter tabletop 50 cm. The tablecloth should be made from one piece of cloth, have a hem of 1 cm and should just touch the floor. Which of the following 2 options would be the most economical: : 1. Width 1 is 90 cm and costs €9.50 per meter, measured per 10 cm and width 2 is 180 cm and costs €17.50 per meter, measured per 10 cm. (Geometry and Trigonometry @ Secondary – junior level)*

5. *The rainfall in mm, recorded at hourly intervals on the hour, over a period from midnight to midday is represented by the function x^2 - 4x +8 where x represents the hour. The temperature measured over the same period increases by 2 degrees C per hour after midnight when the temperature is -3 degrees C? When is the weather worst? (Functions @ Secondary – junior level)*

6. *If it takes 10 years for €1,000 to double in a money market fund. Would it take 20 years for the money to triple? (Number @ Secondary – senior level)*

7. *A fleet car company has to decide between two brands A and B of tyre for its cars. An experiment is conducted using 12 of each brand until they wear out. The sample averages and standard deviations of running distance (in km) are respectively 36,300 and 5,000 for A and 39,100 and 6,100 for B. Which brand should the company opt for? (Statistics and Probability @ Engineering level)*

8. *Simultaneous measurements of electric voltage by two different types of voltmeter yield the following differences: 0.3V, 0.5V, -0.1V, 0.2V,-0.4V, 0.1V, 0.3V, 0.1V, 0.5V and 0.1V, have the instruments been calibrated differently? (Statistics and Probability @ Engineering level)*

9. *Three objects are located on a line at points $p_1 < p_2 < p_3$. These locations are not precisely known. A surveyor measures the distance from the origin to each p_i; denote these measurements by Y_i, i = 1,2,3. From p_1 he measures the distances to p_2 and p_3; denote this by Y_4 and Y_5. From p_2 he measures the distance to p_3; denote this by Y_6. Predict the location of a fourth object located at position $p_2 + p_3 - p_1$. (Statistics and Probability @ B.A / B.Sc. level)*

USAGE TYPE 3 - FURTHER EXAMPLES

APPENDIX 3: SURVEY DISTRIBUTION EMAILS

Copies of survey distribution emails and notices are included in this appendix. Engineers Ireland, the professional body representing engineers in Ireland, distributed the survey questionnaire and the survey support document by direct email, to its 5,755 chartered members. Engineers Ireland also included a direct link to the survey questionnaire on its weekly newsletters on 9th and 16th March 2011 which were emailed to its entire 21,700 members.

From: Damien Owens [mailto:damien@engineersireland.ie]
Sent: 11 February 2011 09:45
To: undisclosed-recipients:
Subject: Important Survey of Chartered Engineers

Dear Chartered Member,
As you are aware Engineers Ireland has been proactive in raising and addressing the profile of mathematics education. This has included a report on the 'Teaching of Maths' and the delivery of a series of online mathematics tutorials for leaving certificate students in Clyde Road and nationally via our webcast facility. As part of the on-going work in this area Engineers Ireland has been approached by NUI Maynooth to capture the views of professional engineers about mathematics education and the extent to which a working knowledge of mathematics is vital to everyday engineering work.
This survey is part of NUI Maynooth's research into the role mathematics plays in the working life of engineers. We anticipate the outcome of this study will contribute to enhancing the structure and content of engineering education, particularly in regard to mathematics quantity, level and conceptual approach.
Your participation in the survey is important to us and is very much appreciated. **All responses are confidential**. The results will be published in early 2012 and all contributors will be sent a copy.
To participate in the survey

- Please open the attachment 'NUIM Survey'.
- The questionnaire will open in a separate window.
- Please proceed to complete the survey.
- A support document 'SURVEY INFO' will appear at the bottom of the screen. If it does not simply click on the paperclip icon (bottom left of screen) and it will appear.
- When completed press SUBMIT button at the top right corner of the screen and follow the instructions.

Please set aside approximately 30 minutes to complete the **survey before Monday 21st February 2011.**
All respondents will be entered into a draw for a prize of two night's bed and breakfast at the luxurious Carton House Hotel, Spa and Golf Club in County Kildare. (www.cartonhouse.com). For further information about the survey please contact Eileen Goold, NUI Maynooth at **eileen.goold@nuim.ie** or telephone 086 179 8175.

On behalf of Engineers Ireland and NUI Maynooth, I would like to thank you for your assistance and valuable time.
Best Regards
Damien
Damien Owens CEng MIEI
Registrar
Engineers Ireland
22 Clyde Road
Ballsbridge
Dublin 4
T: +353 (0)1 665 1333
M: +353 (0)87 2899 363
F: +353 (0)1 668 5508
http://www.engineersireland.ie

Survey Distribution Email.

On 18th February 2011, Engineers Ireland sent an email reminder to the same group of Chartered Engineers.

From: Damien Owens [mailto:26amien@engineersireland.ie]
Sent: 18 February 2011 16:59
To: undisclosed-recipients:
Subject: Important Survey of Chartered Engineers – Thank You / Final call for responses.

Dear Chartered Member,
I would like to thank you for your valuable time in completing the survey distributed last week on the topic of Mathematics usage within the engineering community. We are nearing the deadline for sending completed surveys and the response to date has been encouraging.

If you have not yet completed the survey please refer to the email sent by me on February 11th. If you cannot locate your copy of the survey please email Eileen Goold at eileen.goold@nuim.ie and she will forward a copy together with instructions.

Remember the survey is open to retired engineers also – and you may win that weekend at Carton House.

Thanks and Regards
Damien
Damien Owens Ceng MIEI
Registrar
Engineers Ireland
22 Clyde Road
Ballsbridge

Dublin 4
T: +353 (0)1 665 1333
M: +353 (0)87 2899 363
F: +353 (0)1 668 5508
http://www.engineersireland.ie

Survey Reminder Email.

In attempts to boost the response rate, Engineers Ireland also included a direct link to the survey questionnaire on its weekly newsletters on 9th and 16th March, 2011 which were emailed to 21,700 members.

ENGINEERS IRELAND EVENTS BRIEF
Wednesday, March 9, 2011
ENGINEERS IRELAND EVENTS BRIEF
Wednesday, March 16, 2011

Engineers Ireland has been proactive in raising and addressing the profile of mathematics education including publishing a report on the 'Teaching of Maths' and the delivery of a series of free mathematics tutorials for leaving certificate students.

• Engineers Ireland has been approached by NUI Maynooth to capture the views of professional engineers about mathematics education and the extent to which a working knowledge of mathematics is vital to everyday engineering work. We anticipate the outcome of this study will contribute to enhancing the structure and content of engineering education.

Download Survey

• All responses are confidential and all respondents will be entered into a draw for a prize of two nights bed and breakfast at the luxurious Carton House Hotel, Spa and Golf Club in County Kildare.

For more information, please contact:
Eileen Goold, NUIM.
E:eileen.goold@nuim.ie
T: +353 (0)86 179 8175

Link to Survey on Engineers Ireland's Weekly Newsletters.

APPENDIX 4: SURVEY DATA ANALYSIS

A4.1 Introduction

Survey data analysis is included in Appendix 4 and is organised as follows:

Page number

A4.2 Do You Agree That You Could Perform Satisfactorily In Your Current Job WITHOUT Higher Level Leaving Certificate Mathematics?

Sample size: 365

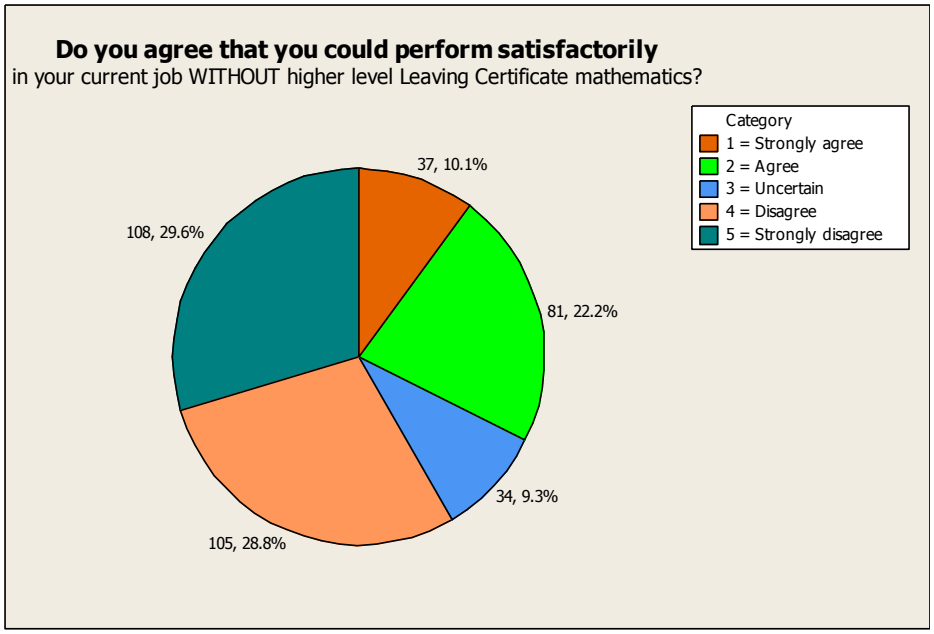


Figure A4-1: Sample size: Engineers' views about doing their job without higher level Leaving Certificate mathematics.

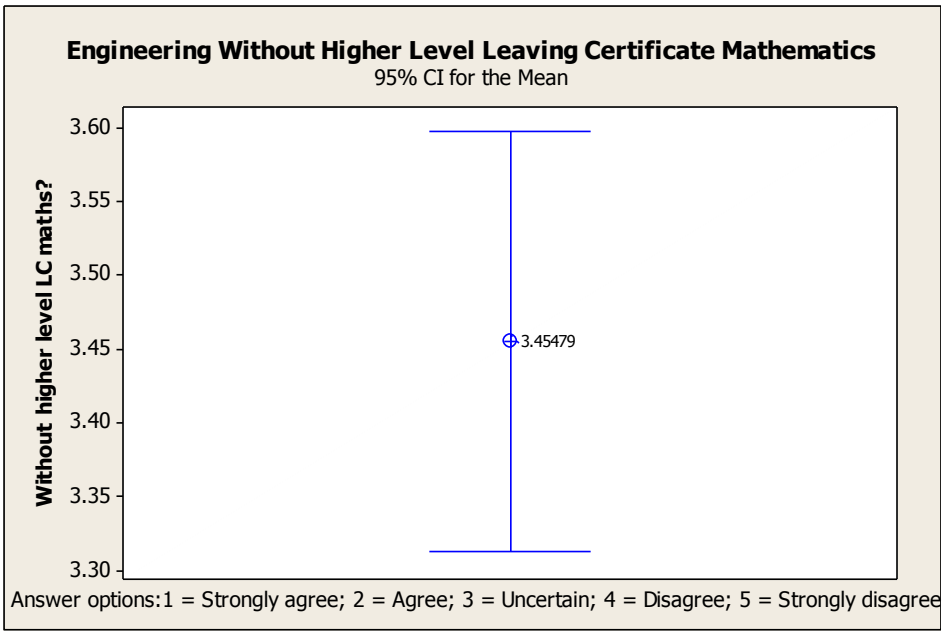


Figure A4-2: Confidence interval: Engineers' views about doing their job without higher level Leaving Certificate mathematics.

A4.2.1 Impact of Engineering Discipline and Role on Perceived Value of Higher Level Leaving Certificate Mathematics in Engineering Practice

Sample size: Main engineering disciplines and roles, figure A4-3.

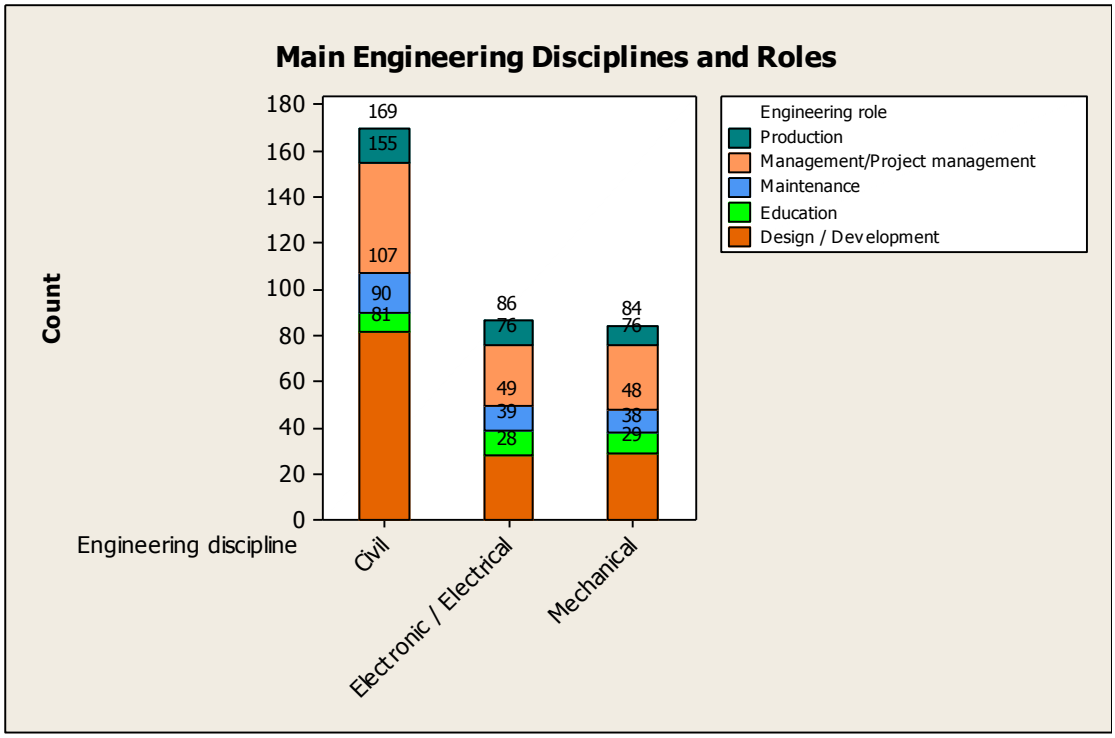


Figure A4-3: Sample size: Main engineering disciplines and roles.

General Linear Model: Without high versus Engineering, Engineering

```
Factor                  Type   Levels  Values
Engineering discipline  fixed       3  Civil, Electronic / Electrical,
                                       Mechanical
Engineering role        fixed       5  Design / Development, Education,
                                       Maintenance, Management/Project
                                       management, Production

Analysis of Variance for Without higher level LC maths?, using Adjusted SS
for Tests

Source                      DF   Seq SS   Adj SS  Adj MS     F      P
Engineering discipline       2    2.395    2.807   1.404  0.75  0.474
Engineering role             4   12.124   15.353   3.838  2.05  0.088
Engineering discipline*      8   31.637   31.637   3.955  2.11  0.035
  Engineering role
Error                      324  607.584  607.584   1.875
Total                      338  653.740

S = 1.36940   R-Sq = 7.06%   R-Sq(adj) = 3.04%
```

Table A4-1: General linear model analysis: Impact of main engineering disciplines and roles on engineers' views about doing their job without higher level Leaving Certificate mathematics.

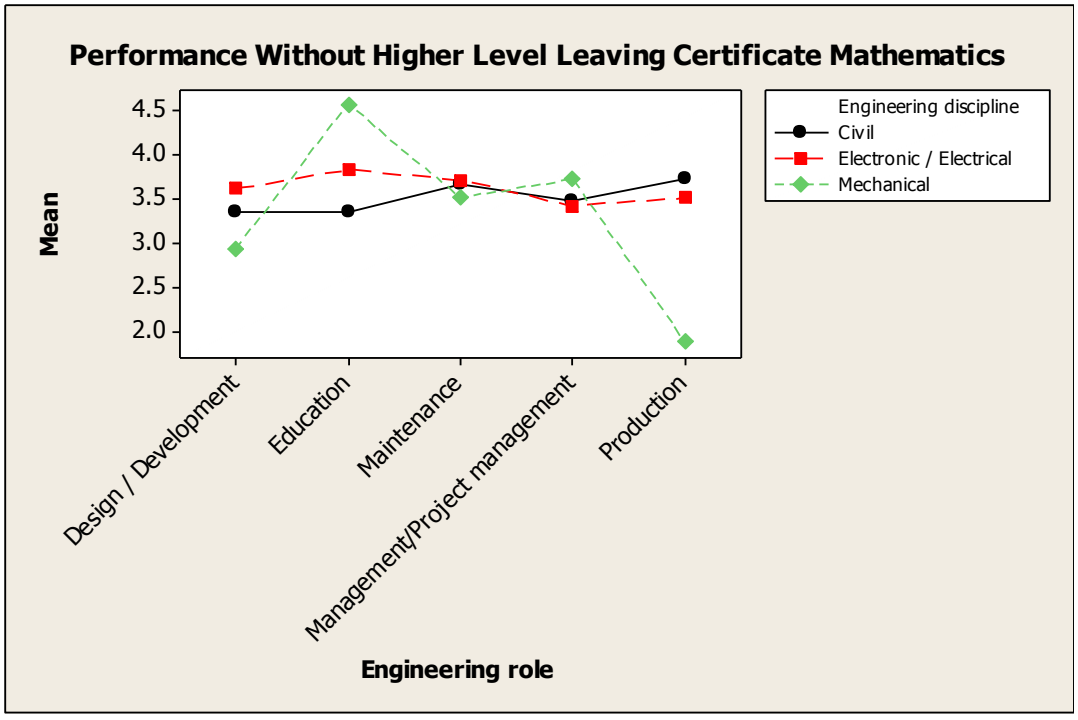


Figure A4-4: Interaction plot: Impact of main engineering disciplines and roles on engineers' views about doing their job without higher level Leaving Certificate mathematics.

A4.3 To What Extent Have You Used *Curriculum Mathematics* In The Last 6 Months?

A4.3.1 Engineers' Mean *Curriculum Mathematics* Usage

Sample size: 365

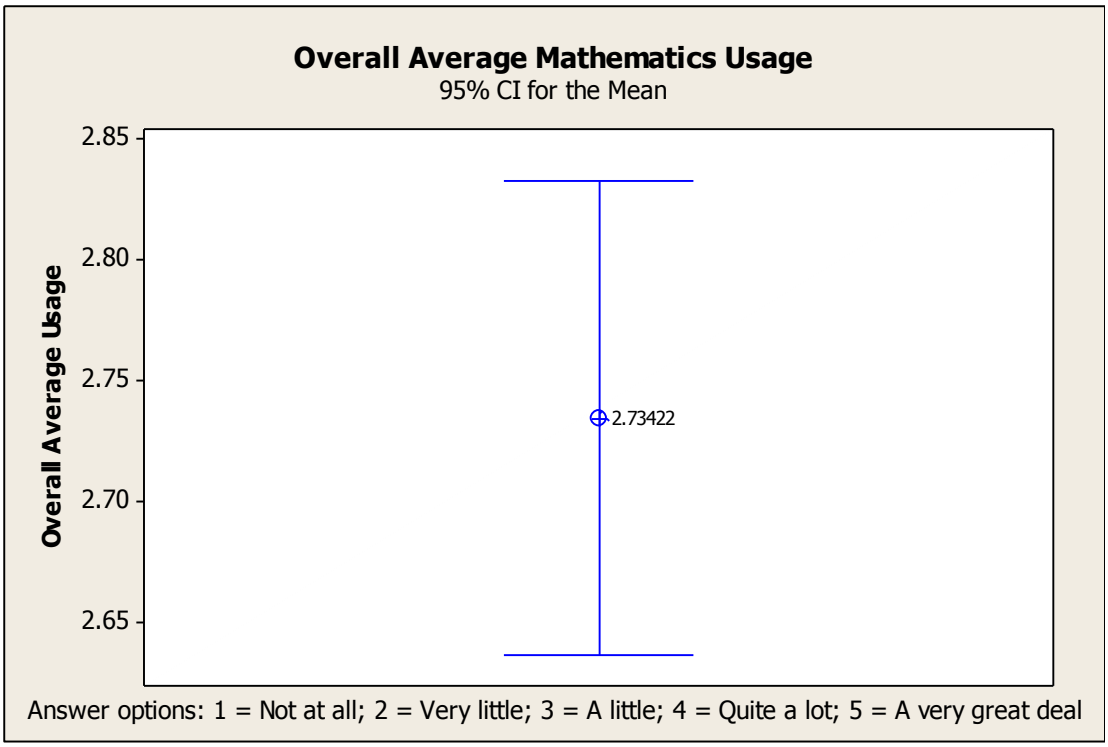


Figure A4-5: Confidence interval: Engineers' mean *curriculum mathematics* usage.

A4.3.2 Engineers' *Curriculum Mathematics* Usage by Domain

Sample size: 365

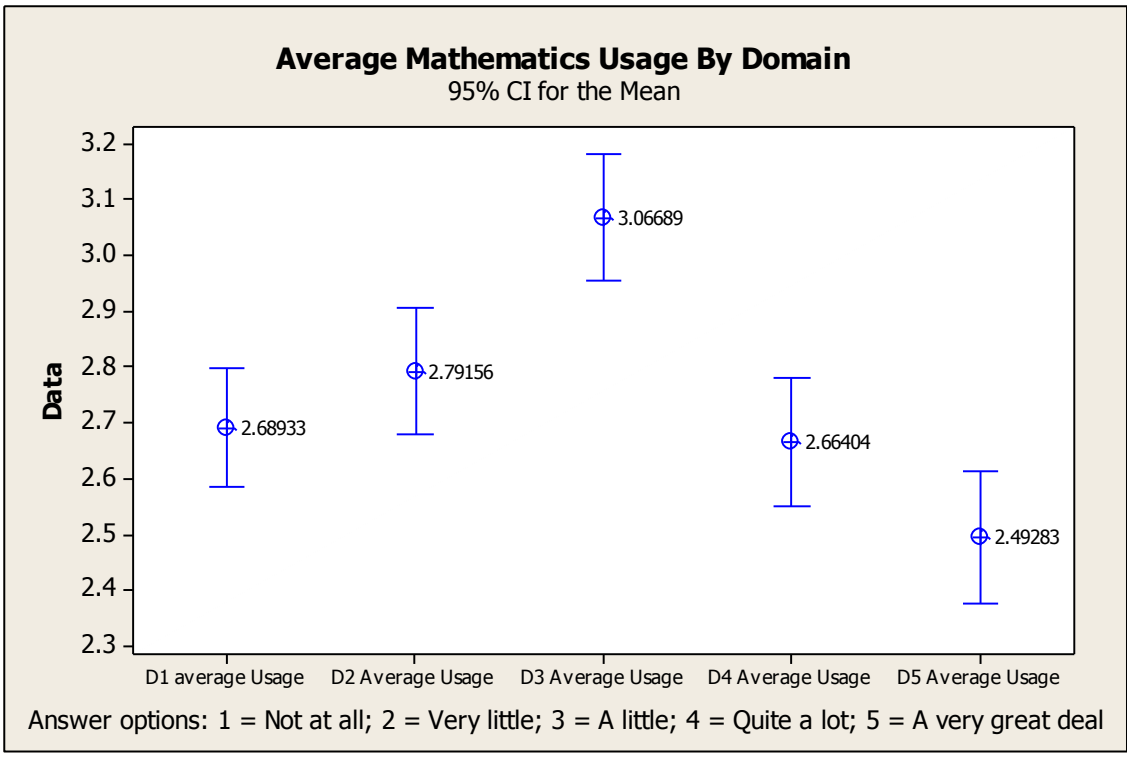


Figure A4-6: Confidence interval: Engineers' mean *curriculum mathematics* usage by domain.

D1 (Statistics & probability); D2 (Geometry & trigonometry); D3 (Number); D4 (Algebra); and D5 (Functions)

A4.3.3 Engineers' *Curriculum Mathematics* Usage by Academic Level

Sample size: 365

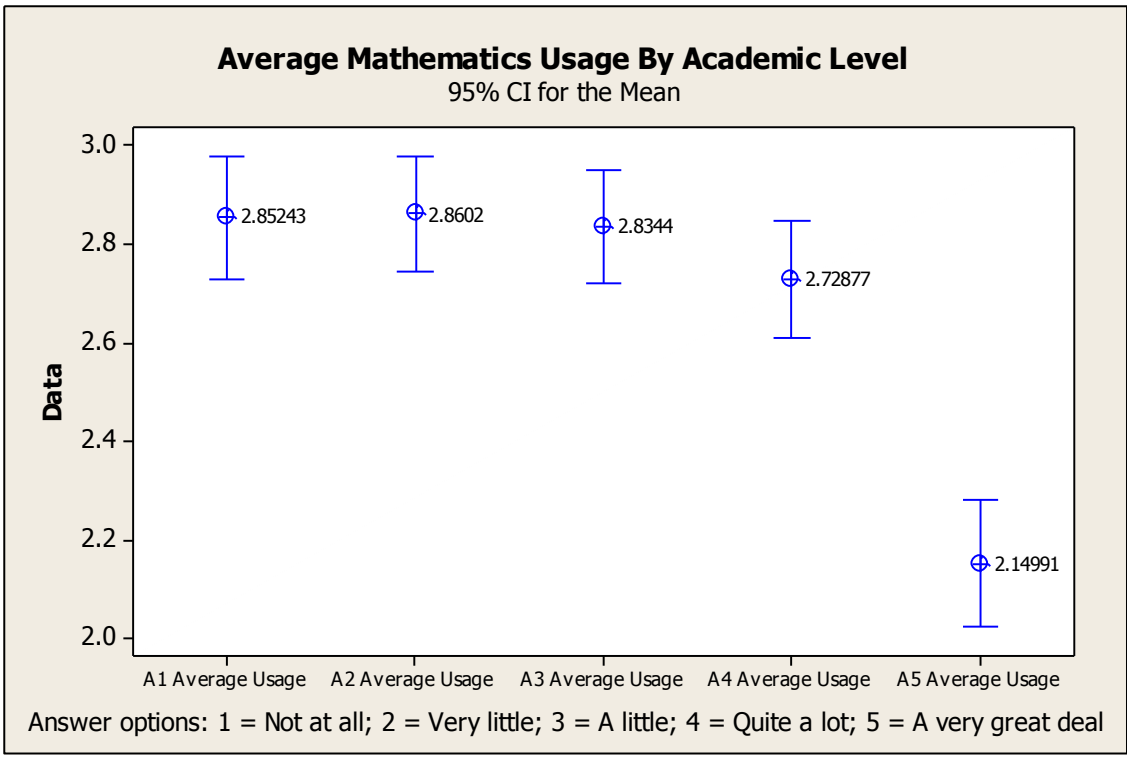


Figure A4-7: Confidence interval: Engineers' mean *curriculum mathematics* usage by academic level.

A1 (Junior secondary); A2 (Intermediate Secondary); A3 (Senior Secondary); A4 (Engineering); and A5 (B.A./ B.Sc.)

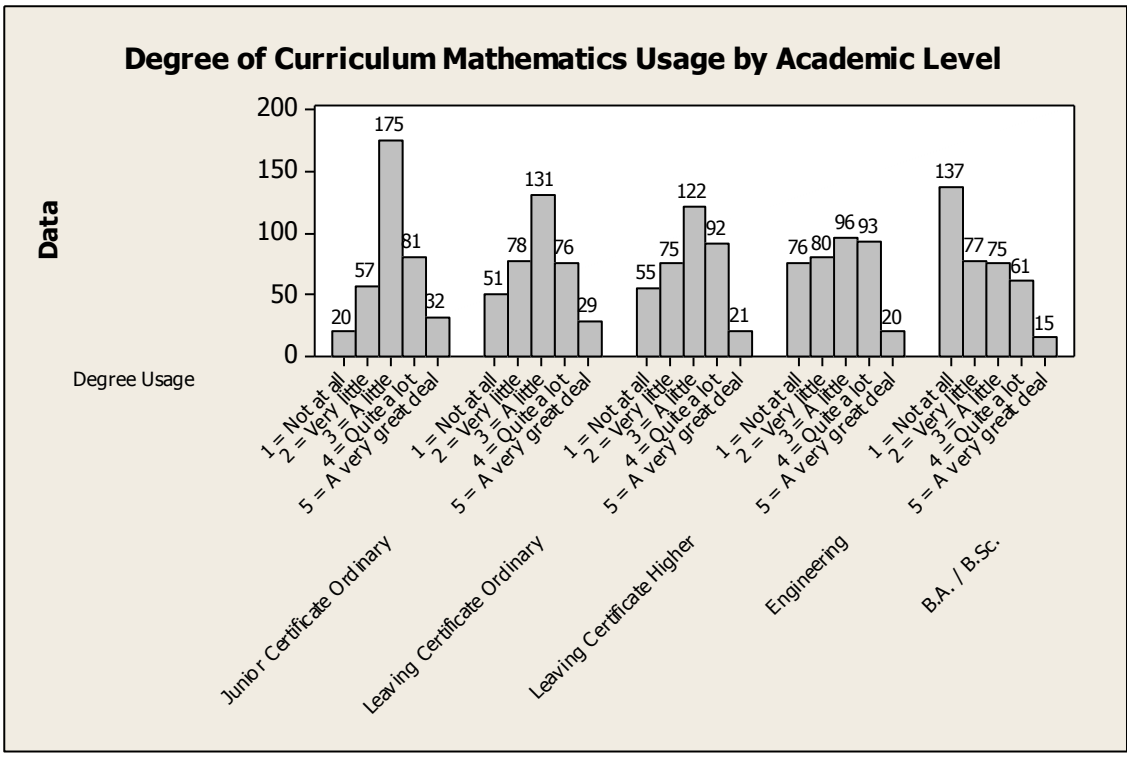


Figure A4-8: Histogram: Engineers' mean *curriculum mathematics* usage by academic level.

Figure A4-8 includes analysis of *curriculum mathematics* usage by academic level. In this analysis each engineer's mean academic level mathematics usage was categorised according to the scale: Not at all (≤ 1.5); Very little (>1.5 ≤ 2.5); A little (>2.5, ≤ 3.5); Quite a lot (>3.5, ≤ 4.5); and A very great deal (> 4.5).

A4.3.4 Engineers' *Curriculum Mathematics* Usage by Usage Type

Sample size: 365

Result:

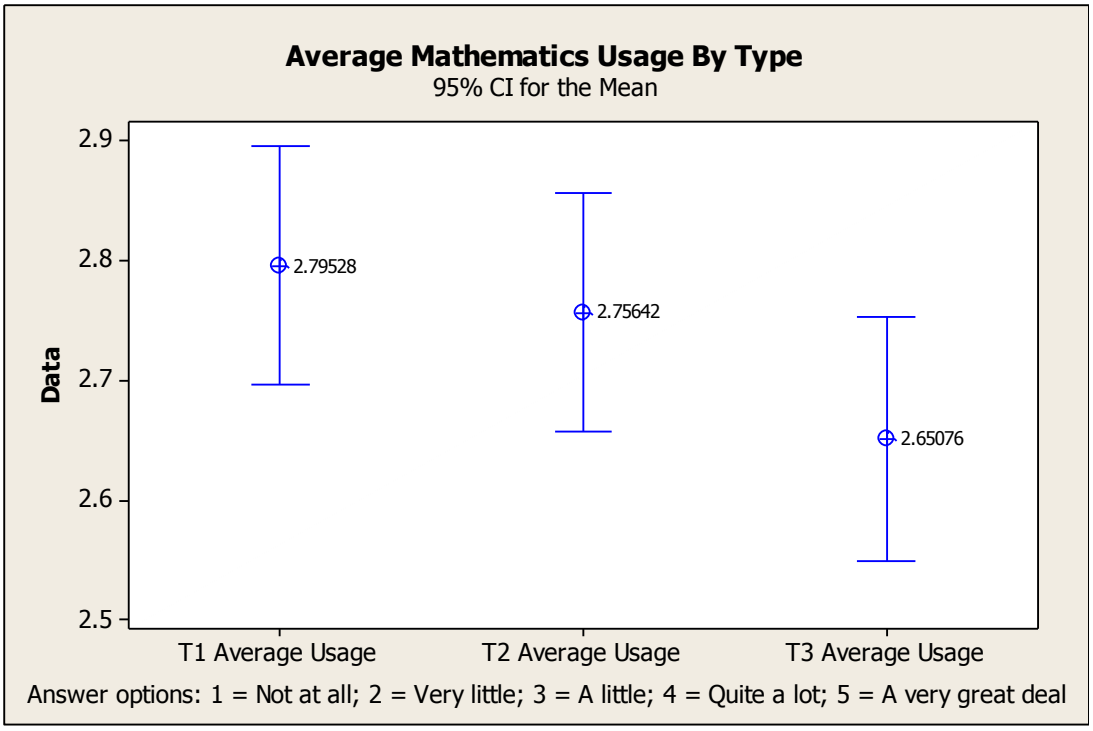


Figure A4-9: Confidence interval: Engineers' mean *curriculum mathematics* usage by type.

T1 (Reproducing); T2 (Connecting); and T3 (Mathematising)

A4.3.5 Effect of Engineering Discipline and Role on *Curriculum Mathematics* Usage

Sample size:

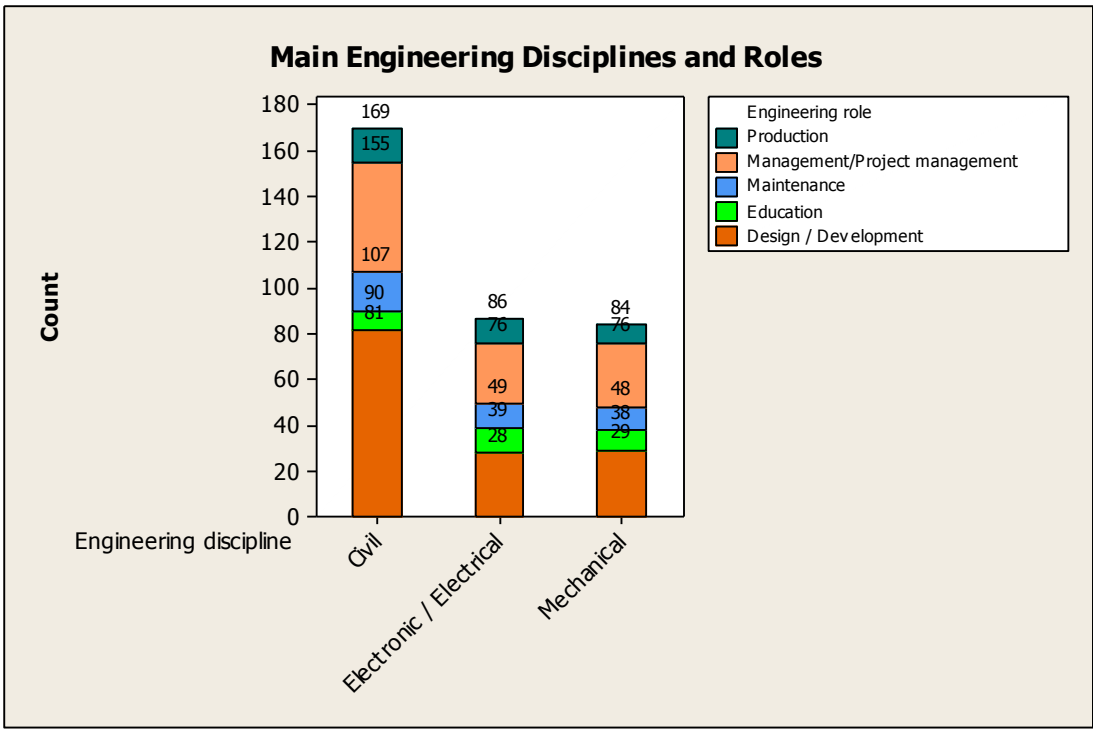


Figure A4-10: Sample size: Effect of engineering discipline and role on *curriculum mathematics* usage.

General Linear Model: Overall Aver versus Engineering , Engineering

```
Factor                  Type   Levels  Values
Engineering discipline  fixed       3  Civil, Electronic / Electrical,
                                       Mechanical
Engineering role        fixed       5  Design / Development, Education,
                                       Maintenance, Management/Project
                                       management, Production


Analysis of Variance for Overall Average Usage, using Adjusted SS for Tests

Source                     DF     Seq SS     Adj SS  Adj MS      F      P
Engineering discipline      2     0.2361     2.5308  1.2654   1.43  0.240
Engineering role            4     3.0457     3.3847  0.8462   0.96  0.431
Engineering discipline*     8    15.1110    15.1110  1.8889   2.14  0.032
  Engineering role
Error                     324   286.2800   286.2800  0.8836
Total                     338   304.6728


S = 0.939990    R-Sq = 6.04%    R-Sq(adj) = 1.98%
```

Table A4-2: General linear model analysis: Effect of engineering discipline and role on overall *curriculum mathematics* usage.

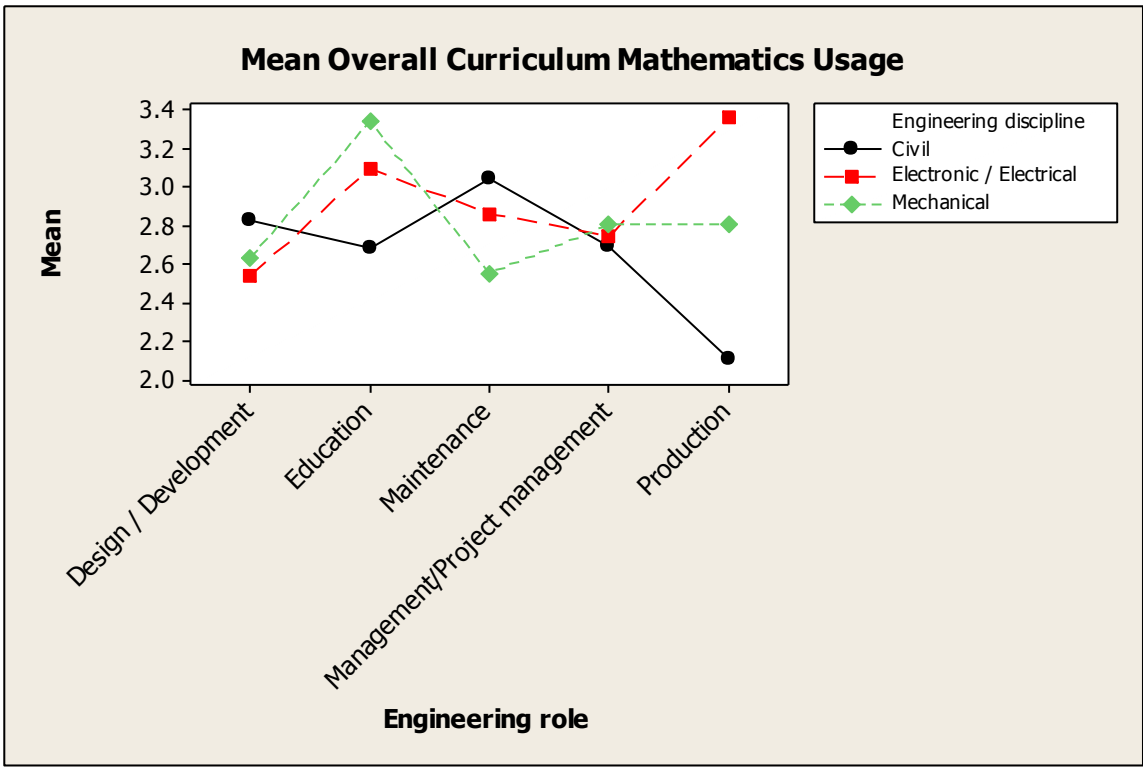


Figure A4-11: Interaction plot: Effect of engineering discipline and role on overall *curriculum mathematics* usage.

General Linear Model: D1 average U versus Engineering , Engineering

```
Factor                  Type   Levels  Values
Engineering discipline  fixed       3  Civil, Electronic / Electrical,
                                       Mechanical
Engineering role        fixed       5  Design / Development, Education,
                                       Maintenance, Management/Project
                                       management, Production


Analysis of Variance for D1 average Usage, using Adjusted SS for Tests

Source                     DF   Seq SS   Adj SS  Adj MS     F      P
Engineering discipline      2    4.486    2.101   1.051  1.00  0.370
Engineering role            4    5.512    6.484   1.621  1.54  0.191
Engineering discipline*     8   17.063   17.063   2.133  2.02  0.043
  Engineering role
Error                     323  340.626  340.626   1.055
Total                     337  367.687


S = 1.02692   R-Sq = 7.36%   R-Sq(adj) = 3.34%
```

Table A4-3: General linear model analysis: Effect of engineering discipline and role on *statistics and probability* usage.

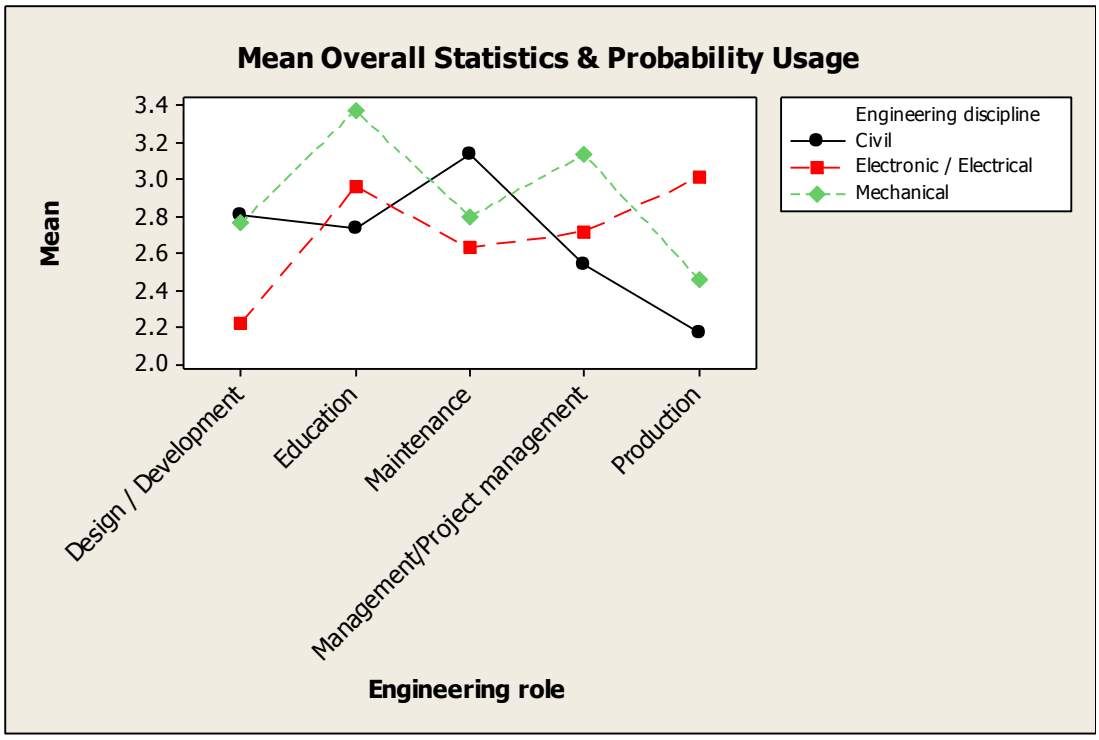


Figure A4-12: Interaction plot: Effect of engineering discipline and role on *statistics and probability* usage.

General Linear Model: D2 Average U versus Engineering , Engineering

```
Factor                   Type   Levels  Values
Engineering discipline   fixed       3  Civil, Electronic / Electrical,
                                        Mechanical
Engineering role         fixed       5  Design / Development, Education,
                                        Maintenance, Management/Project
                                        management, Production


Analysis of Variance for D2 Average Usage, using Adjusted SS for Tests

Source                    DF   Seq SS   Adj SS  Adj MS     F      P
Engineering discipline     2    5.473   11.592   5.796  4.62  0.010
Engineering role           4    1.626    2.224   0.556  0.44  0.777
Engineering discipline*    8   22.291   22.291   2.786  2.22  0.026
  Engineering role
Error                    324  406.355  406.355   1.254
Total                    338  435.745


S = 1.11990   R-Sq = 6.74%   R-Sq(adj) = 2.72%
```

Table A4-4: General linear model analysis: Effect of engineering discipline and role on *geometry and trigonometry* usage.

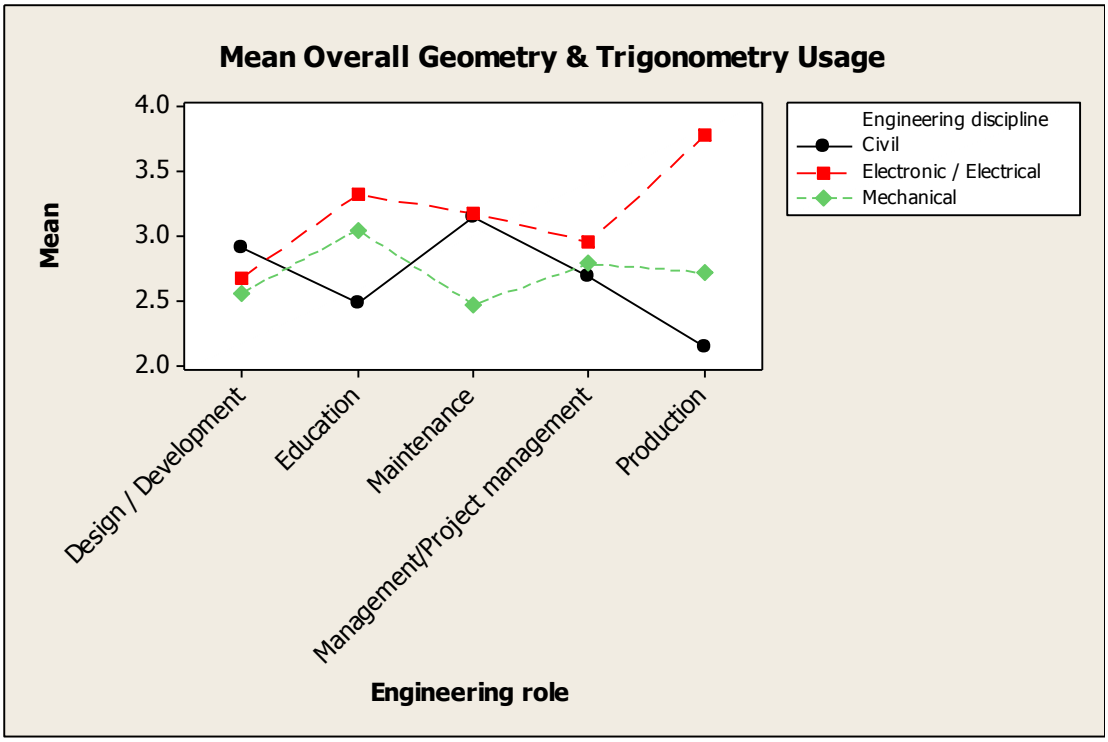


Figure A4-13: Interaction plot: Effect of engineering discipline and role on *geometry and trigonometry* usage.

General Linear Model: D3 Average U versus Engineering , Engineering

```
Factor                   Type   Levels  Values
Engineering discipline   fixed       3  Civil, Electronic / Electrical,
                                        Mechanical
Engineering role         fixed       5  Design / Development, Education,
                                        Maintenance, Management/Project
                                        management, Production


Analysis of Variance for D3 Average Usage, using Adjusted SS for Tests

Source                    DF   Seq SS   Adj SS  Adj MS     F      P
Engineering discipline     2    0.157    0.856   0.428  0.36  0.701
Engineering role           4    4.071    5.141   1.285  1.07  0.373
Engineering discipline*    8   19.332   19.332   2.416  2.01  0.045
  Engineering role
Error                    321  386.823  386.823   1.205
Total                    335  410.382


S = 1.09775   R-Sq = 5.74%   R-Sq(adj) = 1.63%
```

Table A4-5: General linear model analysis: Effect of engineering discipline and role on *number* usage.

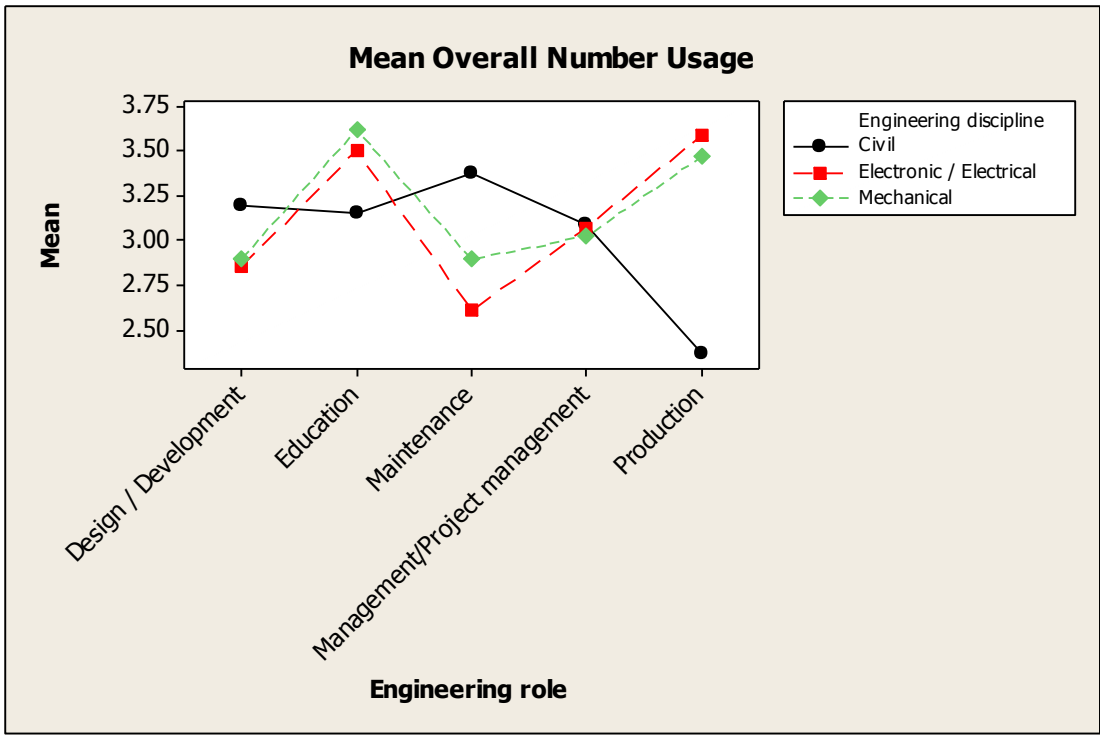


Figure A4-14: Interaction plot: Effect of engineering discipline and role on *number* usage.

General Linear Model: D4 Average U versus Engineering , Engineering

```
Factor                  Type   Levels  Values
Engineering discipline  fixed       3  Civil, Electronic / Electrical,
                                       Mechanical
Engineering role        fixed       5  Design / Development, Education,
                                       Maintenance, Management/Project
                                       management, Production


Analysis of Variance for D4 Average Usage, using Adjusted SS for Tests

Source                     DF   Seq SS   Adj SS  Adj MS     F      P
Engineering discipline      2    1.966    5.114   2.557  2.14  0.119
Engineering role            4    3.771    3.783   0.946  0.79  0.531
Engineering discipline*     8   20.736   20.736   2.592  2.17  0.029
  Engineering role
Error                     321  382.949  382.949   1.193
Total                     335  409.421


S = 1.09224   R-Sq = 6.47%   R-Sq(adj) = 2.39%
```

Table A4-6: General linear model analysis: Effect of engineering discipline and role on *algebra* usage.

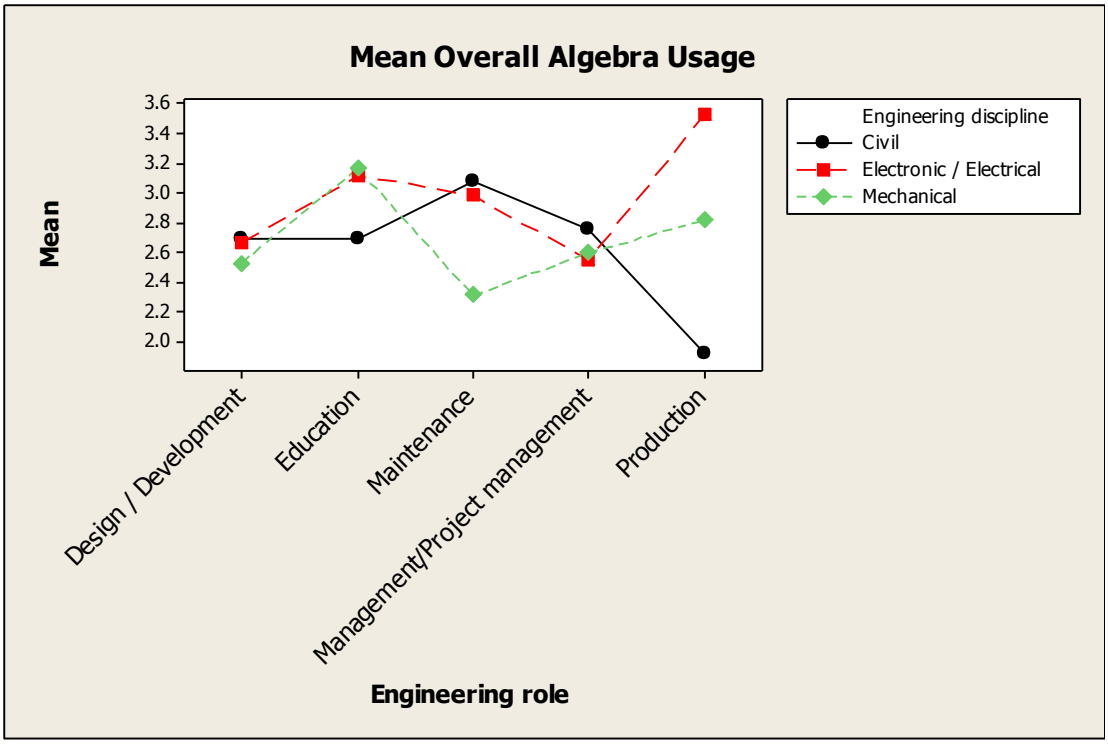


Figure A4-15: General linear model analysis: Effect of engineering discipline and role on *algebra* usage.

General Linear Model: D5 Average U versus Engineering , Engineering

```
Factor                  Type   Levels  Values
Engineering discipline  fixed       3  Civil, Electronic / Electrical,
                                       Mechanical
Engineering role        fixed       5  Design / Development, Education,
                                       Maintenance, Management/Project
                                       management, Production


Analysis of Variance for D5 Average Usage, using Adjusted SS for Tests

Source                    DF   Seq SS   Adj SS  Adj MS     F      P
Engineering discipline     2    0.218    3.084   1.542  1.21  0.301
Engineering role           4    3.396    4.040   1.010  0.79  0.533
Engineering discipline*    8   15.598   15.598   1.950  1.52  0.148
  Engineering role
Error                    322  411.857  411.857   1.279
Total                    336  431.069


S = 1.13095   R-Sq = 4.46%   R-Sq(adj) = 0.30%
```

Table A4-7: General linear model analysis: Effect of engineering discipline and role on *functions* usage.

Power and Sample Size

```
2-Level Factorial Design

Alpha = 0.05  Assumed standard deviation = 1.13095

Factors:    2   Base Design: 2, 4
Blocks:  none


Center                Total  Target
Points  Effect  Reps   Runs   Power  Actual Power
     0       1    11     44     0.8      0.816357
```

Table A4-8: Power and sample size: Effect of engineering discipline and role on *functions* usage.

With a p-value greater than 5% in Table A4-7, it was necessary to test for a type 1 error (the null hypothesis is rejected when it is true). Using a power of 80% (0.8) and the standard deviation calculated in Table A4-7, the "power and sample size" feature of Minitab checks if the sample size is sufficiently large, Table A4-8.

General Linear Model: A3 Average U versus Engineering , Engineering

```
Factor                  Type   Levels  Values
Engineering discipline  fixed       3  Civil, Electronic / Electrical,
                                       Mechanical
Engineering role        fixed       5  Design / Development, Education,
                                       Maintenance, Management/Project
                                       management, Production


Analysis of Variance for A3 Average Usage, using Adjusted SS for Tests

Source                     DF   Seq SS   Adj SS  Adj MS     F      P
Engineering discipline      2    1.141    5.200   2.600  2.30  0.102
Engineering role            4    3.449    5.279   1.320  1.17  0.326
Engineering discipline*     8   20.319   20.319   2.540  2.25  0.024
  Engineering role
Error                     297  335.955  335.955   1.131
Total                     311  360.864


S = 1.06356   R-Sq = 6.90%   R-Sq(adj) = 2.51%
```

Table A4-9: General linear model analysis: Effect of engineering discipline and role on higher level Leaving Certificate mathematics usage.

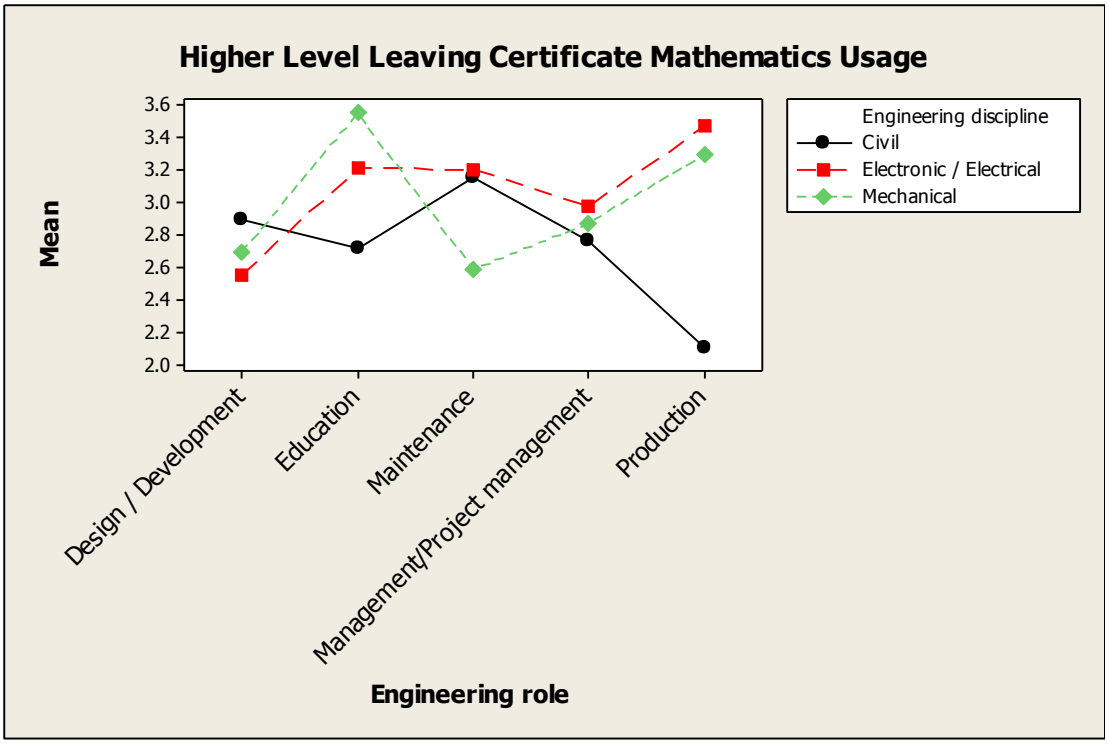


Figure A4-16: Interaction plot: Effect of engineering discipline and role on higher level Leaving Certificate mathematics usage

A4.4 To What Extent, With Or Without Direct Application Of Mathematics, Did Your Mathematics Training (With Its Associated Modes Of Thinking and Analysis) Directly Influence Your Approach To Your Work?

A4.4.1 Engineers' Mean *Thinking* Usage

Sample size: 365

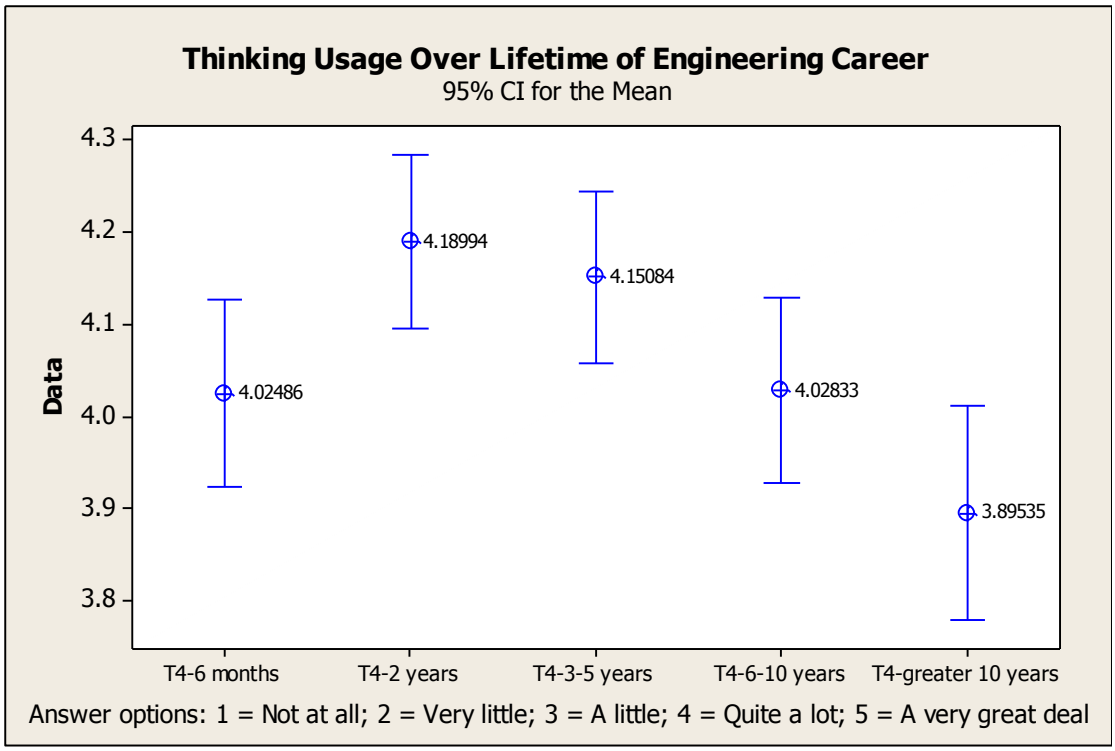


Figure A4-17: Confidence interval: Engineers' mean *thinking* usage.

A4.4.2 Effect of Engineering Discipline and Role on Engineers' *Thinking* Usage

Sample size:

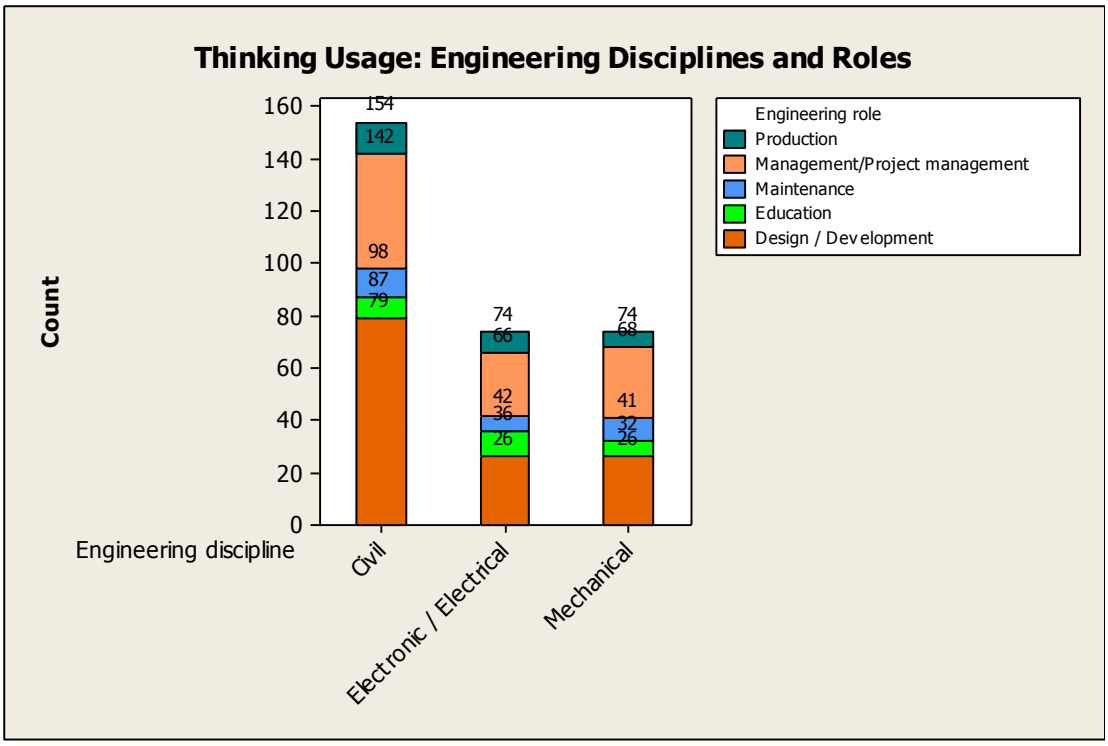


Figure A4-18: Sample size: Effect of engineering discipline and role on *thinking* usage.

General Linear Model: T4-6 months versus Engineering , Engineering

```
Factor                  Type   Levels  Values
Engineering discipline  fixed       3  Civil, Electronic / Electrical,
                                       Mechanical
Engineering role        fixed       5  Design / Development, Education,
                                       Maintenance, Management/Project
                                       management, Production

Analysis of Variance for T4-6 months, using Adjusted SS for Tests

Source                     DF    Seq SS    Adj SS  Adj MS     F      P
Engineering discipline      2    0.1248    0.2737  0.1369  0.20  0.815
Engineering role            4    1.8249    3.1134  0.7783  1.16  0.329
Engineering discipline*     8    5.1552    5.1552  0.6444  0.96  0.467
  Engineering role
Error                     176  117.8271  117.8271  0.6695
Total                     190  124.9319


S = 0.818213   R-Sq = 5.69%   R-Sq(adj) = 0.00%
```

Table A4-10: General linear model analysis: Effect of engineering discipline and role on *thinking* usage.

Power and Sample Size

```
2-Level Factorial Design

Alpha = 0.05  Assumed standard deviation = 0.818213

Factors:    2   Base Design: 2, 4
Blocks:  none


Center                Total  Target
Points  Effect  Reps   Runs   Power  Actual Power
     0       1     6     24     0.8      0.812567
```

Table A4-11: Power and sample size: Effect of engineering discipline and role on *thinking* usage.

A4.4.3 Engineers' Modes of *Thinking*

Sample size: 365

Result:

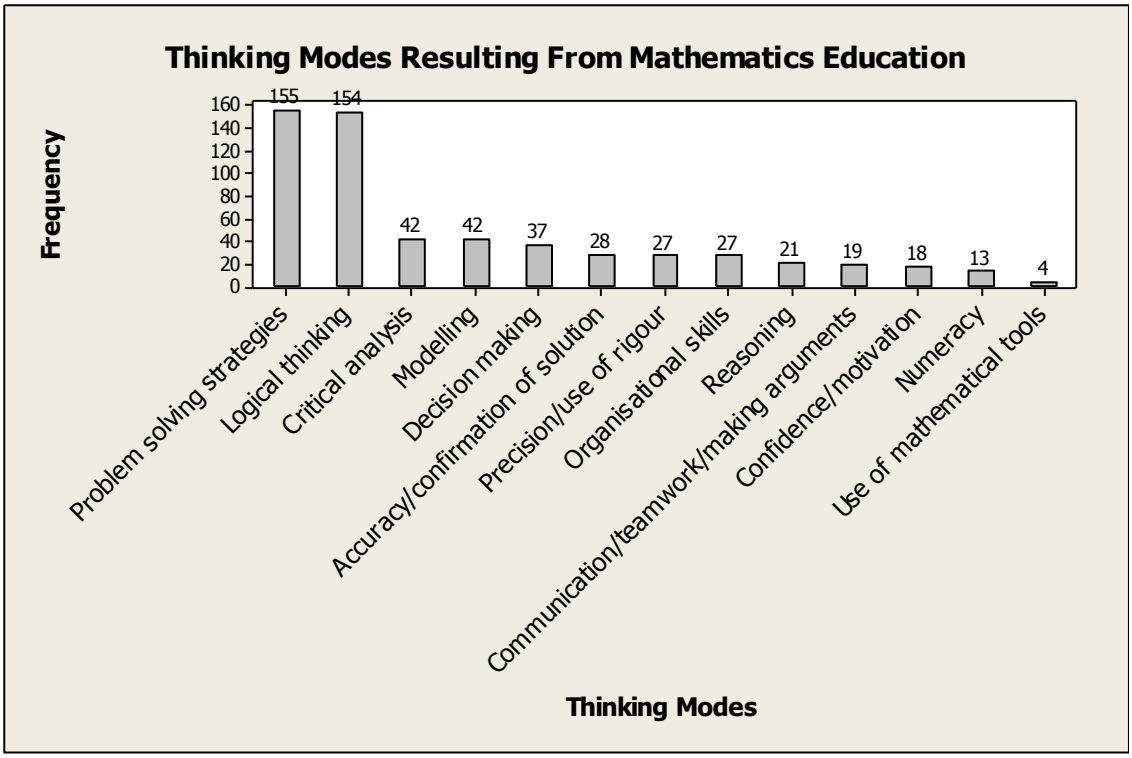


Figure A4-19: Engineers' modes of *thinking.*

A4.4.4 Comparison of Engineers' *Thinking* and *Curriculum Mathematics* Usages

Sample size: 365

Paired T-Test and CI: T4-6 months, Overall Average Usage

```
Paired T for T4-6 months - Overall Average Usage

                         N    Mean   StDev  SE Mean
T4-6 months            362  4.0249  0.9744   0.0512
Overall Average Usage  362  2.7353  0.9543   0.0502
Difference             362  1.2896  1.3688   0.0719


95% CI for mean difference: (1.1481, 1.4311)
T-Test of mean difference = 0 (vs not = 0): T-Value = 17.92  P-Value = 0.000
```

Table A4-12: Paired t-test analysis: Comparison of engineers' *thinking* usage and engineers' overall *curriculum mathematics* usage.

A4.5 *Engaging* with Mathematics in Engineering Practice

A4.5.1 Degree a Specifically Mathematical Approach is Necessary in Engineers' Work

Sample size: 365

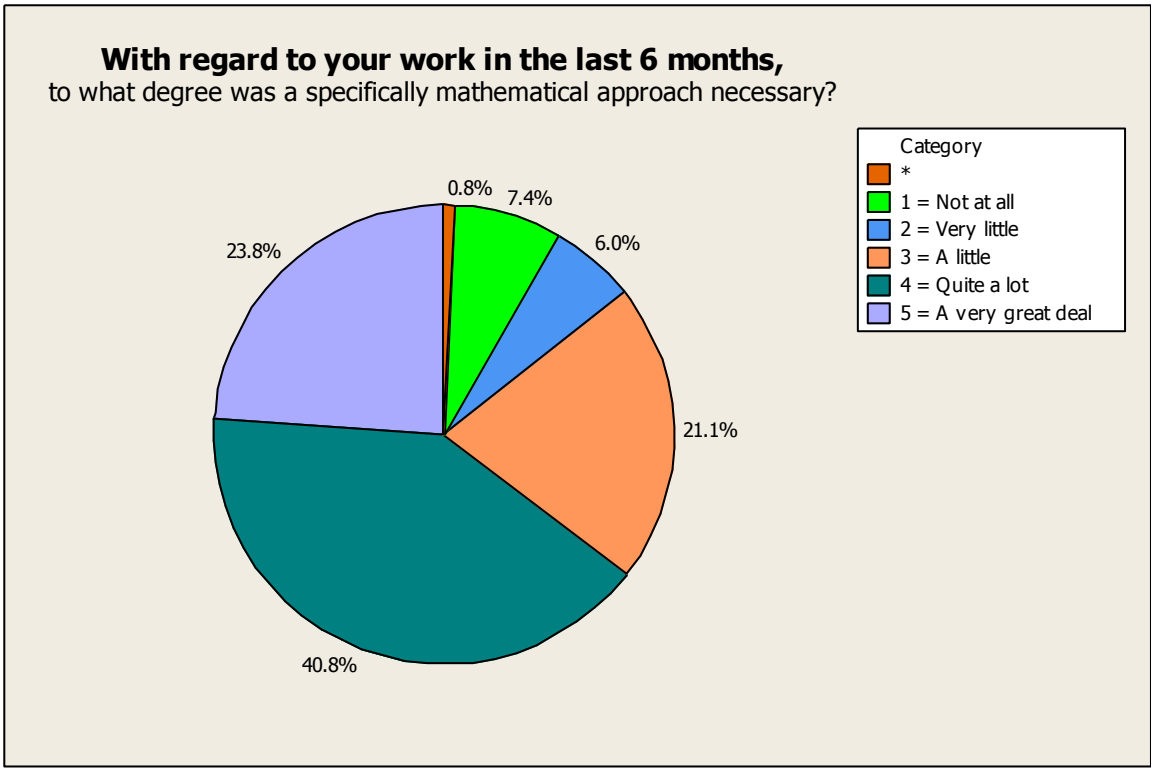


Figure A4-20: The degree a specifically mathematical approach is necessary in engineering practice.

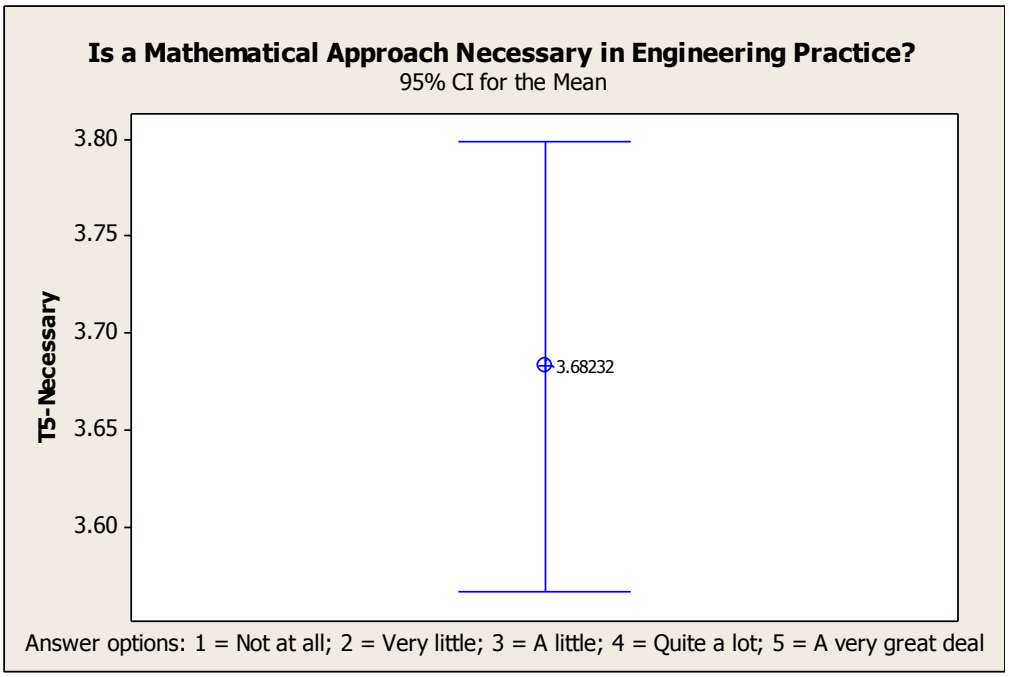


Figure A4-21: Confidence interval: Mean value of degree a specifically mathematical approach is necessary in engineering practice.

Paired T-Test and CI: T5-Necessary, Overall Average Usage

```
Paired T for T5-Necessary - Overall Average Usage

                         N    Mean   StDev  SE Mean
T5-Necessary           362  3.6823  1.1269   0.0592
Overall Average Usage  362  2.7313  0.9547   0.0502
Difference             362  0.9510  1.5010   0.0789


95% CI for mean difference: (0.7958, 1.1061)
T-Test of mean difference = 0 (vs not = 0): T-Value = 12.05  P-Value = 0.000
```

Table A4-13: Paired t-test analysis: Comparison of degree a mathematical approach is necessary and engineers' overall *curriculum mathematics* usage.

Paired T-Test and CI: T5-Necessary, T4-6 months

```
Paired T for T5-Necessary - T4-6 months

                N     Mean   StDev  SE Mean
T5-Necessary  360   3.6833  1.1294   0.0595
T4-6 months   360   4.0333  0.9697   0.0511
Difference    360  -0.3500  0.9557   0.0504


95% CI for mean difference: (-0.4491, -0.2509)
T-Test of mean difference = 0 (vs not = 0): T-Value = -6.95  P-Value = 0.000
```

Table A4-14: Paired t-test analysis: Comparison of degree a mathematical approach is necessary and engineers' *thinking* usage.

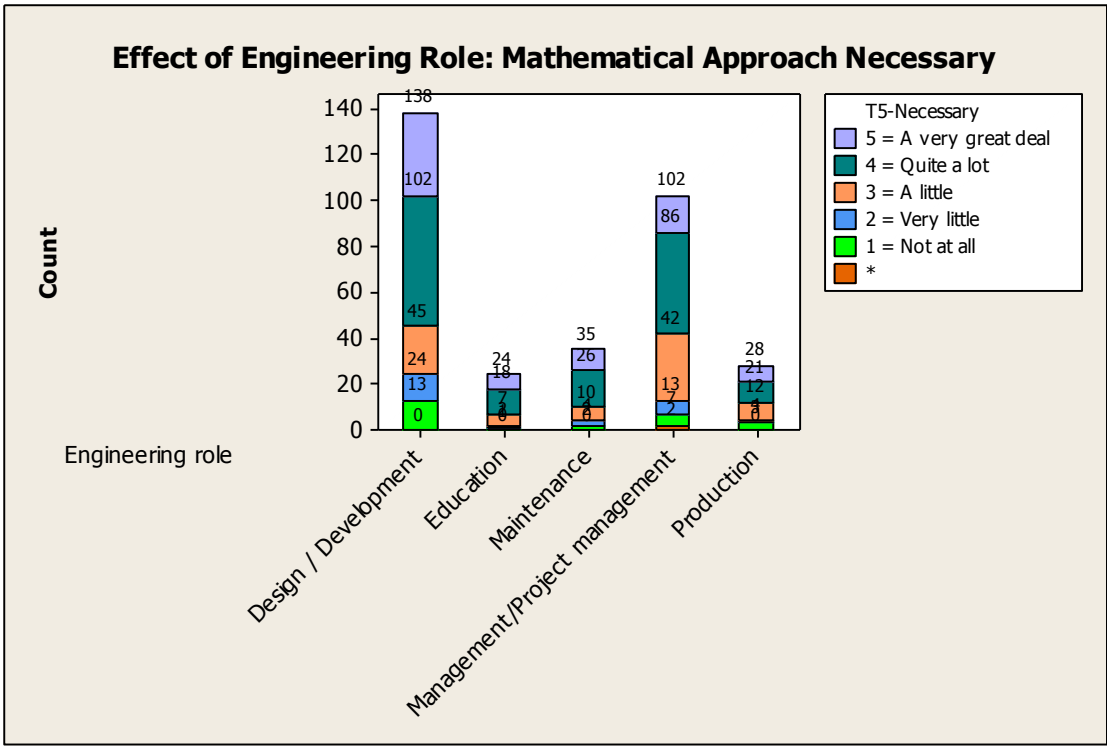


Figure A4-22: Degree mathematical approach necessary in engineering practice, breakdown by engineering role.

A4.5.2 Degree Engineers Seek a Mathematical Approach

Sample size: 365

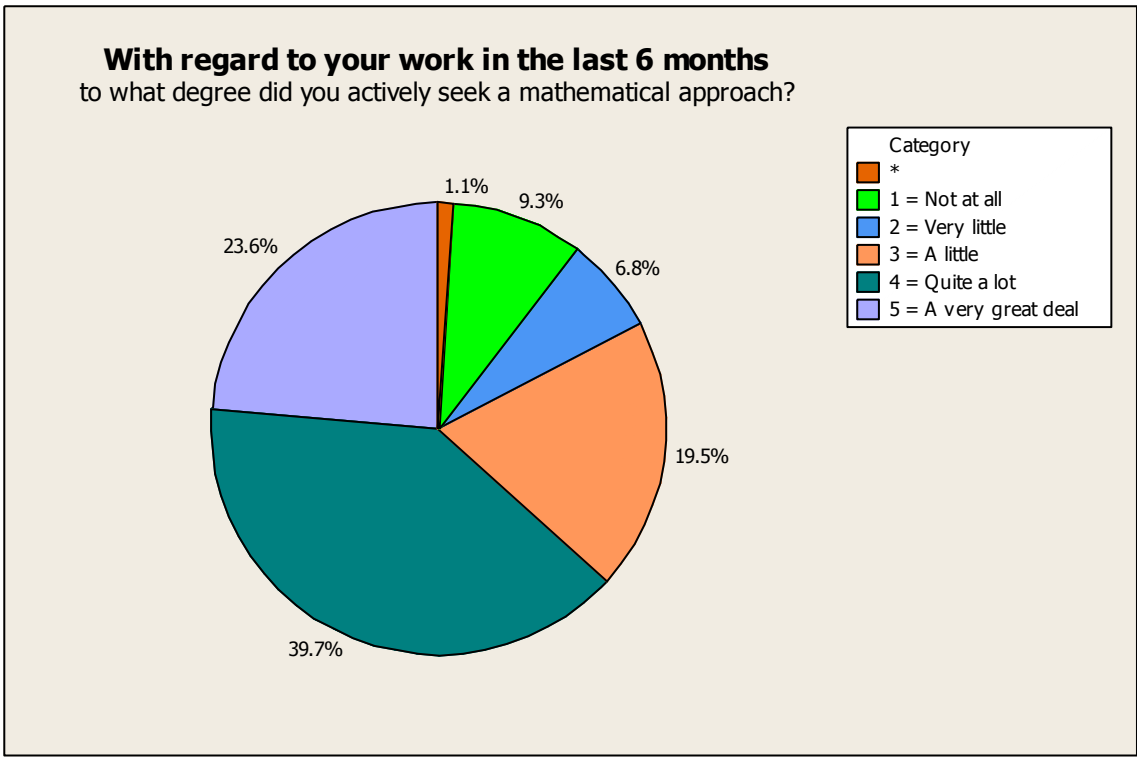


Figure A4-23: The degree engineers seek a mathematical approach in their work.

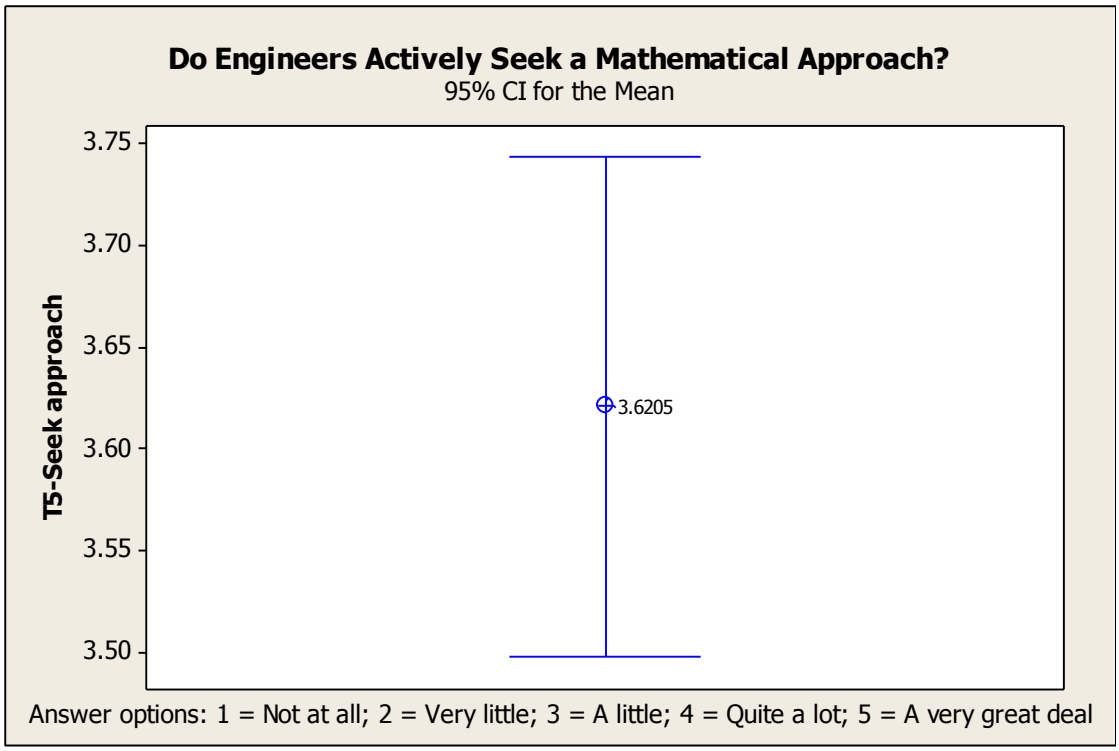


Figure A4-24: Confidence interval: Mean value of degree engineers seek a mathematical approach in their work.

Paired T-Test and CI: T5-Seek approach, T5-Necessary

```
Paired T for T5-Seek approach - T5-Necessary

                     N     Mean   StDev  SE Mean
T5-Seek approach   360   3.6194  1.1929   0.0629
T5-Necessary       360   3.6917  1.1206   0.0591
Difference         360  -0.0722  0.8144   0.0429


95% CI for mean difference: (-0.1566, 0.0122)
T-Test of mean difference = 0 (vs not = 0): T-Value = -1.68  P-Value = 0.093
```

Table A4-15: Paired t-test analysis: Comparison of degree engineers seek a mathematical approach and degree a specifically mathematical approach is necessary.

Power and Sample Size

```
1-Sample t Test

Testing mean = null (versus not = null)
Calculating power for mean = null + difference
Alpha = 0.05  Assumed standard deviation = 0.8144


            Sample  Target
Difference    Size   Power  Actual Power
       0.1     864    0.95      0.950044
```

Table A4-16: Power and sample size: Comparison of degree engineers seek a mathematical approach and degree a specifically mathematical approach is necessary.

Paired T-Test and CI: T5-Seek approach, Overall Average Usage

```
Paired T for T5-Seek approach - Overall Average Usage

                         N    Mean   StDev  SE Mean
T5-Seek approach       361  3.6205  1.1914   0.0627
Overall Average Usage  361  2.7316  0.9546   0.0502
Difference             361  0.8889  1.5822   0.0833


95% CI for mean difference: (0.7251, 1.0526)
T-Test of mean difference = 0 (vs not = 0): T-Value = 10.67  P-Value = 0.000
```

Table A4-17: Paired t-test analysis: Comparison of degree engineers seek a mathematical approach and engineers' overall *curriculum mathematics* usage.

Paired T-Test and CI: T5-Seek approach, T4-6 months

```
Paired T for T5-Seek approach - T4-6 months

                     N     Mean   StDev  SE Mean
T5-Seek approach   360   3.6278  1.1850   0.0625
T4-6 months        360   4.0306  0.9713   0.0512
Difference         360  -0.4028  1.0590   0.0558


95% CI for mean difference: (-0.5125, -0.2930)
T-Test of mean difference = 0 (vs not = 0): T-Value = -7.22  P-Value = 0.000
```

Table A4-18: Paired t-test analysis: Comparison of degree engineers seek a mathematical approach and engineers' *thinking* usage.

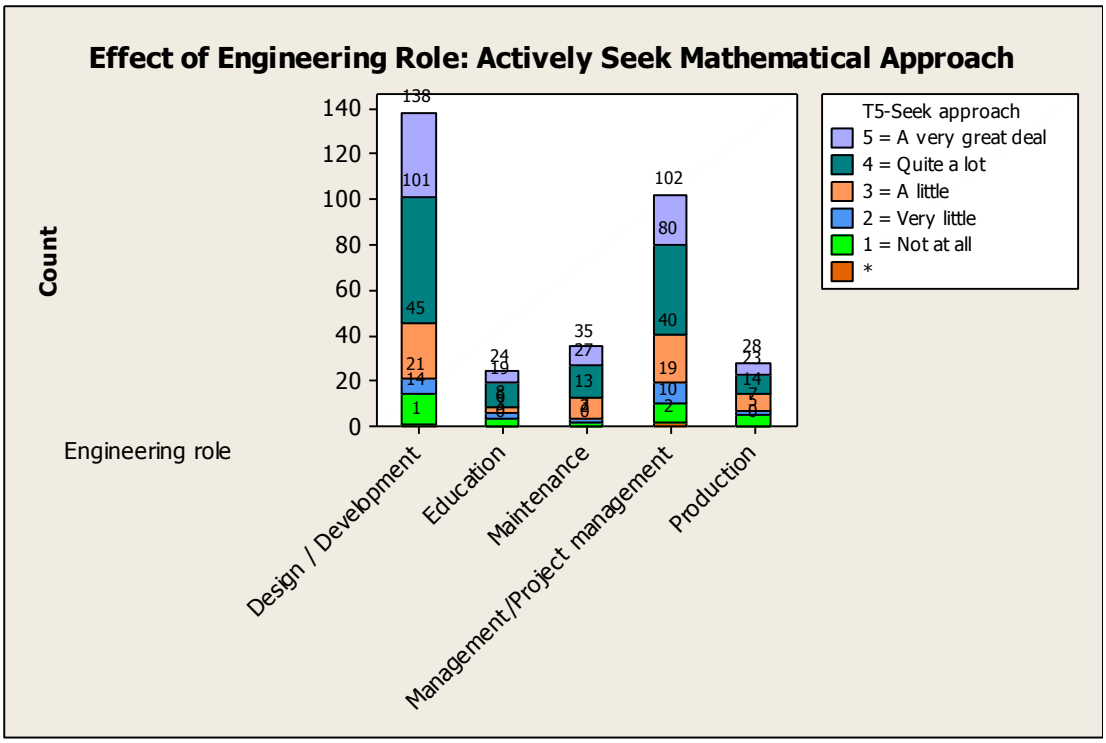


Figure A4-25: Degree engineers seek a mathematical approach, breakdown by engineering role.

A4.5.3 With Regard To Your Work In The Last 6 Months, To What Degree Did You Enjoy Using Mathematics?

Sample size: 365

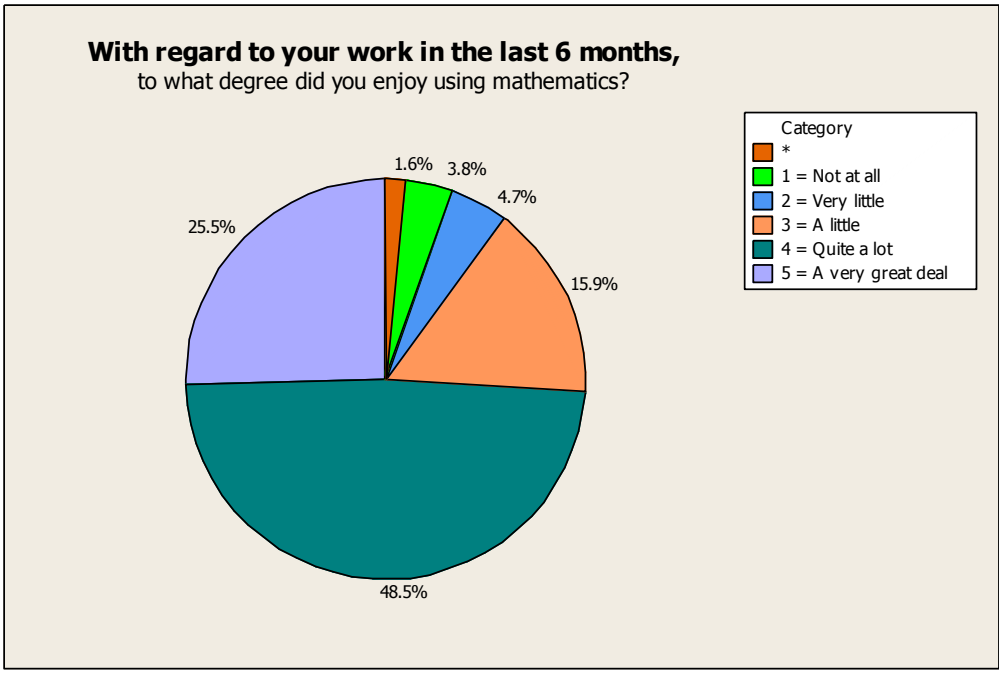


Figure A4-26: The degree engineers enjoy using mathematics in their work.

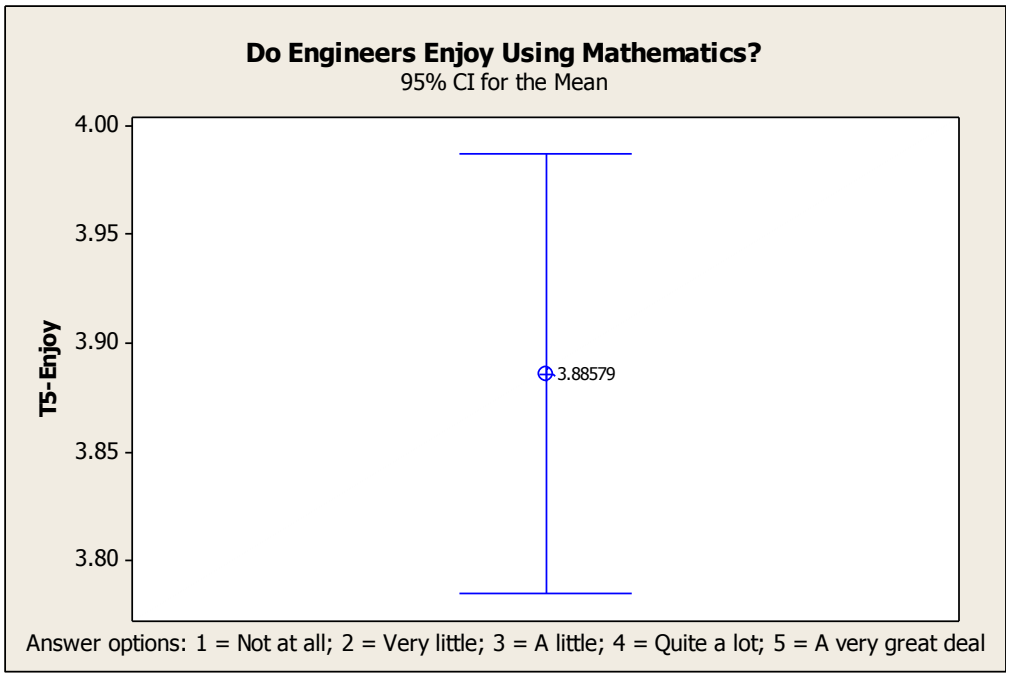


Figure A4-27: Confidence interval: Mean value of degree engineers enjoy using mathematics in their work.

Paired T-Test and CI: T5-Enjoy, Overall Average Usage

```
Paired T for T5-Enjoy - Overall Average Usage

                         N    Mean   StDev  SE Mean
T5-Enjoy               359  3.8858  0.9750   0.0515
Overall Average Usage  359  2.7272  0.9490   0.0501
Difference             359  1.1586  1.3864   0.0732


95% CI for mean difference: (1.0147, 1.3025)
T-Test of mean difference = 0 (vs not = 0): T-Value = 15.83  P-Value = 0.000
```

Table A4-19: Paired t-test analysis: Comparison of degree engineers enjoy using mathematics in work and engineers' overall *curriculum mathematics* usage.

Paired T-Test and CI: T5-Enjoy, T5-Seek approach

```
Paired T for T5-Enjoy - T5-Seek approach

                   N    Mean   StDev  SE Mean
T5-Enjoy         359  3.8858  0.9750   0.0515
T5-Seek approach 359  3.6184  1.1944   0.0630
Difference       359  0.2674  0.9864   0.0521


95% CI for mean difference: (0.1650, 0.3698)
T-Test of mean difference = 0 (vs not = 0): T-Value = 5.14  P-Value = 0.000
```

Table A4-20: Paired t-test analysis: Comparison of degree engineers enjoy using mathematics in work and degree engineers actively seek mathematical approach.

Paired T-Test and CI: T5-Enjoy, Enjoy maths

```
Paired T for T5-Enjoy - Enjoy maths

              N     Mean   StDev  SE Mean
T5-Enjoy    357   3.8852  0.9748   0.0516
Enjoy maths 357   4.1092  0.8688   0.0460
Difference  357  -0.2241  1.0333   0.0547


95% CI for mean difference: (-0.3316, -0.1165)
T-Test of mean difference = 0 (vs not = 0): T-Value = -4.10  P-Value = 0.000
```

Table A4-21: Paired t-test analysis: Comparison of degree engineers enjoy using mathematics in work and degree engineers enjoyed school mathematics.

A4.5.4 With regard to your work in the last 6 months, to what degree did you feel confident dealing with mathematics?

Sample size: 365

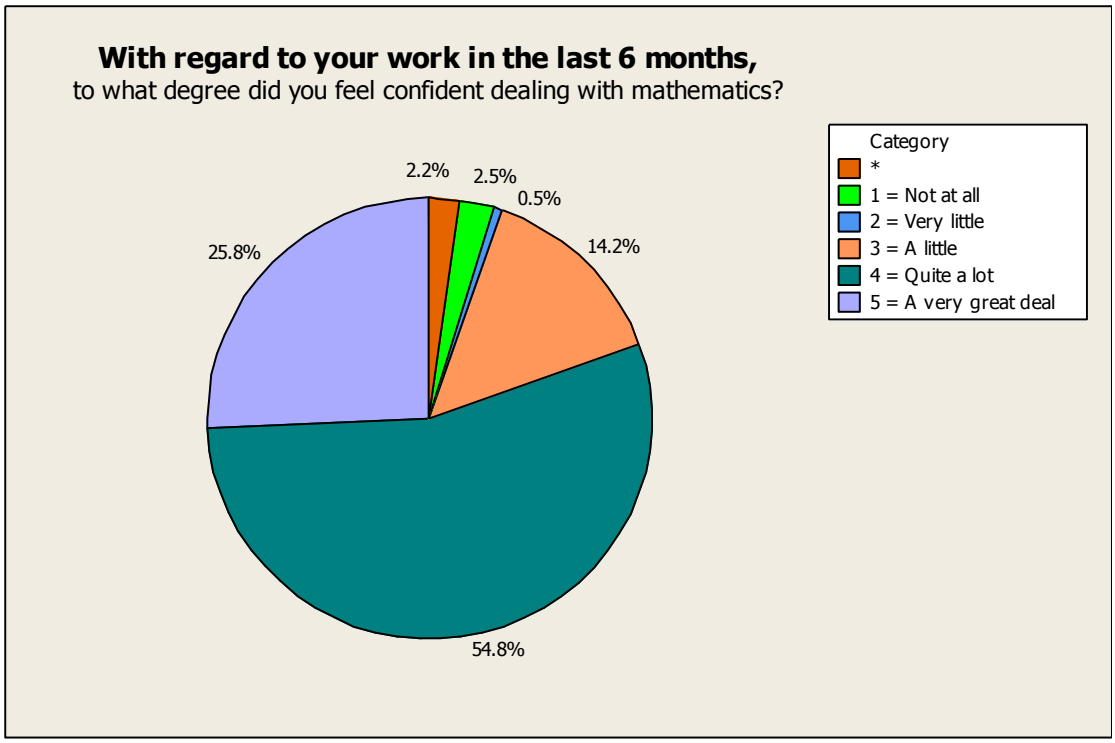


Figure A4-28: The degree engineers feel confident dealing with mathematics.

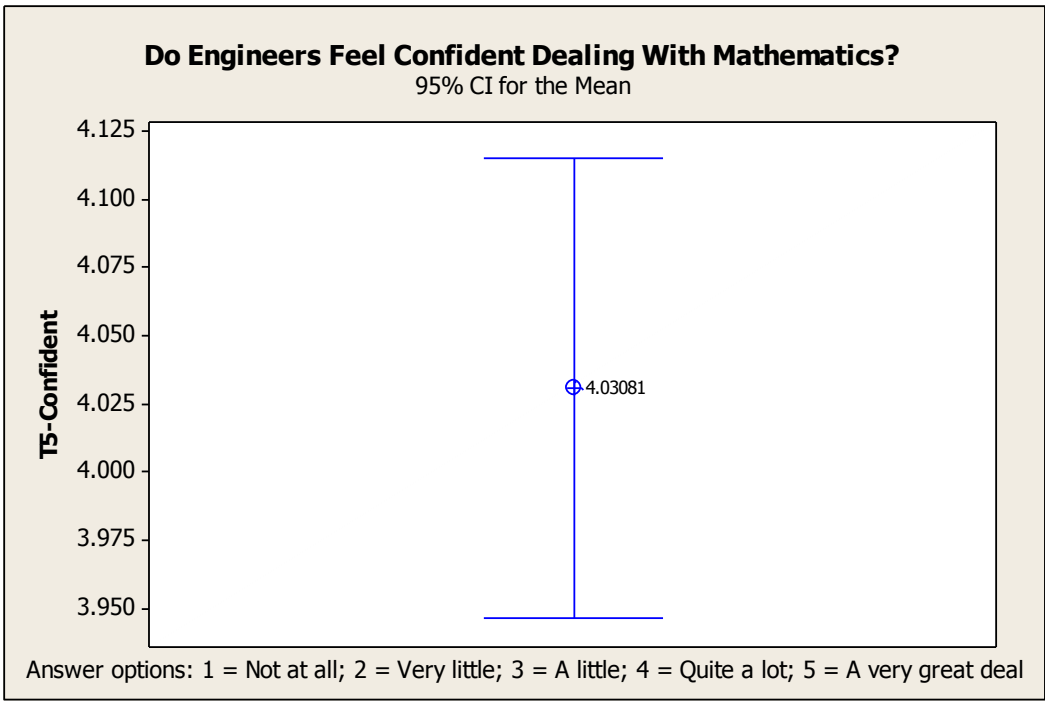


Figure A4-29: Confidence interval: Mean value of the degree engineers feel confident dealing with mathematics.

Paired T-Test and CI: T5-Confident, Overall Average Usage

```
Paired T for T5-Confident - Overall Average Usage

                          N    Mean   StDev  SE Mean
T5-Confident            357  4.0308  0.8119   0.0430
Overall Average Usage   357  2.7382  0.9530   0.0504
Difference              357  1.2926  1.2772   0.0676


95% CI for mean difference: (1.1597, 1.4255)
T-Test of mean difference = 0 (vs not = 0): T-Value = 19.12  P-Value = 0.000
```

Table A4-22: Paired t-test analysis: Comparison of degree engineers feel confident using mathematics and engineers' overall *curriculum mathematics* usage.

Paired T-Test and CI: T5-Confident, T4-6 months

```
Paired T for T5-Confident - T4-6 months

               N    Mean   StDev  SE Mean
T5-Confident  356  4.0309  0.8130   0.0431
T4-6 months   356  4.0225  0.9726   0.0515
Difference    356  0.0084  1.0028   0.0531


95% CI for mean difference: (-0.0961, 0.1129)
T-Test of mean difference = 0 (vs not = 0): T-Value = 0.16  P-Value = 0.874
```

Table A4-23: Paired t-test analysis: Comparison of degree engineers feel confident using mathematics and engineers' *thinking* usage.

Power and Sample Size

```
1-Sample t Test

Testing mean = null (versus not = null)
Calculating power for mean = null + difference
Alpha = 0.05  Assumed standard deviation = 1.0028


            Sample  Target
Difference    Size   Power  Actual Power
       0.1    1309    0.95      0.950045
```

Table A4-24: Power and sample size: Comparison of degree engineers feel confident using mathematics and engineers' *thinking* usage.

Paired T-Test and CI: T5-Confident, T5-Seek approach

```
Paired T for T5-Confident - T5-Seek approach

                   N    Mean   StDev  SE Mean
T5-Confident      357  4.0308  0.8119   0.0430
T5-Seek approach  357  3.6162  1.1903   0.0630
Difference        357  0.4146  1.0529   0.0557


95% CI for mean difference: (0.3050, 0.5242)
T-Test of mean difference = 0 (vs not = 0): T-Value = 7.44  P-Value = 0.000
```

Table A4-25: Paired t-test analysis: Comparison of degree engineers feel confident using mathematics and degree engineers actively seek mathematical approach.

Paired T-Test and CI: T5-Confident, T5-Enjoy

```
Paired T for T5-Confident - T5-Enjoy

               N    Mean   StDev  SE Mean
T5-Confident  356  4.0309  0.8130   0.0431
T5-Enjoy      356  3.8820  0.9773   0.0518
Difference    356  0.1489  0.7998   0.0424


95% CI for mean difference: (0.0655, 0.2322)
T-Test of mean difference = 0 (vs not = 0): T-Value = 3.51  P-Value = 0.001
```

Table A4-26: Paired t-test analysis: Comparison of degree engineers feel confident using mathematics and degree engineers enjoy using mathematics in work.

Paired T-Test and CI: T5-Confident, Enjoy maths

```
Paired T for T5-Confident - Enjoy maths

               N     Mean   StDev  SE Mean
T5-Confident  355   4.0310  0.8107   0.0430
Enjoy maths   355   4.1155  0.8541   0.0453
Difference    355  -0.0845  0.9907   0.0526


95% CI for mean difference: (-0.1879, 0.0189)
T-Test of mean difference = 0 (vs not = 0): T-Value = -1.61  P-Value = 0.109
```

Table A4-27: Paired t-test analysis: Comparison of degree engineers feel confident using mathematics and degree engineers enjoyed school mathematics.

Power and Sample Size

```
1-Sample t Test

Testing mean = null (versus not = null)
Calculating power for mean = null + difference
Alpha = 0.05  Assumed standard deviation = 0.9907


           Sample  Target
Difference   Size   Power  Actual Power
       0.1   1278    0.95      0.950097
```

Table A4-28: Power and sample size: Comparison of degree engineers feel confident using mathematics and degree engineers enjoyed school mathematics.

A4.5.5 With Regard To Your Work In The Last 6 Months, To What Degree Did You Have A Negative Experience When Using Mathematics?

Sample size: 365

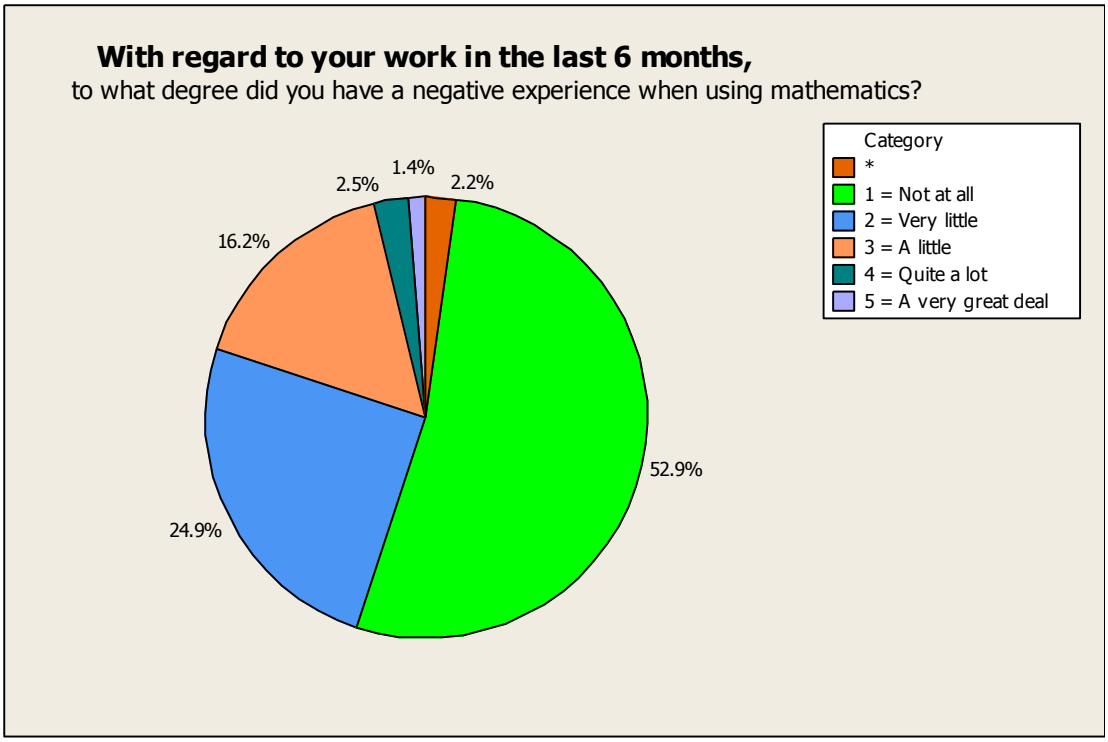


Figure A4-30: The degree engineers had a negative experience when using mathematics.

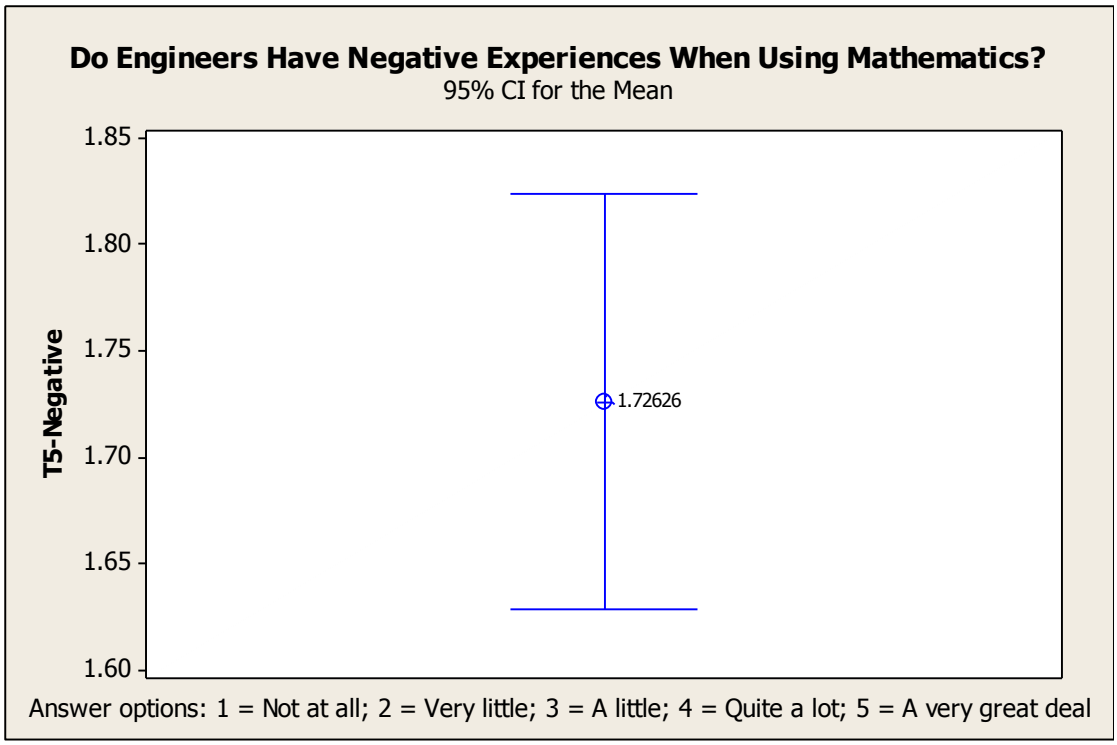


Figure A4-31: Mean value of the degree engineers had a negative experience when using mathematics.

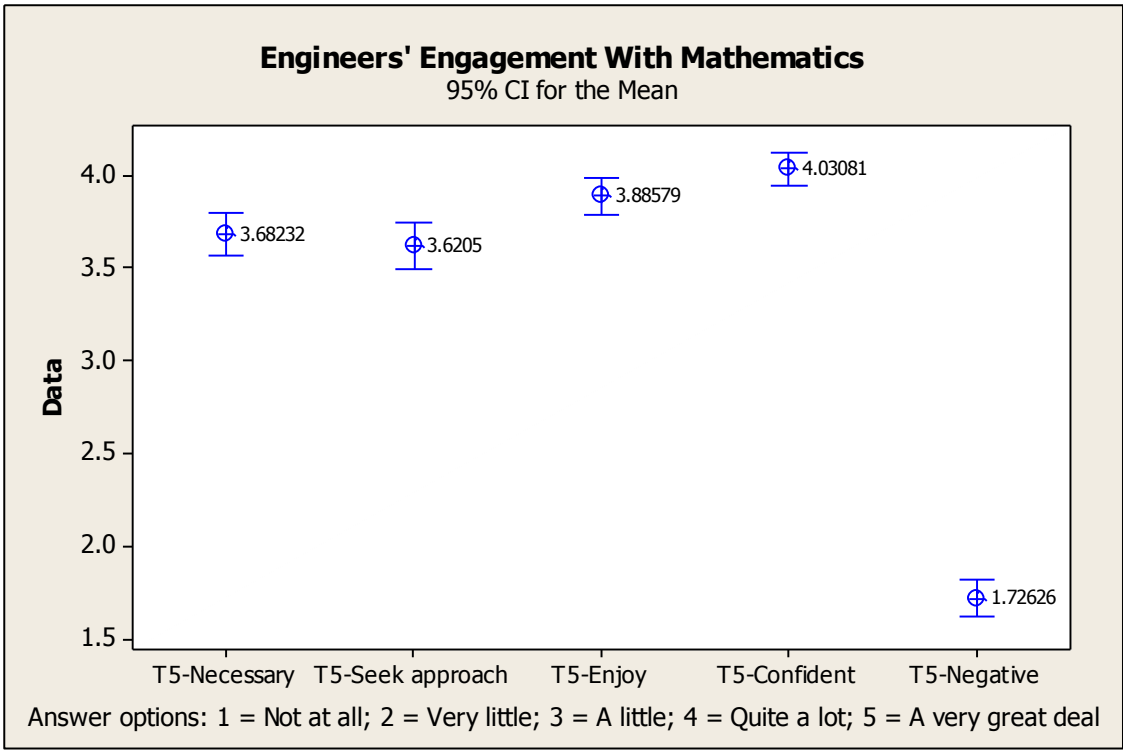


Figure A4-32: Mean value of the engineers' *engaging* usage.

A4.6 School Mathematics

A4.6.1 Did You Enjoy mathematics in Secondary School?

Sample size: 365

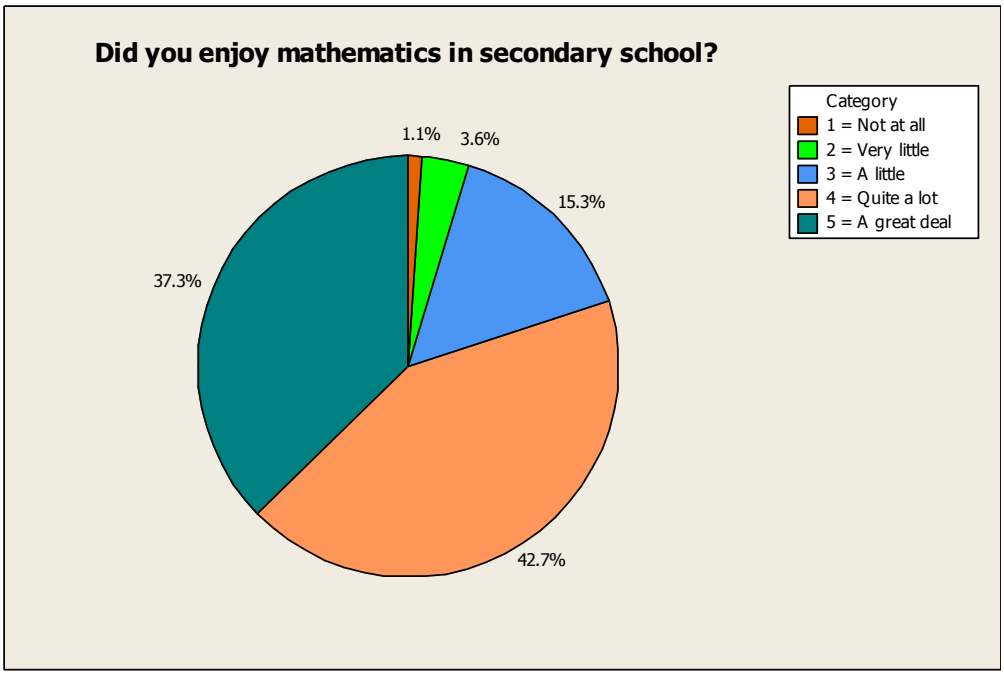


Figure A4-33: Engineers' enjoyment of school mathematics.

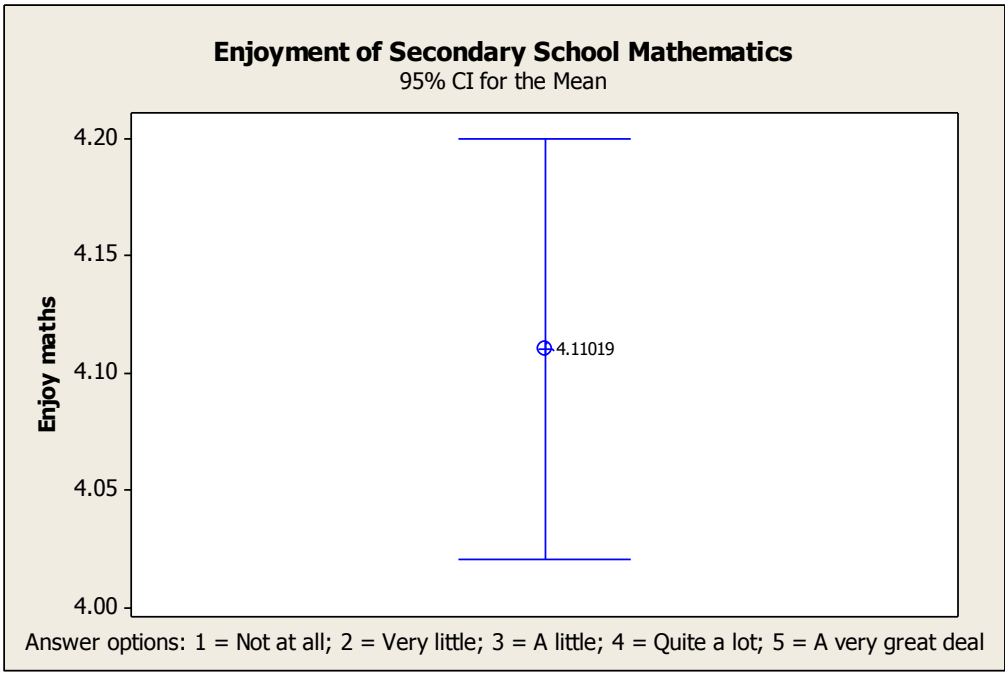


Figure A4-34: Mean value of engineers' enjoyment of school mathematics.

A4.6.2 What Events, Experiences, Aptitudes Or Other Factors Within And Outside Of School Contributed To Your Interest In And learning Of Mathematics?

Sample size: 365

A4.6.2.1 Within Primary School

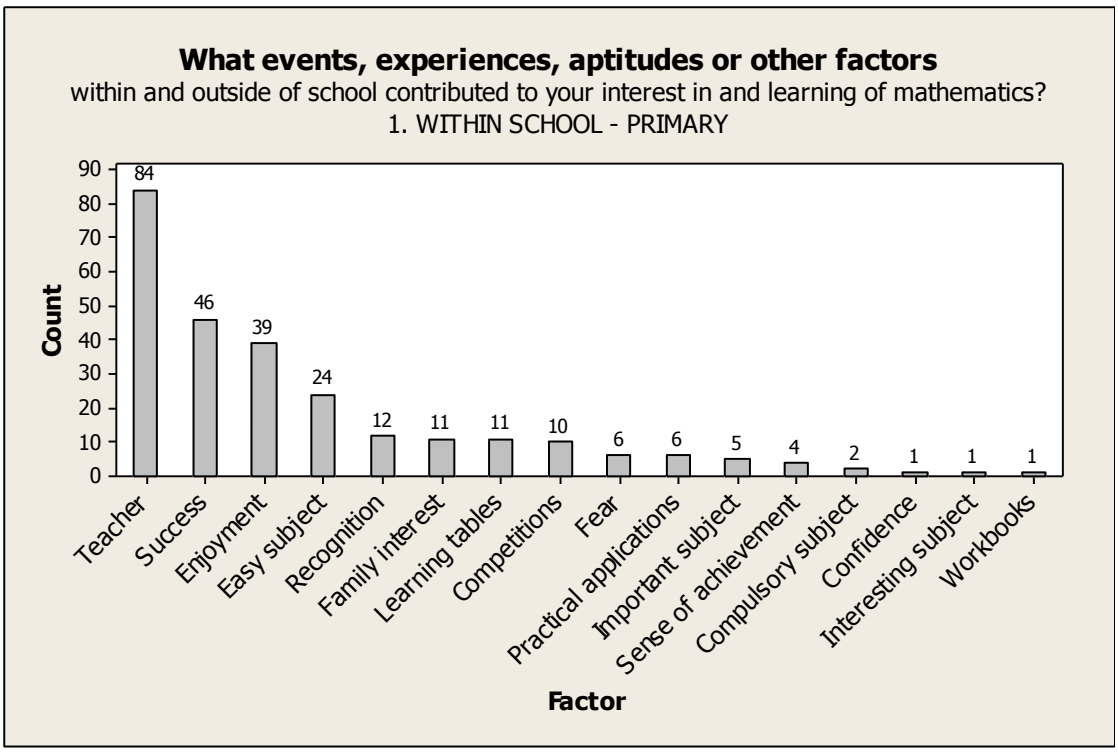


Figure A4-35: Factors within primary school contributing to mathematics learning.

A4.6.2.2 Within Secondary School - Years 1 & 2

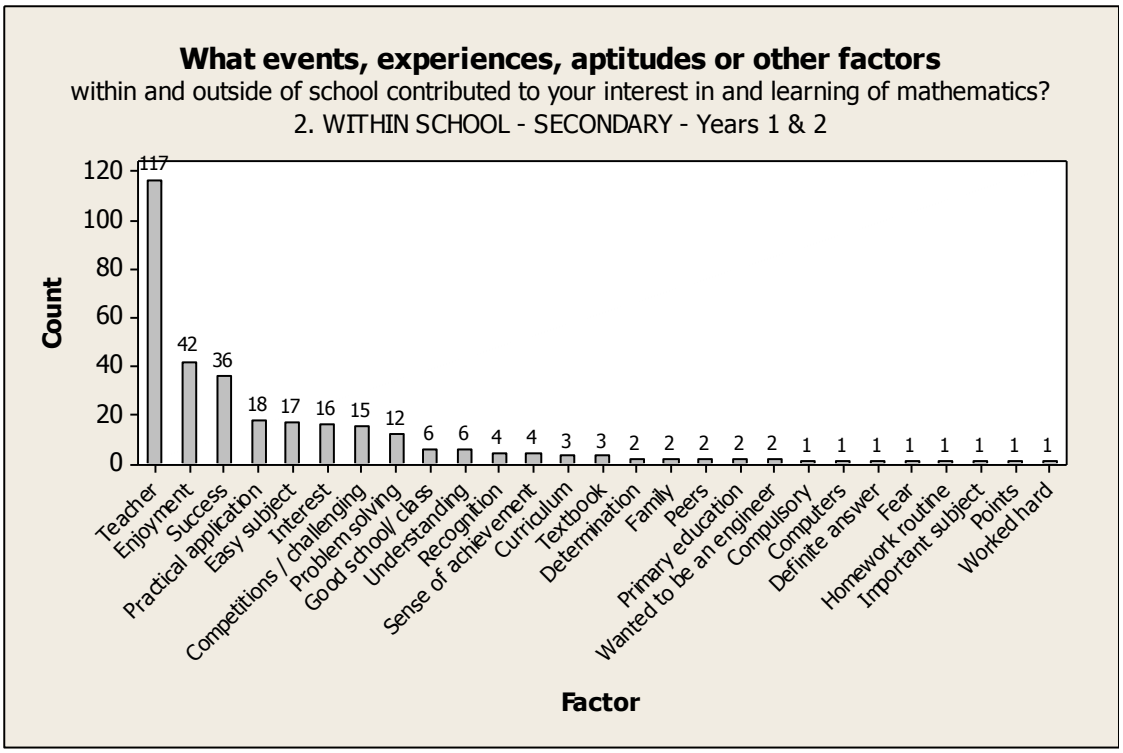


Figure A4-36: Factors within secondary school (years 1 & 2) contributing to mathematics learning.

A4.6.2.3 Within Secondary School - Junior Certificate

Result:

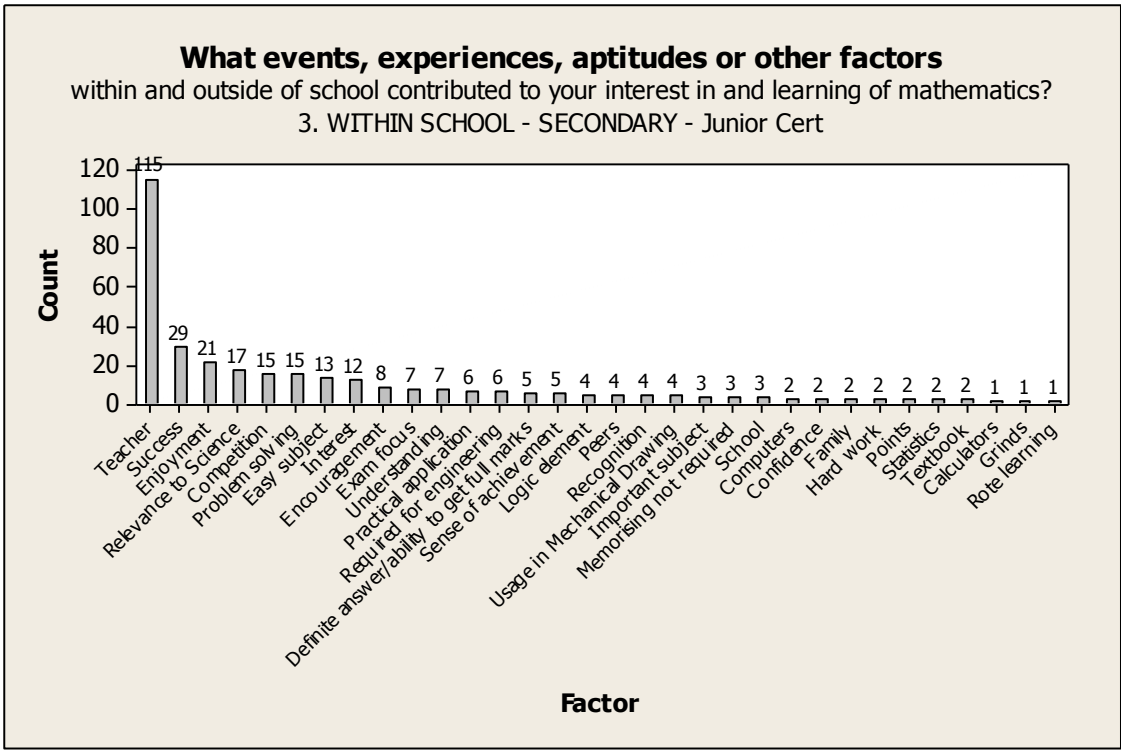


Figure A4-37: Factors within secondary school (Junior Certificate) contributing to mathematics learning.

A4.6.2.4 Within Secondary School – Leaving Certificate

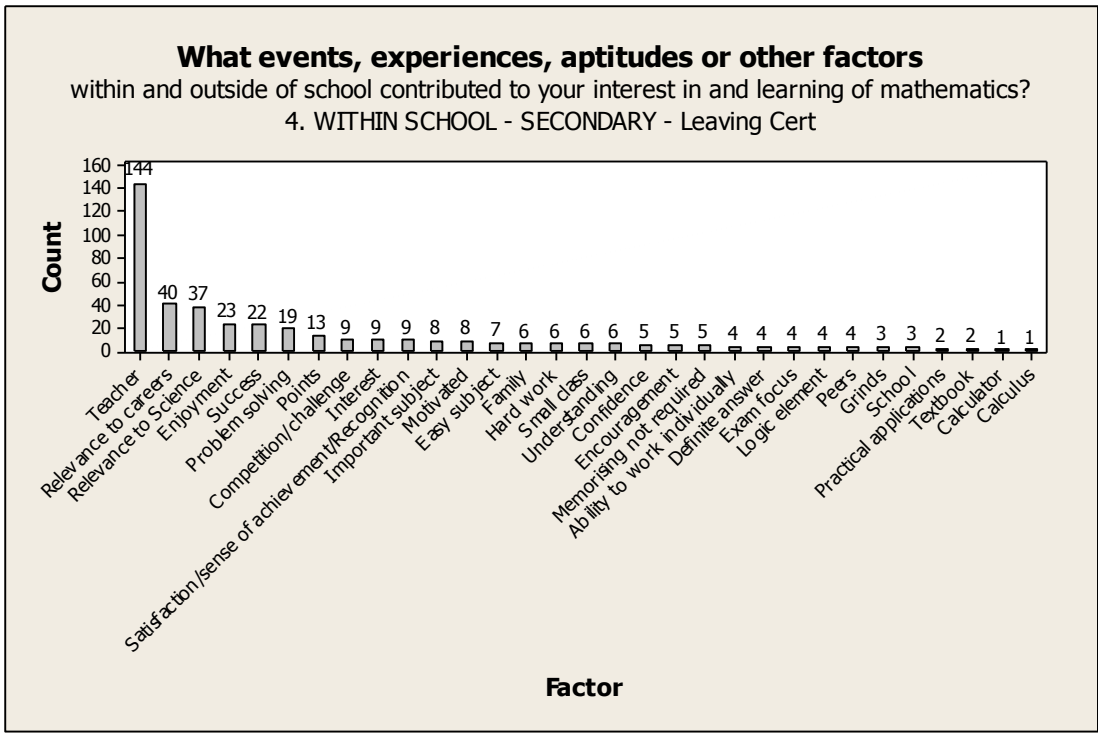


Figure A4-38: Factors within secondary school (Leaving Certificate) contributing to mathematics learning.

A4.6.2.5 Outside Primary School

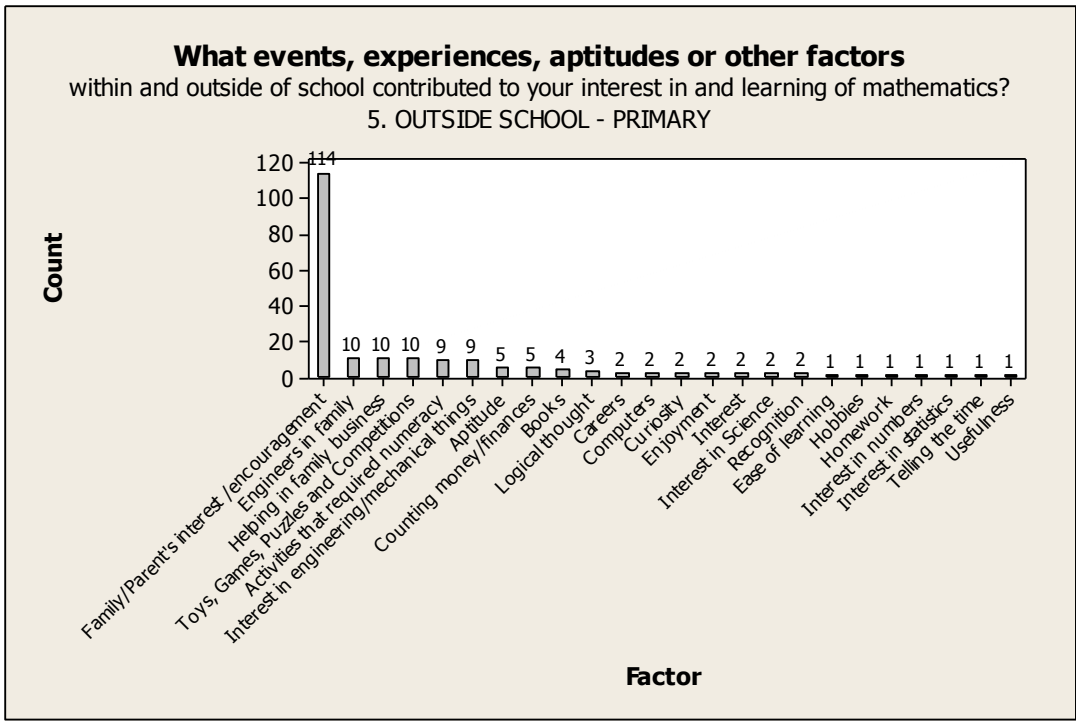


Figure A4-39: Factors outside primary school contributing to mathematics learning.

A4.6.2.6 Outside Secondary School - Years 1 & 2

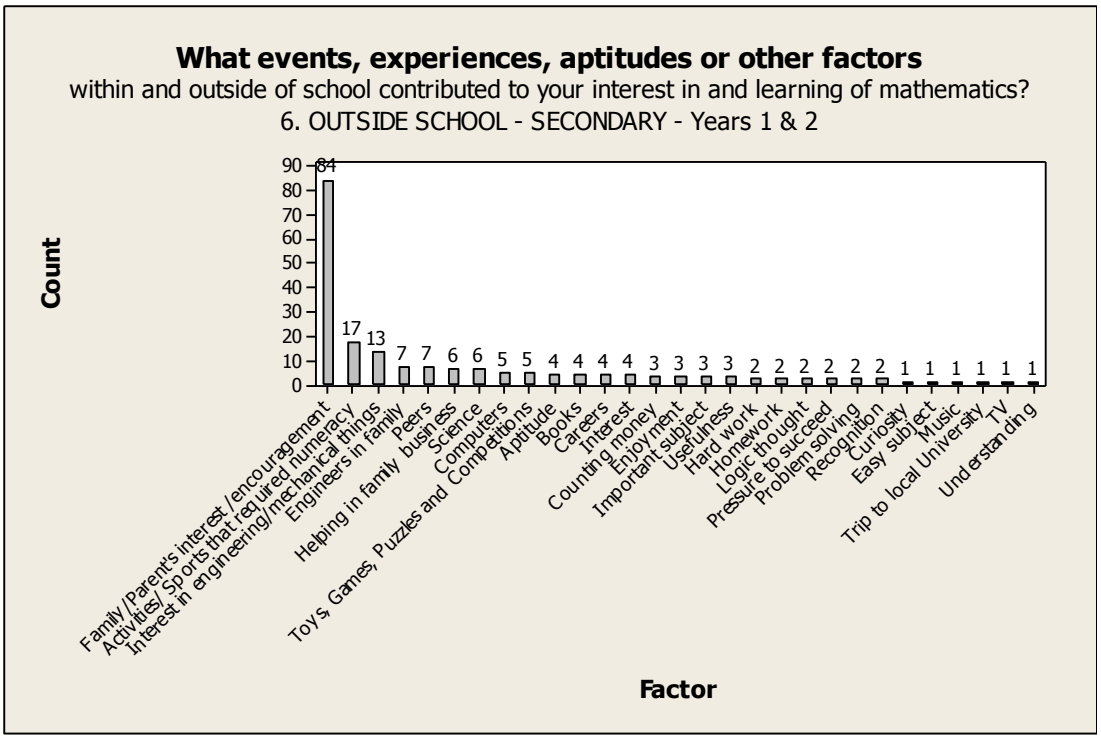


Figure A4-40: Factors outside secondary school (years 1 & 2) contributing to mathematics learning.

A4.6.2.7 Outside Secondary School - Junior Certificate

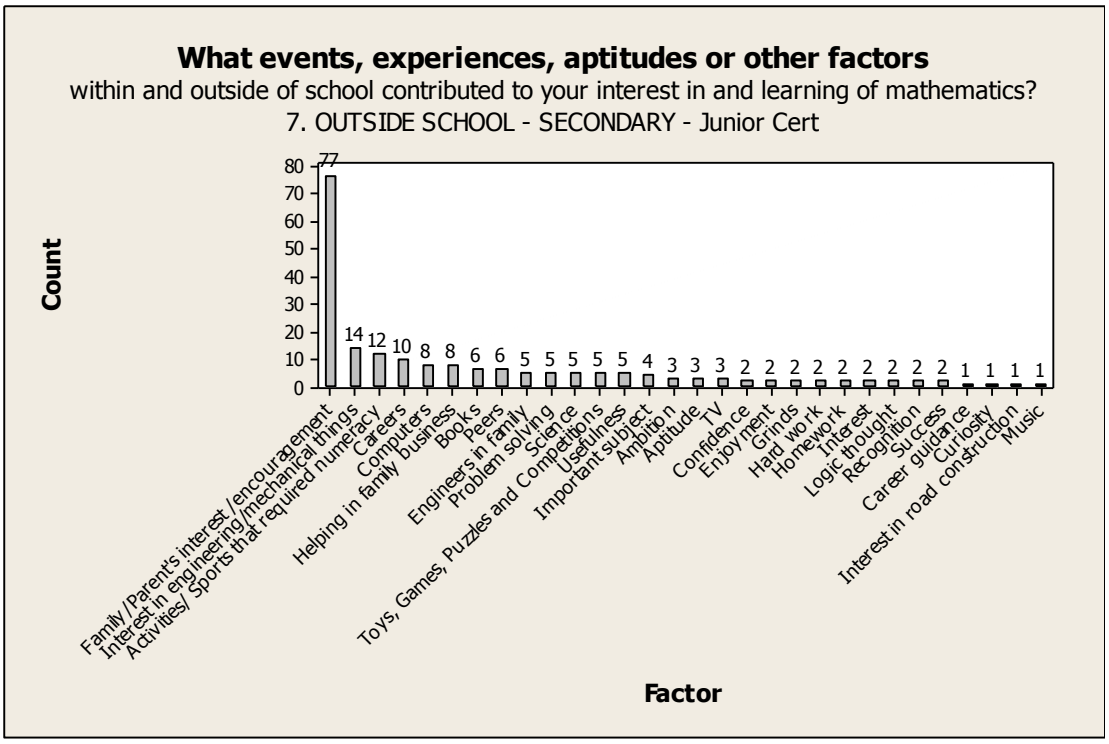


Figure A4-41: Factors outside secondary school (Junior Certificate) contributing to mathematics learning.

A4.6.2.8 Outside Secondary School - Leaving Certificate

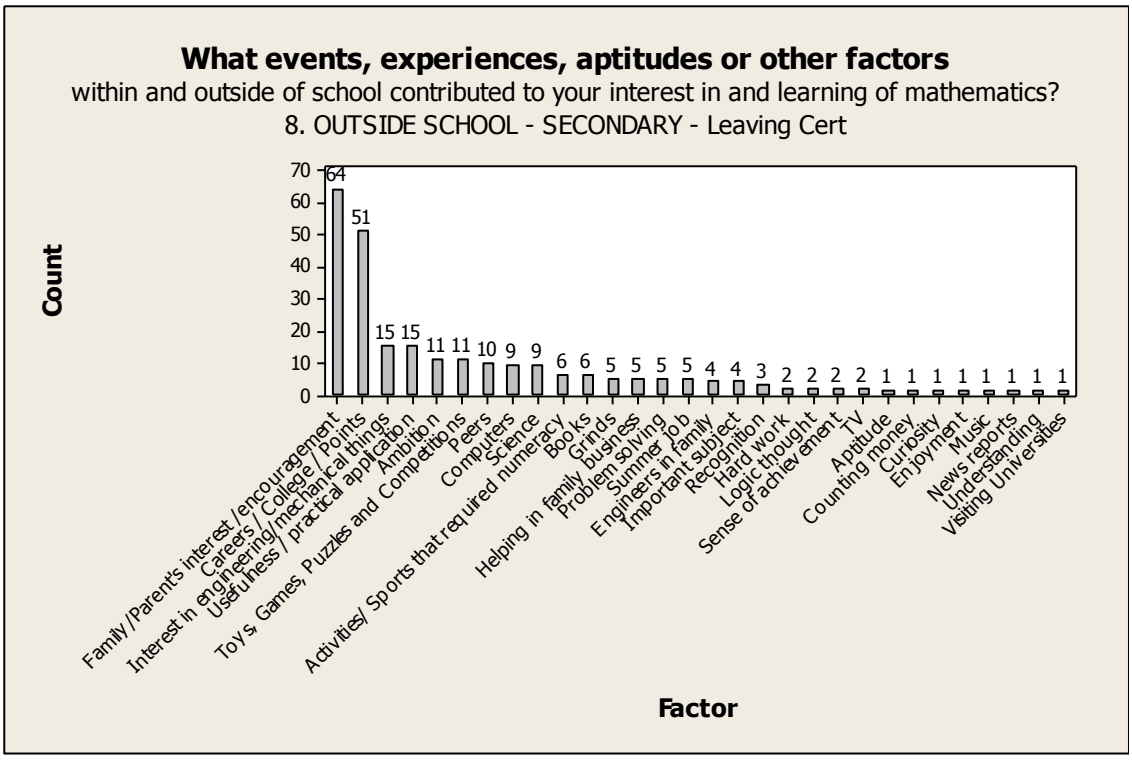


Figure A4-42: Factors outside secondary school (Leaving Certificate) contributing to mathematics learning.

A4.7 To what degree did your feelings about mathematics impact your choice of engineering as a career?

Sample size: 364

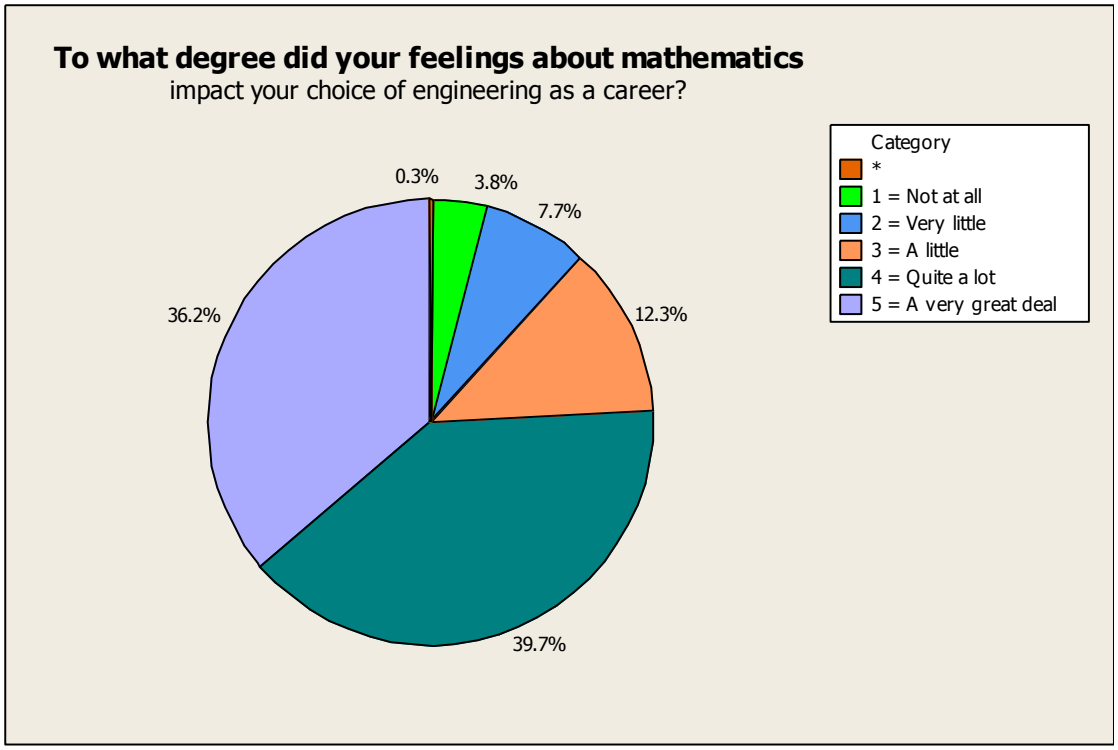


Figure A4-43: Degree that feelings about mathematics impacted engineers' career choice.

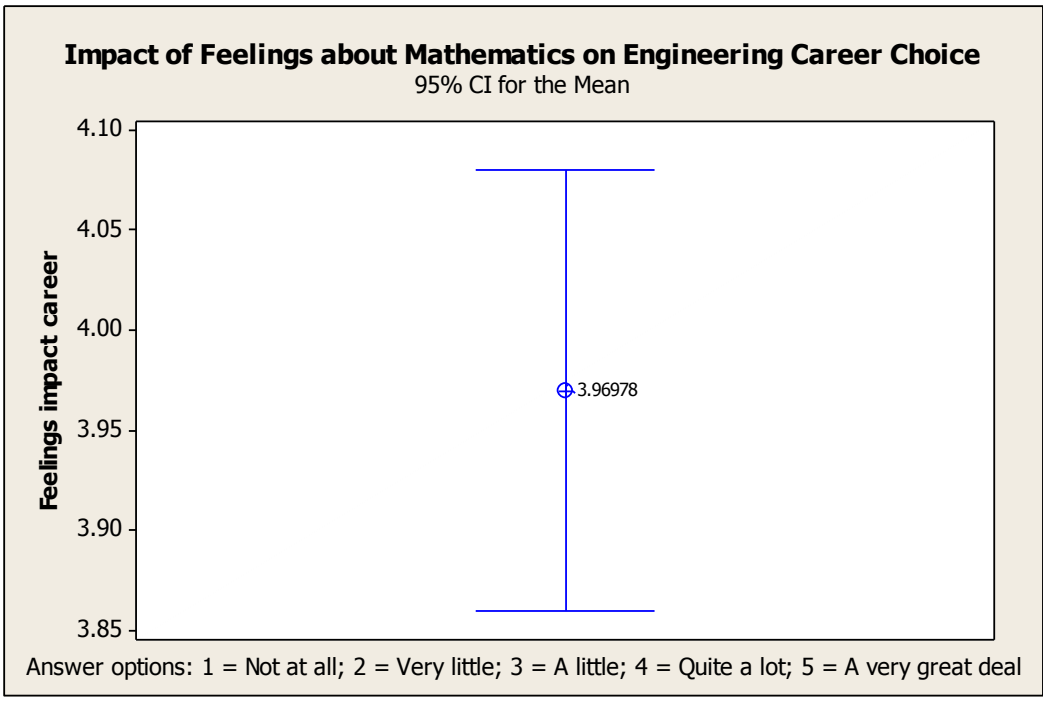


Figure A4-44: Confidence interval: Mean value of degree that feelings about mathematics impacted engineers' career choice.

Paired T-Test and CI: Feelings impact career, Enjoy maths

```
Paired T for Feelings impact career - Enjoy maths

                          N     Mean   StDev  SE Mean
Feelings impact career  362   3.9696  1.0692   0.0562
Enjoy maths             362   4.1077  0.8693   0.0457
Difference              362  -0.1381  0.9372   0.0493


95% CI for mean difference: (-0.2350, -0.0413)
T-Test of mean difference = 0 (vs not = 0): T-Value = -2.80  P-Value = 0.005
```

Table A4-29: Paired t-test analysis: Comparison of degree engineers' feelings about mathematics impact choice of engineering as a career and degree engineers enjoyed school mathematics.

A4.8 How, in your view, could young people's affective engagement (e.g. enjoyment) with mathematics be improved?

Sample size: 364

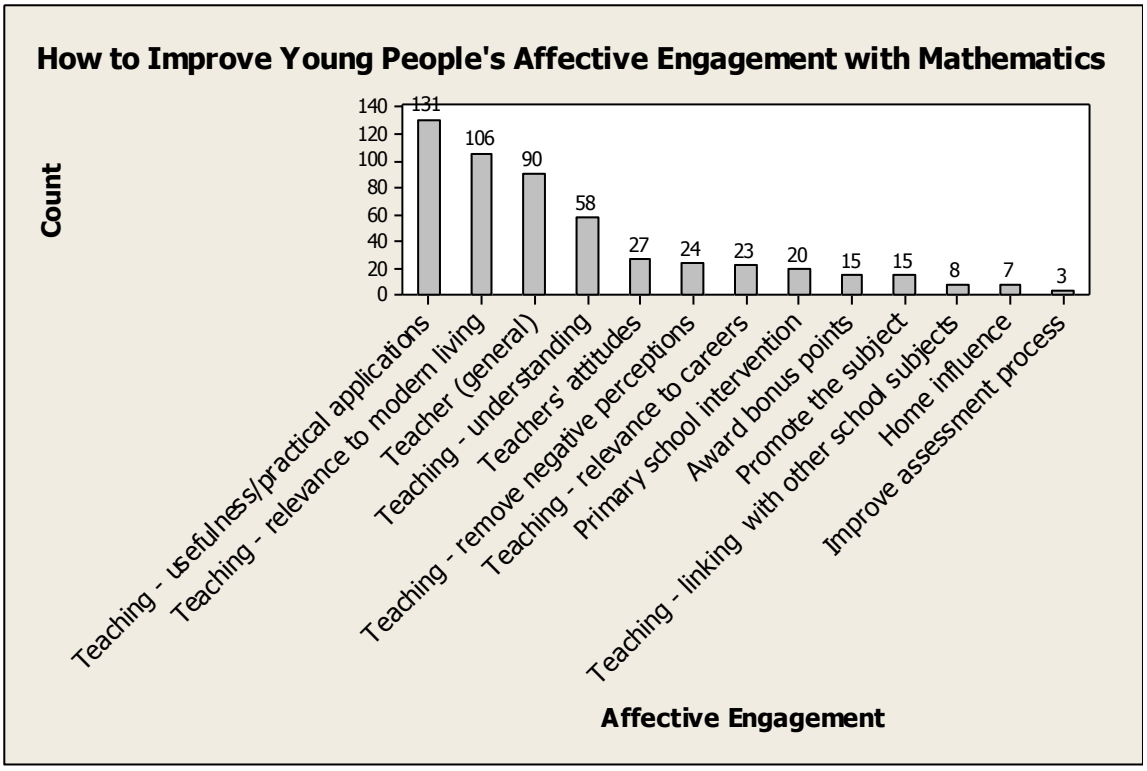


Figure A4-45: How to improve young people's affective engagement with mathematics.

Examples of engineers' responses to an open question, how young people's affective engagement with mathematics could be improved, included:

- Teaching - usefulness/practical applications (24.86%): "show students worked examples of usefulness and applicability to real life situations"; "I enjoyed maths more at college because I could see its uses in other disciplines"; "I feel that pupils wonder why do I need to know this"; "school work should involve activities that mean something to the students and not just be a series of problem solutions that they neither understand nor see a use for"; "I disliked pure maths, applied maths was very interesting"; "calculus seems useless until you see it used in fluids and thermodynamics, statistics likewise is used extensively in both engineering and finance disciplines but from memory seemed quite obtuse in secondary school"; and "look at industry and design, figure out what maths is used and develop a curriculum around these topics".
- Teaching - relevance to modern living (20.11%): "make the curriculum more relevant to modern living"; "engage with the recent achievements that maths has

produced"; "maths education needs to be more sociable, associate it with visual arts, new communications, etc."; "young students must see and experience where maths fits into their own everyday lives"; "mathematics is generally taught as an abstract subject and not really identified with the practicalities of modern life or everyday experience"; and "review the syllabus to make maths more relevant to modern society ".

- Teacher (general) (17.08%): "teaching is the biggest issue facing maths"; "I put my affective engagement with maths mainly down to the teacher"; "To me, it is all down to the teacher"; "If you don't like the teacher you won't like maths"; "I had an excellent maths teacher, he was approachable, and I guess made maths as fun as it could possibly be"; "a good teacher is paramount to the success and engagement of the student"; "mathematics is a difficult subject for the vast majority of people and teachers must have the skills, enthusiasm and ability necessary to teach the subject"; "engineers and persons with high mathematical achievements must be encouraged to look at teaching second level maths"; employ teachers that enjoy maths and who can teach"; "the teacher needs to have a sound grasp of maths, and a genuine interest in the subject, in order to fully impart the theory of maths to students and to give students the chance to learn maths from someone who is confident in their knowledge of the subject"; "some excellent maths teachers developed in me a love of maths"; "my excellent teacher"; and "much of the problem sadly lies with teachers and teaching methods and particularly those teaching maths without a major in maths at University".
- Teaching - understanding (11.06%): "the biggest difficulty with maths is the ability of students to visualize the concept"; "a strong reason for students not enjoying maths is that they don't understand it"; "I am of the strong view that considerably greater effort needs to go into maths at primary level so that pupils going into second level understand the basics"; "some students can be very intimidated by higher maths, teachers must make it easier to understand and thus encourage students to take higher maths"; "better instruction in the classroom by people who can relate the subject matter to reality, and speak in a language that can be understood by students"; "my leaving certificate maths teacher (arts student) did not understand what she was teaching"; "less emphasis on mechanical routines and formula based solutions and more emphasis on understanding and logical arguments"; "get teachers who actually understand maths"; "I dropped out of honours maths in my leaving cert year due to a lack of understanding"; "maths is a subject where students quickly get left behind when they do not understand the principals"; "we had a very interesting teacher who took time to get us to understand the reasons for approaching problems in a particular way rather than force us to learn by rote"; and " some brilliant mathematicians I have known have been very poor teachers, frequently unable to understand why a student could not grasp the concept being taught".
- Teachers' attitudes (5.12%): "teachers' interest in maths and their attitude to it decides a student's interest and attitude"; "in my experience the personality of mathematics teachers has always been quite dour and boring and especially those who dress accordingly in knitted cardigans or bow ties"; "my maths teacher would have preferred that we all did pass maths, she continuously tried to persuade us

that honours maths was too difficult"; "need a motivated and enthusiastic teacher"; "teachers with a genuine love of the maths"; "teachers who pass their enthusiasm onto the students"; "fear of maths stems from teachers attitudes"; and "the key in my view is having an enthusiastic teacher at second level that brings the subject alive and brings students along with him/her".

- Teaching – remove negative perceptions (4.55%): "there is a perception amongst young people (and accepted by teachers) that higher level maths is difficult, other higher level subjects are considered 'easier' and so pass maths is often used as a 7th subject"; "teacher should work to remove the stigma about the difficulty of higher level maths"; "teachers present higher level maths as very time consuming and that is a big 'turn-off' for students in leaving certificate"; "many students are intimidated by the perceived difficulty of higher maths, teachers should dispel this myth"; "only teachers can remove the 'fear factor'"; " there appears to be a disproportionate amount of fear among secondary level students about the difficulty of maths"; and "teachers have done little to change the negative image of maths".
- Teaching - relevance to careers (4.36%): "I believe that work and career exposure showing the massive opportunities for mathematically inclined individuals would surely encourage a higher participation rate"; "the correlation between "hard sums" and elevated opportunity in business and life, is well recognised in industry and commerce, but is inadequately communicated to high school students"; "if teachers showed the link between maths and jobs"; and "teachers should modernise their teaching to provide an appreciation for students on the usage of maths in the working environment".
- Primary school intervention (3.79%): "the problem with mathematics starts with our primary school system"; "I see from my own children that much more emphasis is placed on reading, writing and art compared to maths in primary school"; "I developed my interest for higher level maths in the primary school"; "I got a good start in primary school"; " instil a greater interest in maths from a very early stage by making it fun to do in primary school"; "improve maths education at primary level"; and "if a primary school child dismisses maths (or rather, themselves as able mathematicians) it's difficult to re-engage them".

A4.9 Would You Like To Make Any Additional Comments?

Sample size: 171

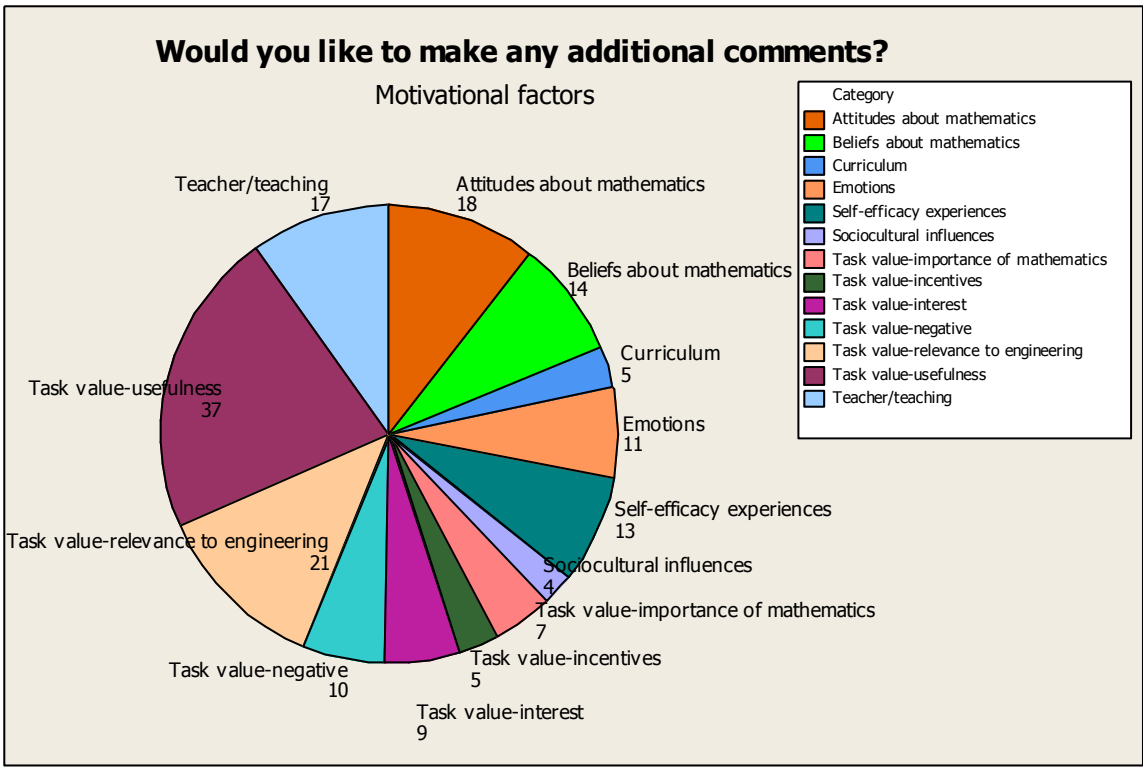


Figure A4-46: Engineers' additional comments.

A sample of the engineers additional comments include:

- Task value - usefulness/practical applications:

  "it's important that teachers are able to explain where a branch of maths would ultimately be used"; "in every period of my career the structured thinking that mathematics teaches served me well"; "maths instilled in me a train of thought that allows me to analyse situations thoroughly"; "ability in mathematics demonstrates capability of rational thought that universities and employers consider essential in a wide range of jobs"; "knowing maths at engineering level makes finance very easy"; "my maths education encourages me to think, it is a great benefit in general management"; "I strongly believe that a sound basis in mathematics is essential for all aspects of life, regardless of professions, monthly household budgets, tax returns, ability to save, risk analysis, decision making etc. If more people had stronger skills in the area, I believe that social / economic problems would reduce".

- Task value - relevance to engineering:

"maths is fundamental to engineering"; "I could not envisage working in engineering without a good grounding and interest in mathematics"; "statistics, risk theory, logic and similar are all necessary in engineering"; "a thorough knowledge of maths is vital to ensure correct safe engineering designs are actual carried out with due diligence"; "maths gave me that practical, logical approach on which engineering and project management rely on"; "there is hardly a day that goes by that I don't use my secondary school maths. When it gets to the third level maths, I use them only occasionally, and as for pure maths, there are a few of my engineering colleagues who use them, but not very often"; and "maths may not be obviously used by engineers at all times but a mathematical ability is necessary to making crucial decisions".

- Task value – interest:

  "I believe that interest inspires mathematical ability and visa-versa"; "students should be encouraged from a very young age to take an interest in maths"; "it is important that maths is taught in an interesting way to keep young people interested"; "my son struggling with higher maths until we employed a grind teacher who was able to explain the subject and make it more interesting"; " I was an average pupil in secondary school however it wasn't until university that maths interested me and then I excelled in maths"; " with modern internet facilities and computer resources there are ample opportunities for students to be taught maths in a way that interests them".

- Task value-importance of mathematics:

  "I cannot over emphasise the importance of higher mathematics"; "there is a need for an environment where maths is valued"; "maths is important in a society like Ireland where there are many difficulties": "in Ireland there is a misguided acceptance in society that mathematics is not important"; and "studying mathematics was my best investment".

- Task value- incentives:

  "incentives, such as higher points, for maths would, in my view, bring a greater number of students back to studying maths again"; "humour, practical participation and competition with intrinsic and extrinsic rewards are the key ways to improve mathematics"; "some students need to visually see the problem, solution, benefits and rewards of mathematics"; and "while maths is quite enjoyable, there is need to link excellence in maths to possible rewards in life".

- Task value-negative:

  "I really have done little with the higher maths I studied in college since I left a big consultants practice where I did a lot of design work";

" In an engineering career a very high level maths is only required by the few who go into computer modelling and research"; "advanced maths such as third order integration and Laplace transforms etc. are of little benefit to 99% of engineers"; "drop the requirement for honours maths, it is not necessary, for engineering" and "engineering is not so much about mathematics; it's about communication and creative thinking" ; "since graduating I have not used any of the maths taught in college, nor could I remember any of it".

- Attitudes about mathematics:

  "I found maths boring and difficult"; "maths was time-consuming at school"; "for me attitude is the biggest single factor affecting students' maths achievements"; "the impression that people had of higher maths being difficult impacted on my enjoyment and performance at leaving certificate"; "my classmates' attitude towards me was very negative when I performed well at maths in secondary school"; and "I got away with murder in school because I was good at maths".

- Beliefs about mathematics:

  "If you have not developed a logically thinking brain/aptitude for mathematics by Junior Cert level it is already too late"; "there is a belief that it is cool to be poor at maths"; "when I was in school I was told that computer programming was all about maths, in fact it isn't"; "the perception that mathematics is overly difficult and time consuming at leaving cert is leading many schools and students to drop higher level mathematics in favour of subjects considered to be easier"; "my 12 year old son got the perception from school that math is hard and you have to be really smart to do well in it".

- Self- efficacy experiences:

  "I struggled with maths in primary school and I believed I was not good at maths"; "students often and wrongly lose confidence in their maths abilities in secondary school due to lack of primary school basics"; "the active involvement in practical application of engineering contributed to my increasing confidence in using mathematics as a tool"; "schooling gave me the knowledge that mathematical tools exist and the confidence to go try apply them"; "I am not comfortable with statistics beyond the very basic level"; "I would enjoy using more maths in my work however I have lost the ability over the years"; and "I believe that I have a natural ability to understand mathematics".

- Emotions:

  "there is a fundamental flaw in Irish education (beginning even in primary school), where students are allowed to develop a fear or discomfort with maths"; "with maths there is always the fear of mistakes"; "too many teachers impart a fear or dislike of maths";

"biggest impact for kids developing a love of maths is a good teacher"; "I believe the teaching approach has a very significant impact on students feelings surrounding maths"; and "I love the beauty of numbers".

- Curriculum:

  "the junior and leaving cert curricula are frighteningly broad"; "the leaving cert maths course has been embarrassingly dumbed down"; "do not remove calculus from the higher level mathematics course"; "an appropriate syllabus approach needs to be developed at secondary and third level that reflects the realities of our needs"; "the level of mathematics studied at college was ridiculous, it was 100% theoretical and had no connection with real life".

- Sociocultural influences:

  "If you don't have a good teacher or you can't ask for help at home, you probably will find it more difficult to succeed in maths"; "it was a friend that helped me restore my love of maths"; "it is important that children have the necessary support to do home projects on maths and related topics"; "I was influenced by my family who have been designers, builders, engineers and teachers of various types, for the past five generations"; and "a good standard of maths was almost a rule in my family".

- Teacher/teaching:

  "maths needs to be taught by persons who fully understand the subject and have a significant qualification and training in maths"; " teaching by rote doesn't work with maths"; "it is critical that those teaching maths have a love for it, even at primary level"; "maths teaching at primary level is critical and an aptitude for teaching maths should be developed in teacher training"; "it's particularly important to have exceptional teachers for maths as it is viewed as the most boring subject by many": "I think a lot of maths teachers in secondary school are bad and don't fully understand maths themselves" and "the standard of maths in schools will improve only if the quality and interest of the teachers improves".

APPENDIX 5: INTERVIEW PARTICIPANTS' EMAIL

A copy of the email sent to a sample of practising Chartered Engineers requesting their participation in the interview study is included in this appendix.

Dear ……..

I'm following up on Engineers Ireland's and NUI Maynooth's survey on the "role of mathematics in engineering practice" which you so kindly participated in. Thank you for doing so. The analysis of the survey is almost complete. In order to give meaning to the findings, there is a need to conduct a small number of interviews, which will be a further exploration of the role of mathematics in engineering practice and the role of mathematics in the formation of engineers. Ideally, these interviews need to cover a range of engineering disciplines and include engineers working in diverse roles. Would you be available to participate in such an interview? The interviews will last no longer than 2 hours, your name will not be associated with any of the findings and I can meet you at a time and place that suits you. I realise that this is a big ask but it also an opportunity to contribute to the engineering profession and to the education of engineers. I would really appreciate if you can be available for one of these interviews. Please feel free to call me to discuss.

Kind regards,

Eileen Goold

086-1798175

Email to Interview Participants.

APPENDIX 6: INTERVIEW PROTOCOL

INTERVIEW PROTOCOL

The Role of Mathematics in Engineering Practice and in the Formation of Engineers

INTRODUCTION

- Time allocation 2 hours
- Tape recording
- Anonymity
- Build rapport

PURPOSE OF STUDY [2 mins]

The purpose of this study is to:

1. Explore the role of mathematics in engineering practice e.g. what mathematics used in your work?
2. Explore the relationship between students' experiences with school mathematics and choice of engineering career. e.g. what were your feelings about school mathematics? Why did you choose to be an engineer?
3. Explore survey findings

USE OF RESULTS

It is anticipated that findings from this study will relate to students' declining interest in engineering careers and the value of mathematics in engineering practice and will also inform prospective engineering students, mathematics and engineering educators, the engineering profession and society. Findings will be presented in the researcher's PhD thesis and will also be reported in research publications and conference proceedings.

BACKGROUND [1 min]

1. Gender?
2. Chartered Egineer? (level 8 + 4 years relevant experience)
3. Discipline?
4. Role?
5. Company type & size?
6. Current position?
7. Leaving Certificate mathematics level?

INTERVIEW: 2 main questions

1. **What is the role of mathematics in engineering practice? (53 minutes)**
2. **Is there a relationship between students' experiences with school mathematics and their choice of engineering as a career? (34 minutes)**
3. **Additional comments (30 minutes)**

QUESTION 1: What is the role of mathematics in engineering practice?

1. **Most engineers have higher level Leaving Certificate mathematics grades, in your view, is this necessary for engineering practice? Why do you say this?**

[2 mins]

2. **Do you agree that you could perform satisfactorily in your current job without higher level Leaving Certificate mathematics?**

[3 mins]

Yes? No? How would you rate your response? Why?

(Response options: 1 = Strongly agree; 2 = Agree; 3 = Uncertain; 4 = Disagree; 5 = Strongly disagree)

Why do you say that?

In your view, why do you think 32% of engineers agree? 58% disagree?

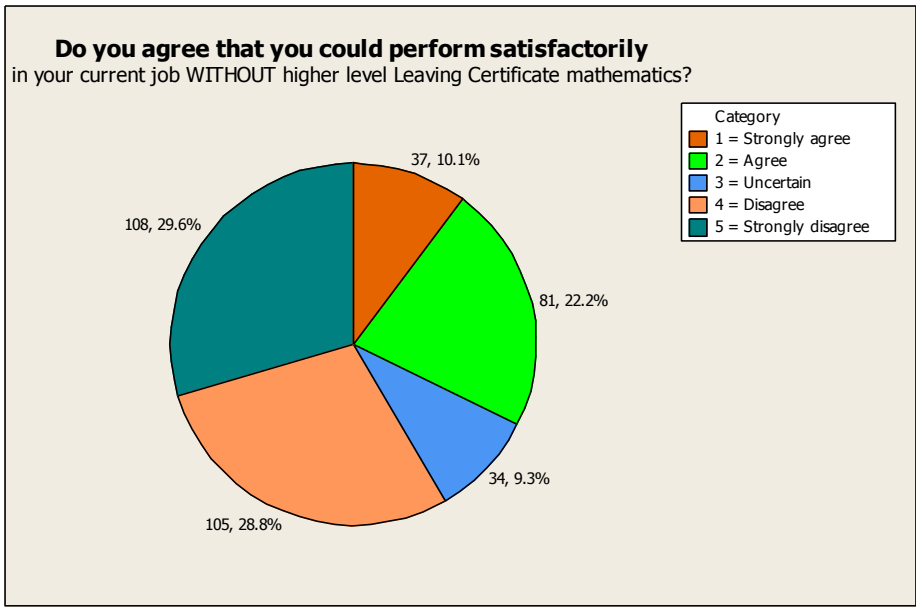


Figure A6-1.

3. *Curriculum mathematics usage* [15 mins]

Explanation of Domain, Academic Level and Usage Type as measured in the survey

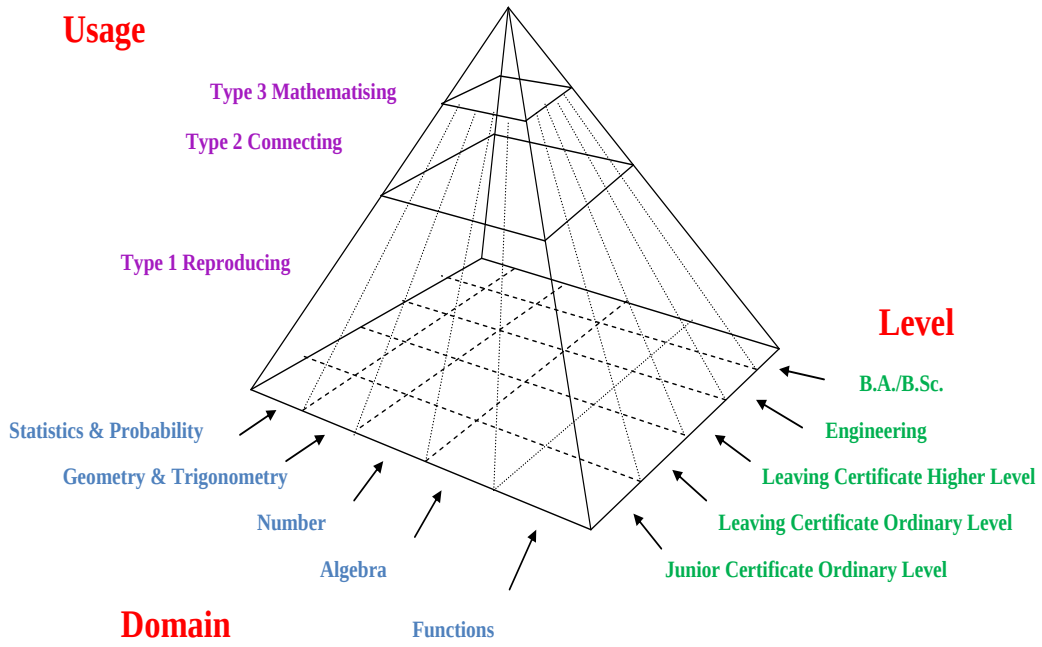


Figure A6-2.

With reference to the above pyramid, what mathematics have you used in your work in the last 6 months? Can you give examples of this usage?

With reference to the above pyramid, how would you rate your usage of the following?

(Response options: 1 = Not at all; 2 = Very little; 3 = A little; 4 = Quite a lot; 5 = A very great deal)

All curriculum mathematics
D1 Statistics & Probability
D2 Geometry & Trigonometry
D3 Number
D4 Algebra
D5 Functions
A1 Junior secondary
A2 Intermediate secondary
A3 Senior secondary
A4 Engineering
B.A./ B.Sc.
T1 Reproducing
T2 Connecting
T3 Mathematising

Why do you think your work requires these levels of *curriculum mathematics* usage?

In your view, why do you think engineers responded as follows?

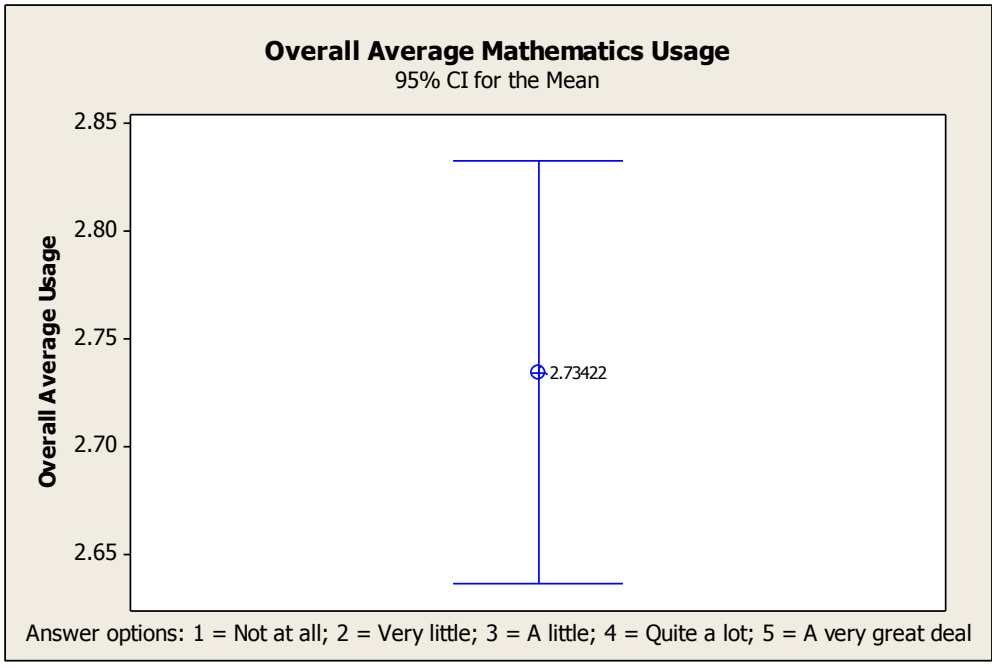


Figure A6- 3.

Interview Protocol Page 4 of 21

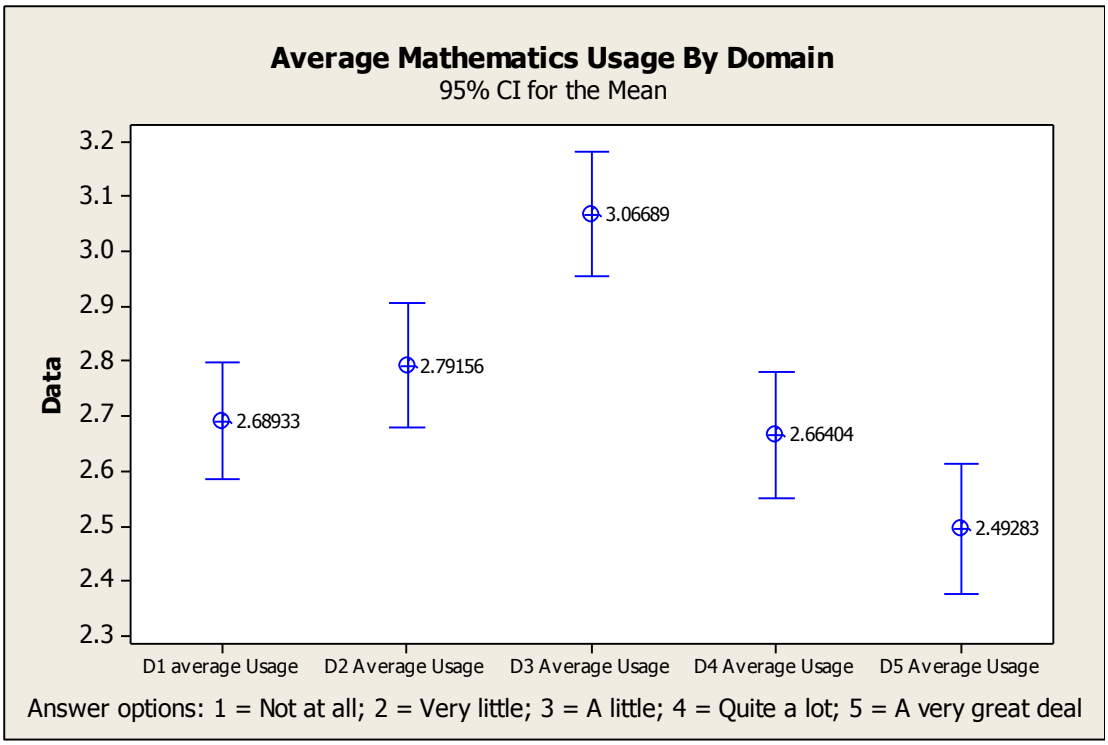


Figure A6-4.

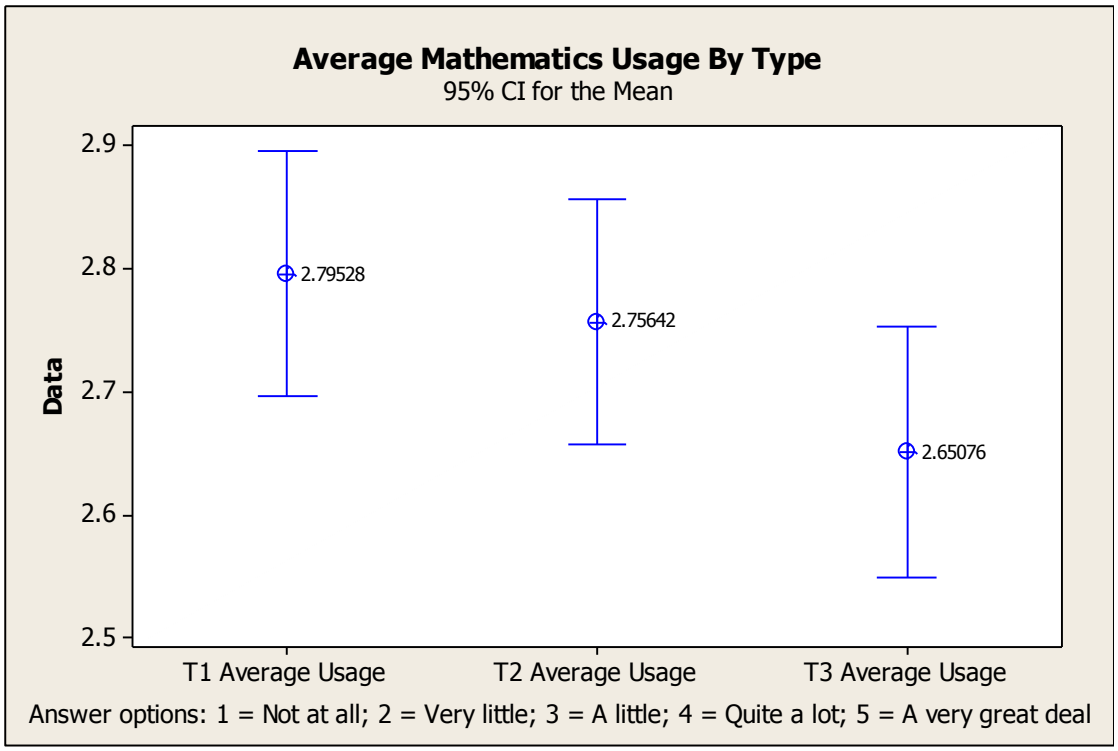


Figure A6-5.

Interview Protocol Page 5 of 21

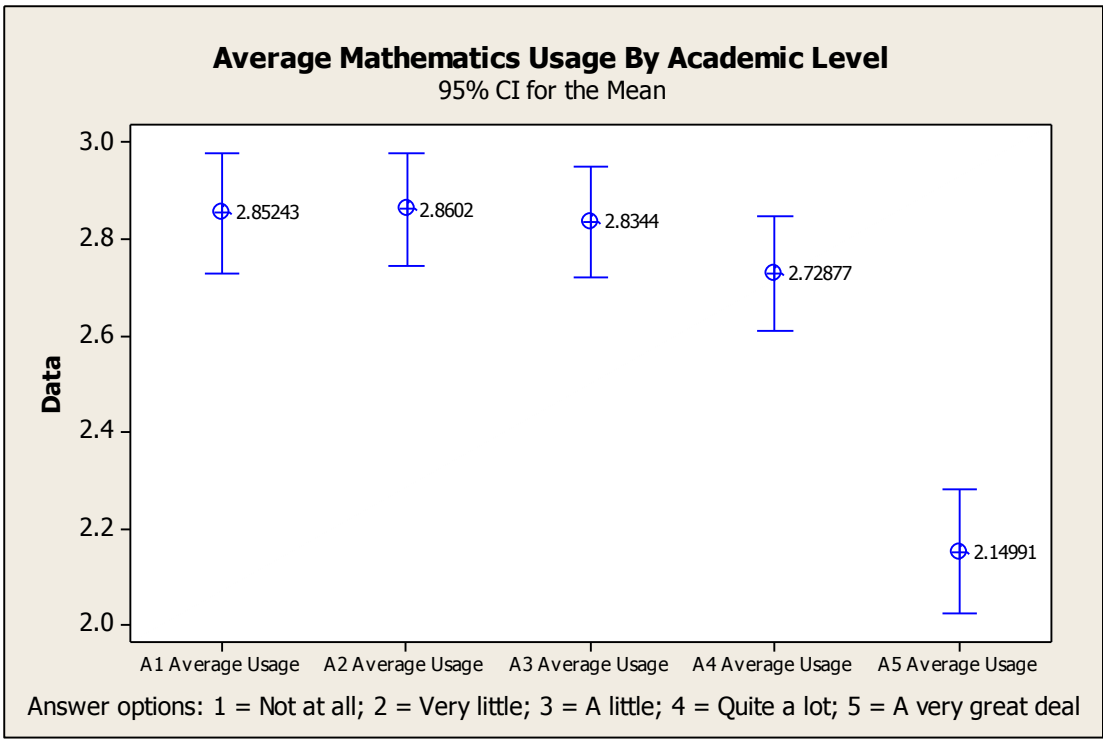


Figure A6-6.

Do you think that your engineering role, discipline and organisation impact on the *curriculum mathematics* you use in your work? Why?

Do you think that *curriculum mathematics* usage varies by engineering role, discipline and organisation generally? Why?

What other factors influence mathematics usage in engineering practice? Do you think that your mathematics usage is influenced by your work colleagues? Why?

4. *Thinking* usage [10 mins]

Explanation of *thinking* usage: *- Usage of mathematical modes of thinking learned and practised through mathematics, e.g. methods of analysis and reasoning, logical rigour, problem solving strategies (e.g. problem decomposition and solution re-integration), recognition of patterns, use of analogy, and a sense of what the solution to a problem might be.)*

To what degree did your *thinking* usage influence your approach to your work?

(Response options: 1 = Not at all; 2 = Very little; 3 = A little; 4 = Quite a lot; 5 = A very great deal)

1. **In the last 6 months?**
2. **Within 2 years of graduating**
3. **Within 3-5 years after graduating**
4. **Within 6 – 10 years after graduating**
5. **Greater than 10 years after graduating**

Why do you think your work requires these levels of *thinking* usage?

In your view, why do you think engineers responded as follows?

1. In the last 6 months
    a. 74.5% of responses are Quite a lot /A very great deal
    b. Mean response = 4.02
2. Within 2 years of graduating
    a. 79.8% of responses are Quite a lot /A very great deal
    b. Mean response = 4.19
3. Within 3-5 years after graduating
    a. 81.1% of responses are Quite a lot /A very great deal
    b. Mean response = 4.15
4. Within 6 – 10 years after graduating
    a. 82.6% of responses are Quite a lot /A very great deal
    b. Mean response = 4.03
5. Greater than 10 years after graduating
    a. 66.8% of responses are Quite a lot /A very great deal
    b. Mean response = 3.90

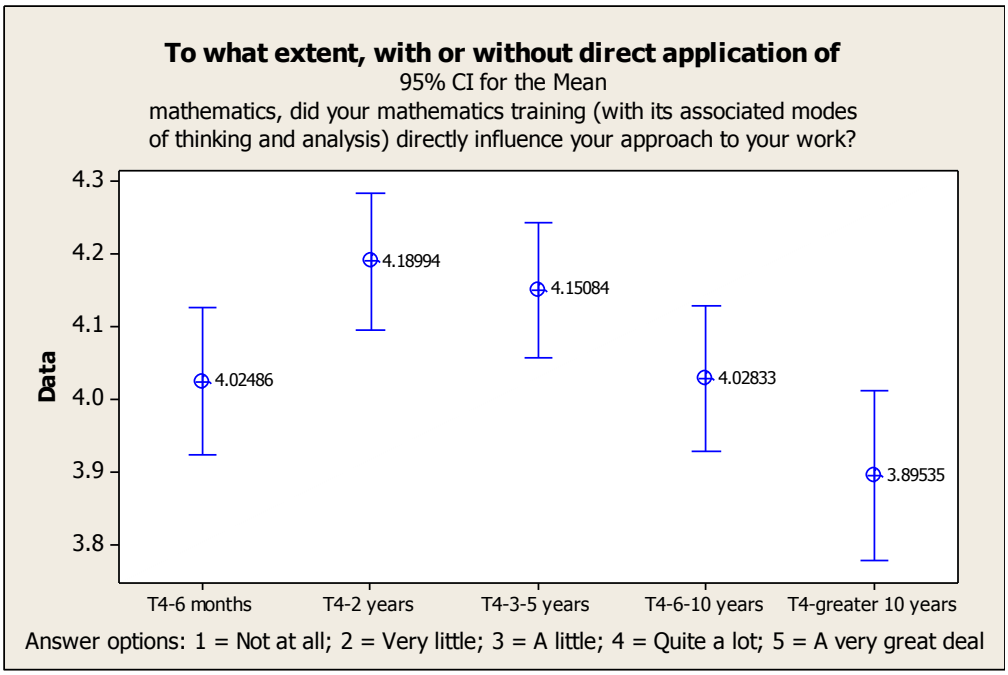


Figure A6-7.

5. Modes of *thinking* [10 mins]

What modes of *thinking*, resulting from your mathematics education, influence your work performance?

Can you list 3 your top three *thinking* modes?

Why are these important to your work?

In your view, why do you think engineers choose the following modes and in this order?

1. Problem solving strategies (155)
2. Logical thinking (154)
3. Critical analysis(42)
4. Modelling (42)
5. Decision making (37)
6. Accuracy/confirmation of solution (28)
7. Precision/use of rigour (27)
8. Organisational skills (27)
9. Reasoning (21)
10. Communication/teamwork/making arguments (19)
11. Confidence/motivation (18)
12. Numeracy (13)
13. Use of mathematical tools (4)

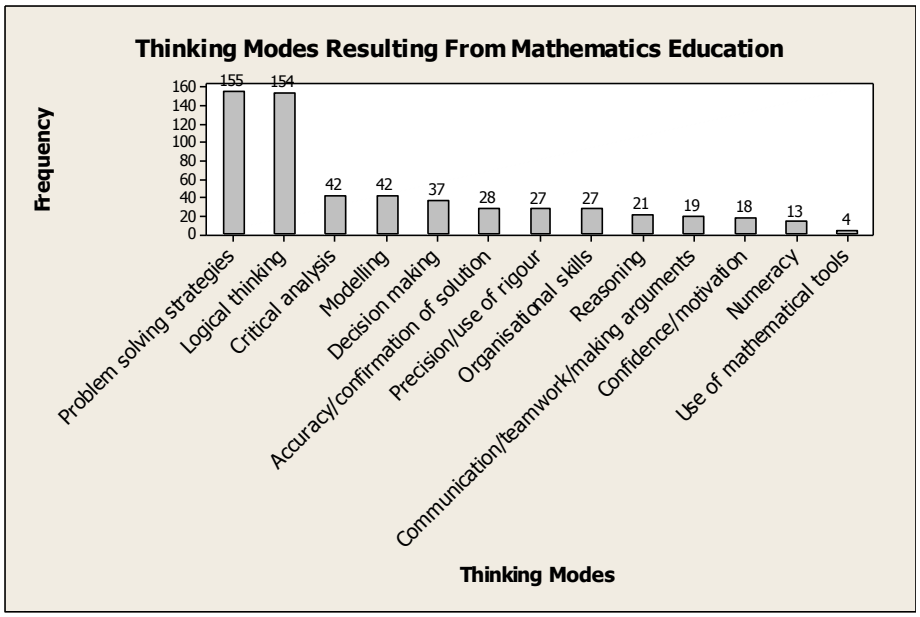


Figure A6-8.

6. *Curriculum mathematics* usage vs. *Thinking* usage [3 mins]

In your work, how would you compare your *curriculum mathematics* usage with your *thinking* usage?

Why do you think that mean values of engineers' *thinking* usage (3.90 – 4.19) are significantly greater than mean values of *curriculum mathematics* usage (2.15 – 3.07)?

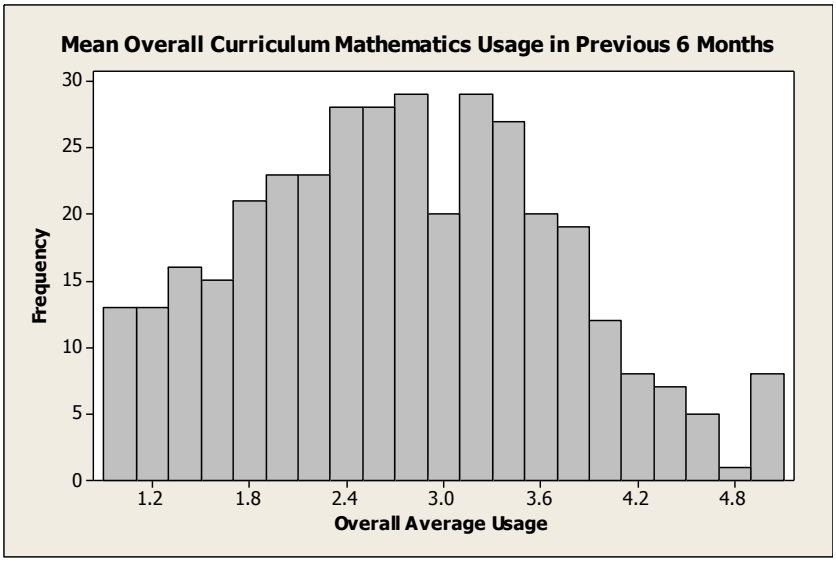


Figure A6-9.

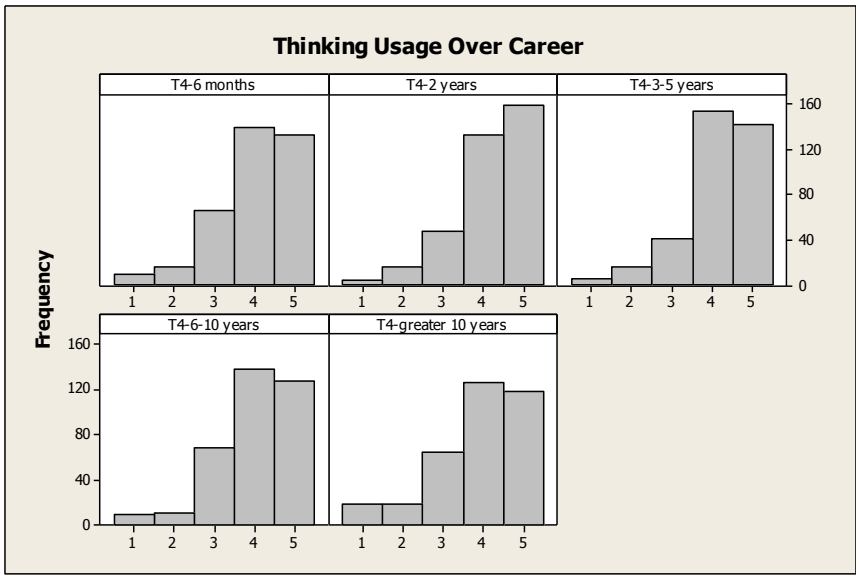


Figure A6-10.

7. *Engaging* usage [10 mins]

Explanation of *engaging* usage: - *Motivation and persistence to take or engage with a mathematical approach to a problem as a result of one's attitudes, beliefs, emotions, goals, sense of value, interest, confidence and self-efficacy.)*

With regard to your work in the last 6 months, to what degree …

(Response options: 1 = Not at all; 2 = Very little; 3 = A little; 4 = Quite a lot; 5 = A very great deal)

1. **Was a specifically mathematical approach necessary?** **Why was this?**
2. **Did you actively seek a mathematical approach?** **Why was this?**
3. **Did you enjoy using mathematics?** **Why was this?**
4. **Did you feel confident using mathematics?** **Why was this?**
5. **Did you have a negative experience when using mathematics?** **Why was this?**

In your view, why do you think engineers responded as follows?

1. Was a specifically mathematical approach necessary?
    a. 64.6% of responses are Quite a lot /A very great deal
    b. Mean response = 3.68
2. Did you actively seek a mathematical approach?
    a. 63.3% of responses are Quite a lot /A very great deal
    b. Mean response = 3.62

3. Did you enjoy using mathematics?
    a. 74.0% of responses are Quite a lot /A very great deal
    b. Mean response = 3.68
4. Did you feel confident using mathematics?
    a. 80.6% of responses are Quite a lot /A very great deal
    b. Mean response = 4.03
5. Did you have a negative experience when using mathematics?
    a. 77.8% of responses are Very little/ Not at all
    b. Mean response = 1.73

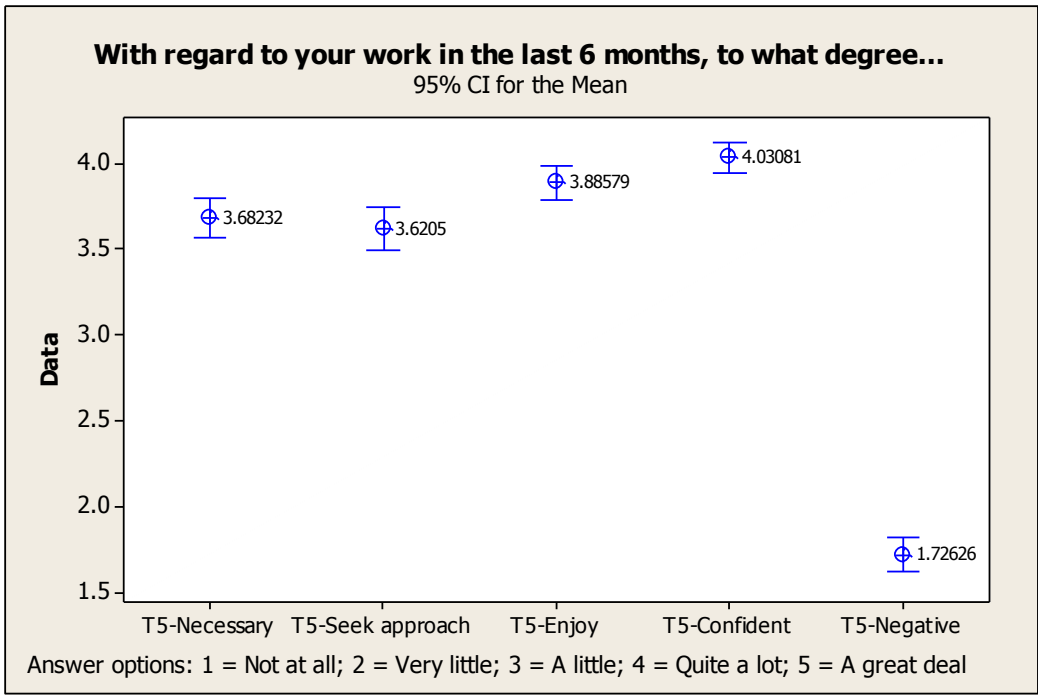


Figure A6-11.

QUESTION 2: Is there a relationship between engineers' experiences with school mathematics and their choice of engineering as a career?

A. Did you enjoy mathematics in secondary school? [3 mins]

Yes? No? How would you rate your response? Why?

(Response options: 1 = Not at all; 2 = Very little; 3 = A little; 4 = Quite a lot; 5 = A great deal)

In your view, why do you think that?

1. 80% engineers' responses are: Quite a lot/ A great deal?
2. Mean response = 4.11?

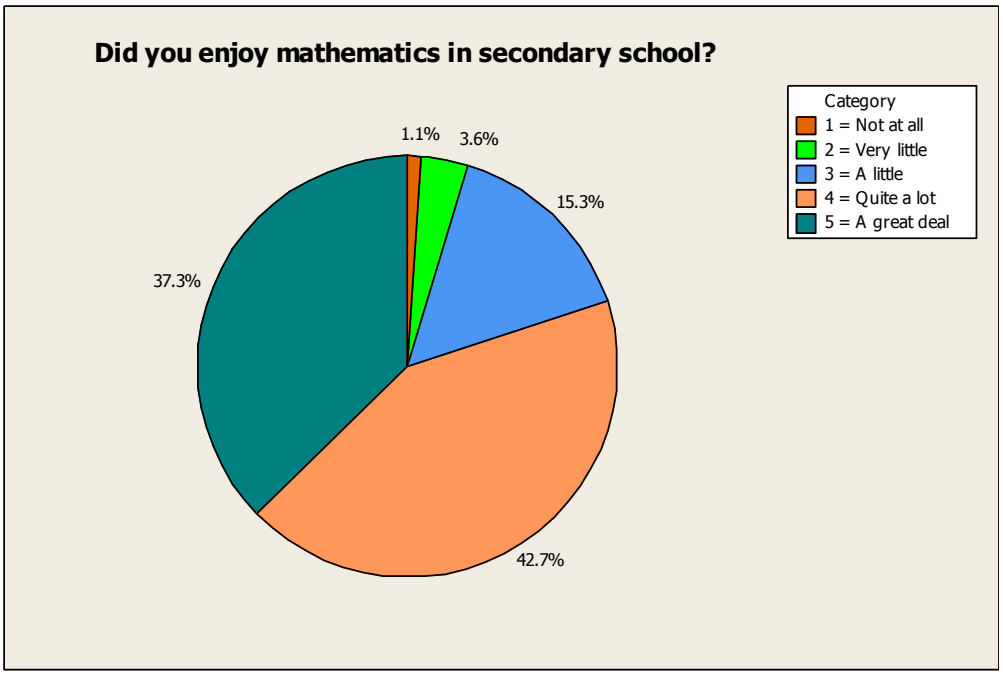


Figure A6-12.

Did you enjoy school mathematics more/or less than your school friends? What contributed to your enjoyment / lack of enjoyment of school mathematics? Why?

Did your school friends' influence your interest in mathematics? Why?

Were you confident doing school mathematics? Why?

B. Young people's affective engagement [5 mins]

Only a minority of students sit higher level Leaving Certificate mathematics and many of those subsequently choose not to stay with numerate studies. How, in your view, could young people's affective engagement (e.g. enjoyment) with mathematics be improved?

Why do you suggest this?

In your view why do you think engineers choose the following?

1. Usefulness/practical applications & examples (24.86%)
2. Relevance to modern living (20.11%)
3. Teacher/training (17.08%)
4. Understanding (11.06%)
5. Teachers' attitude (5.12%)
6. Negative perceptions (4.55%)
7. Relevance to careers (4.36%)
8. Primary school intervention (3.79%)

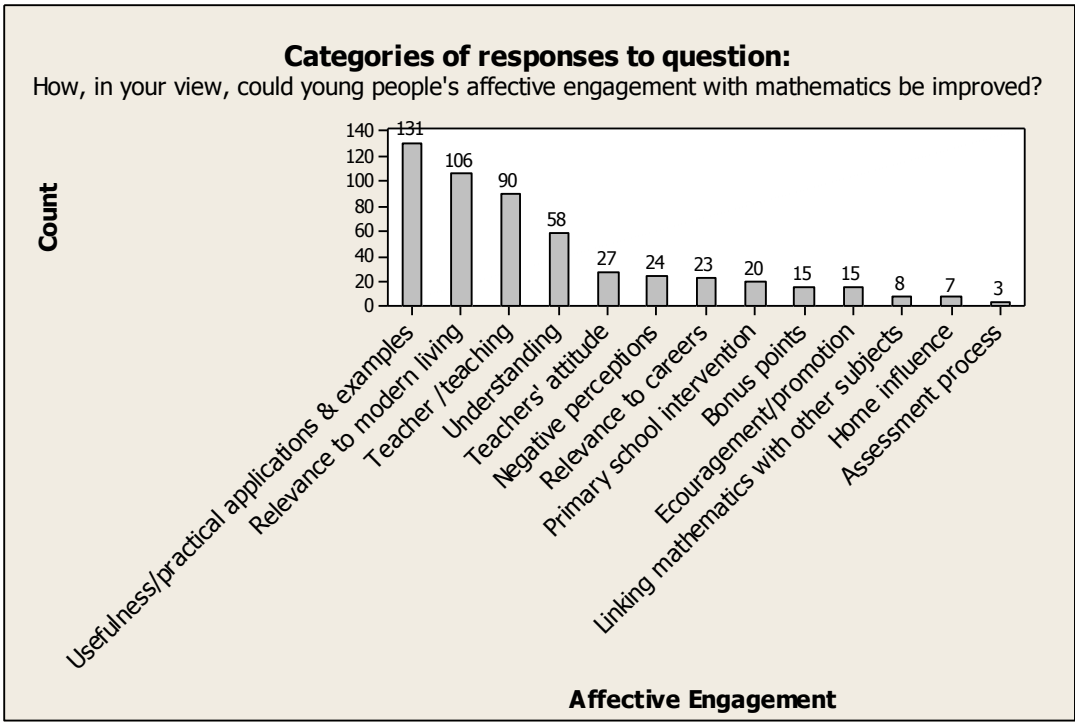


Figure A6-13.

C. Factors within or outside of school that contribute to interest in and learning of mathematics? [16 mins]

What events, experiences, aptitudes or other factors within or outside of school contributed to your interest in and learning of mathematics?

1. **Within primary school? How did these improve interest & learning?**

In your view, why do you think engineers choose the following modes?

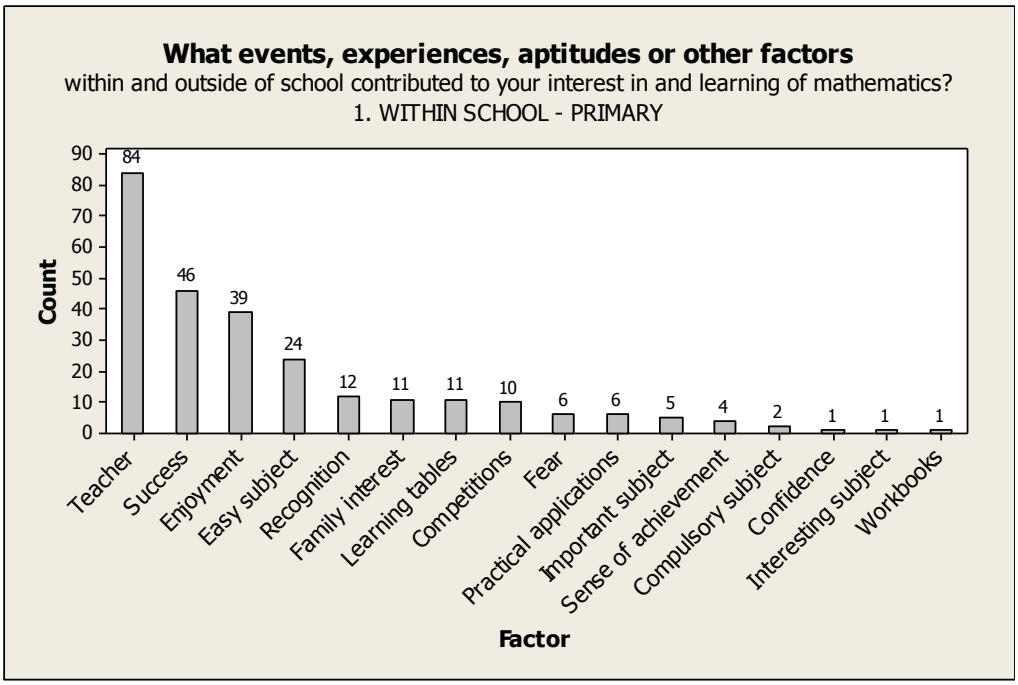


Figure A6-14.

2. **Within secondary school – years 1 & 2? How did these improve interest & learning?**

In your view, why do you think engineers choose the following modes?

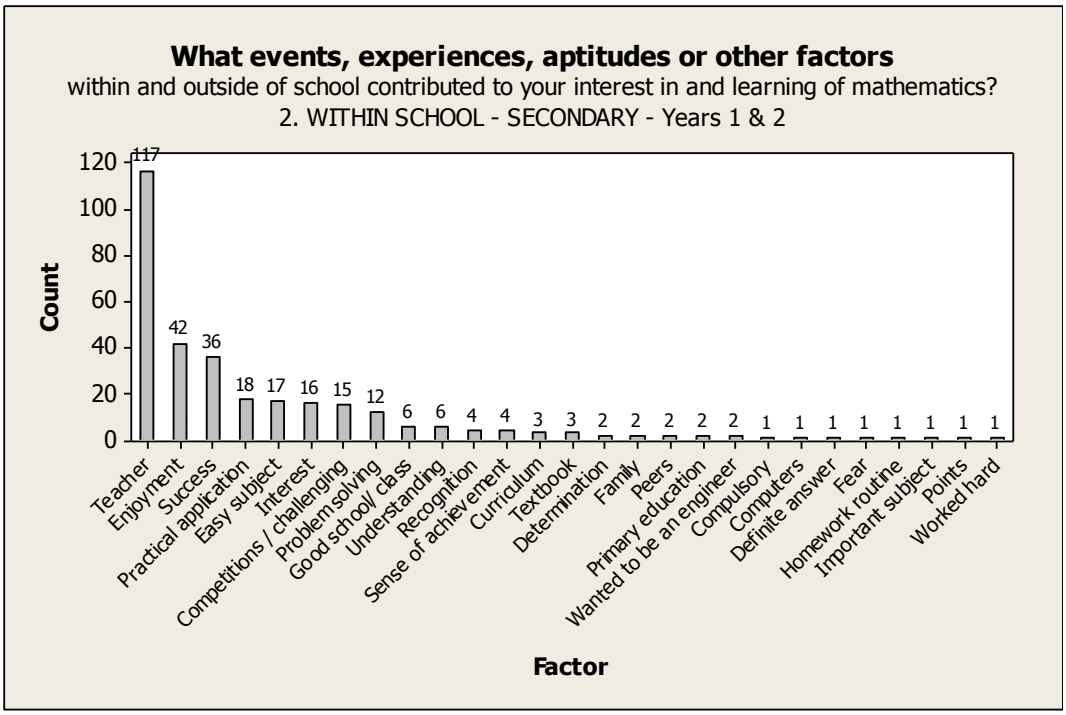


Figure A6-15.

3. Within secondary school – Junior Certificate? How did these improve interest & learning?

In your view, why do you think engineers choose the following modes?

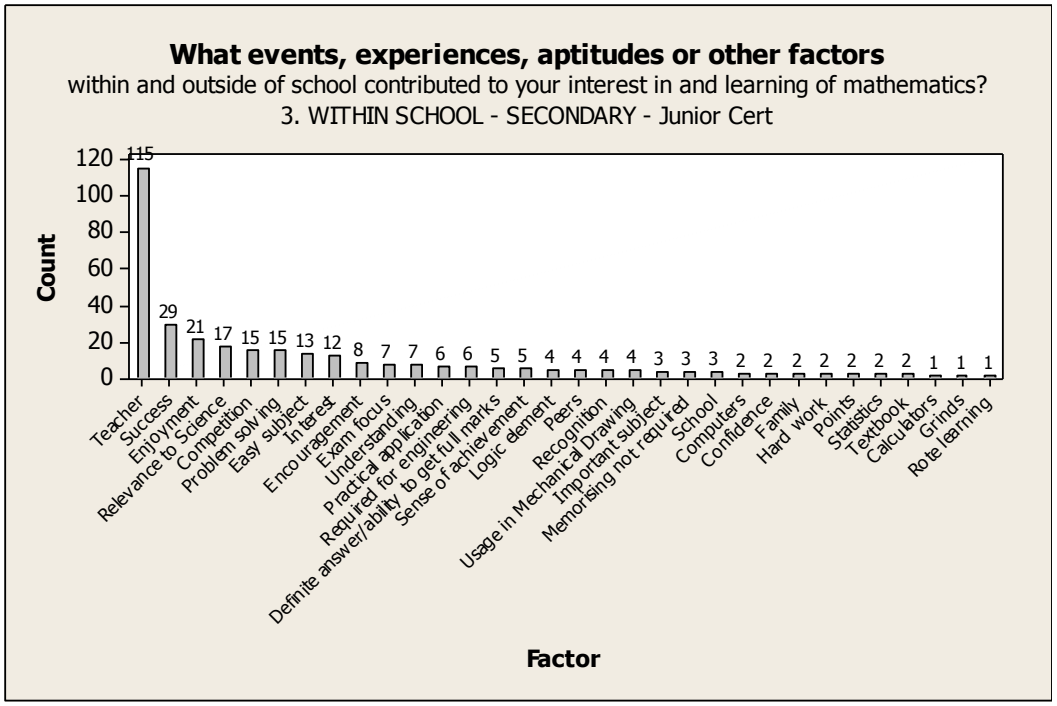


Figure A6-16.

4. **Within secondary – Leaving Certificate? How did these improve interest & learning?**

In your view, why do you think engineers choose the following modes?

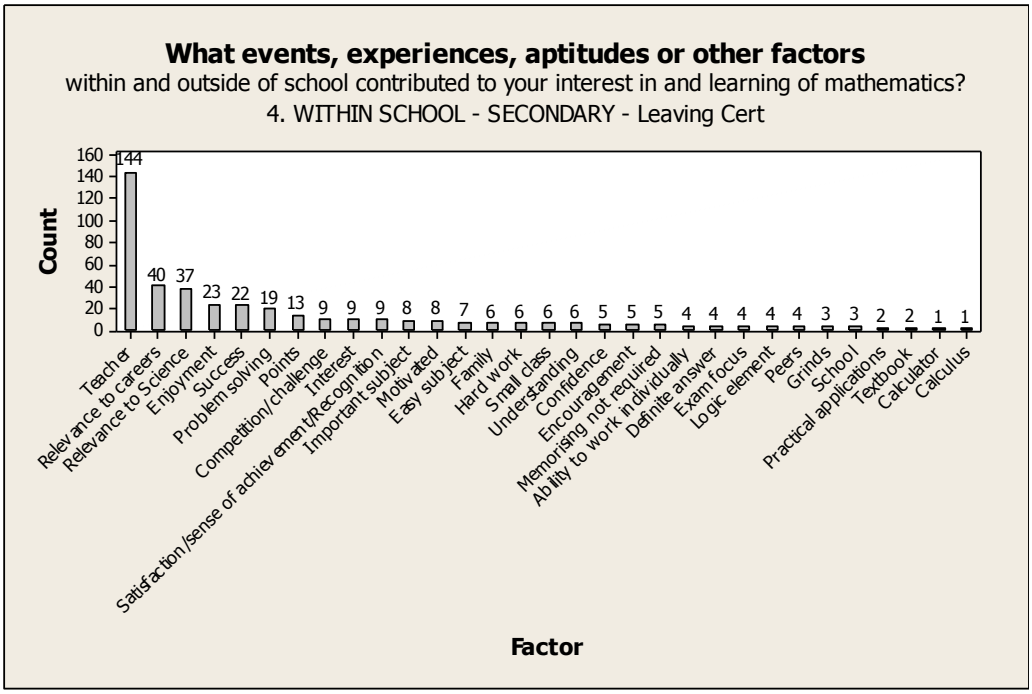


Figure A6-17.

5. **Outside primary school? How did these improve interest & learning?**

In your view, why do you think engineers choose the following modes?

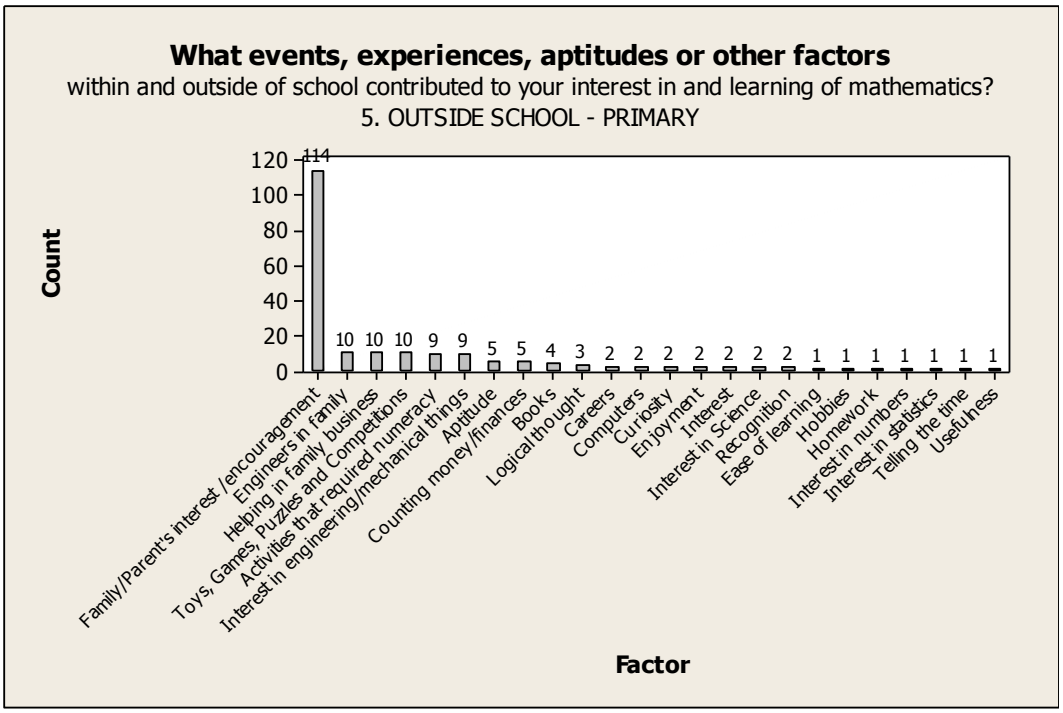


Figure A6-18.

6. Outside secondary school – years 1 & 2? How did these improve interest & learning?

In your view, why do you think engineers choose the following modes?

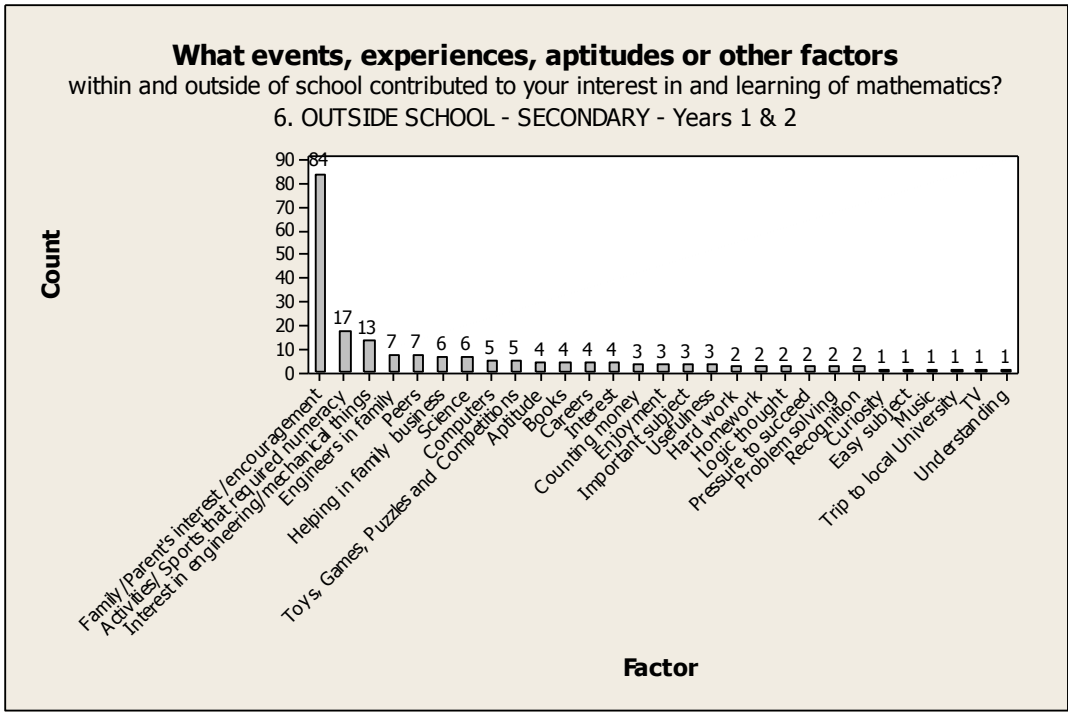


Figure A6-19.

7. **Outside secondary – Junior Certificate? How did these improve interest & learning?**

In your view, why do you think engineers choose the following modes?

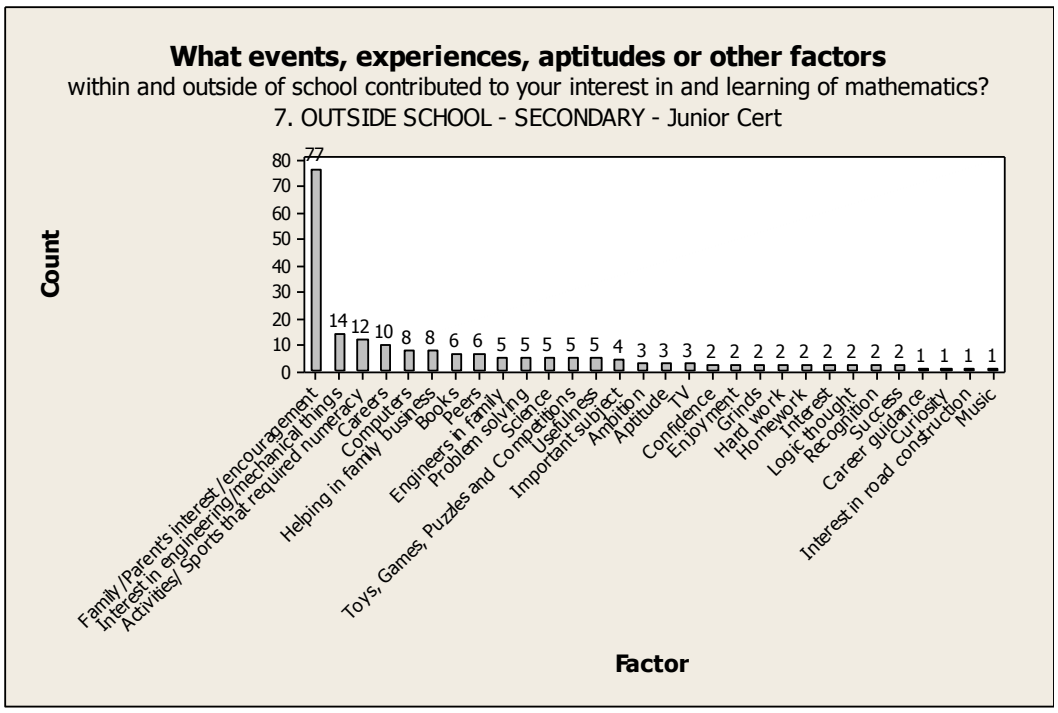


Figure A6-20.

8. **Outside secondary – Leaving Certificate? How did these improve interest & learning?**

In your view, why do you think engineers choose the following modes?

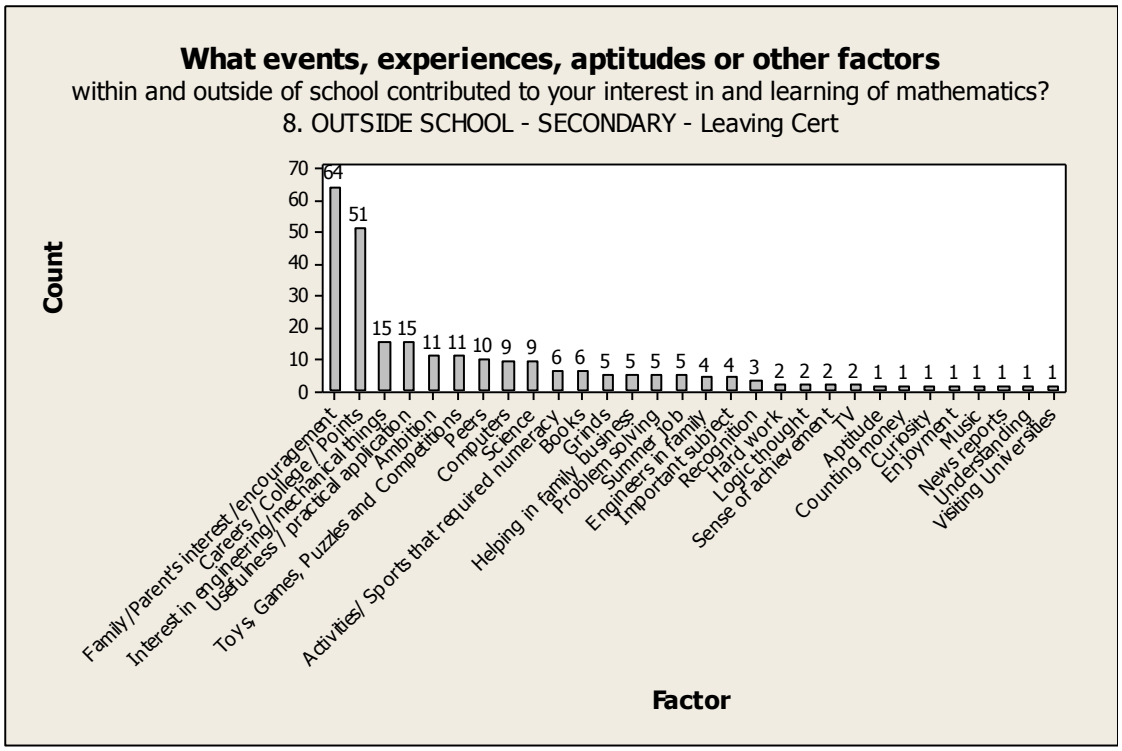


Figure A6-21.

D. Feelings /views about school mathematics [5 mins]

Can you recall your feelings about school mathematics?

What impact did these feelings have on your interest in and learning of mathematics?

In school, did you have any strong views about mathematics? Why?

- e.g. hard-easy / useful / enjoyable / gender specific
- remembering facts and rules/ getting the right answer / procedures and methods
- ways of solving problems / risking a mistake solving a mathematics problem/ puzzles

Did you ever get emotional about school mathematics? Why?

At school, what motivated you in mathematics class?

E. Feelings about mathematics and career choice [5 mins]

Why did you choose to become an engineer?

To what degree did your feelings about mathematics impact your choice of engineering as a career?

(Response options: 1 = Not at all; 2 = Very little; 3 = A little; 4 = Quite a lot; 5 = A very great deal)

Why do you think this was so?

In your view, why do you think engineers responded as follows?

1. 75.9% of responses are Quite a lot /A very great deal
2. Mean response = 3.97

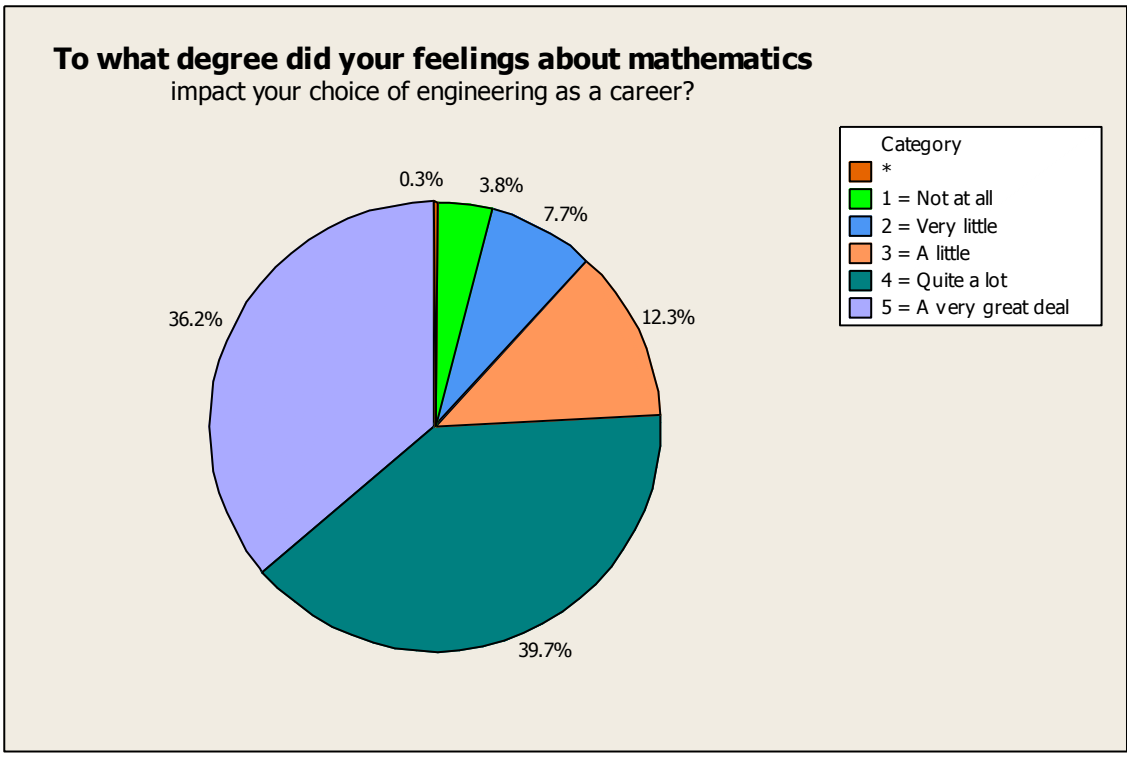


Figure A6-22.

Interview Protocol Page 20 of 21

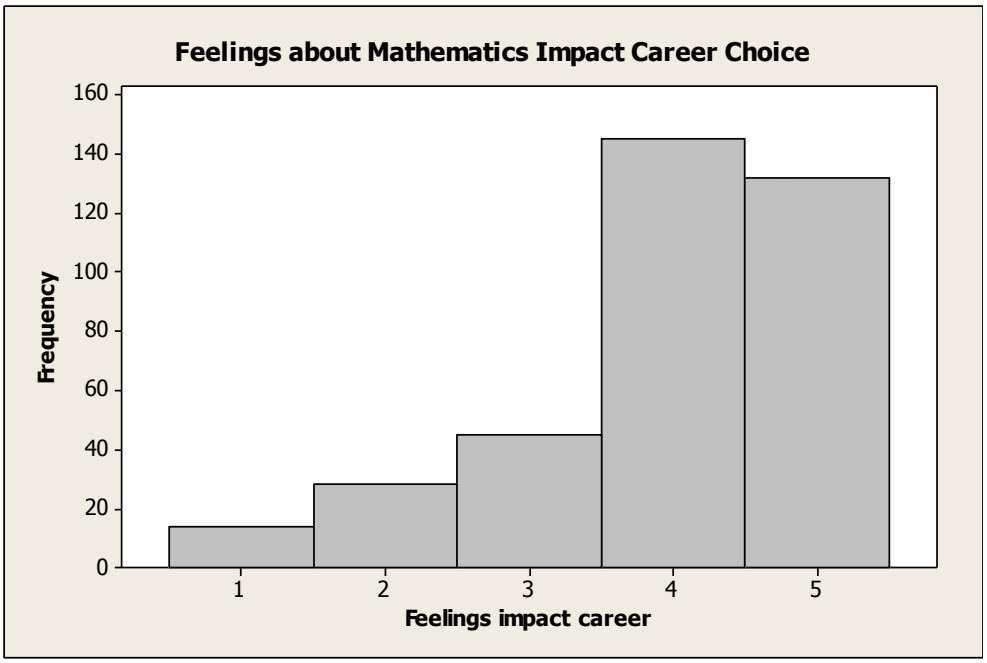


Figure A6-23.

ADDITIONAL COMMENTS [30 mins]

Two main questions:

1. What is the role of mathematics in engineering practice?

e.g. what mathematics do you use in your work?

How do you use mathematics?

Is a mathematical approach necessary in your work?

2. Is there a relationship between students' experiences with school mathematics and their choice of engineering as a career?

E.g. What were your feelings about school mathematics?

Why did you choose to become an engineer?

APPENDIX 7: INTERVIEW PARTICIPANTS' STORIES

Interview participants' stories are included in Appendix 7. The interviewees have alphabetic pseudonyms according to their *curriculum mathematics* usage, Table A7-1.

Pseudonym	Gender	Company Sector	Engineering Discipline	Engineering Role	Curriculum Mathematics Usage	Leaving Certificate Mathematics Level	Leaving Certificate Year
A	M	Pharmaceutical	Chemical	Design / Development	1.28	H	1990
B	M	Telecommunications	Electronic / Electrical	Technology ServiceSales Manager	1.52	H	1984
C	M	Project engineering	Mechanical	Design / Development	1.76	O	1985
D	M	Retired/ Project engineering	Mechanical	Project Management	1.88	H	1966
E	F	Project engineering	Civil	Design / Development	2.04	H	1997
F	M	Energy distribution	Mechanical	Project Management	2.08	H	1985
G	M	Electricity distribution	Electronic / Electrical	Commercial	2.09	H	1994
H	F	Project engineering	Civil, Rail, Water	Design / Development, Resident Eng.	2.33	H	1997
J	M	University	Biomedical	Education, Research	2.67	N/A	1971
K	M	IT consultancy	Electronic / Electrical	Information Technology Consultancy	2.68	H	1995
L	M	Project engineering	Electronic / Electrical	Design / Development	2.9	H	1997
M	M	Consumer electronics	Manufacturing / Production	Design / Development	2.91	H	1991
N	M	Local authority	Civil	Maintenance	3.34	O	1981
O	M	Software	Software	Design / Development	3.51	H	1979
P	M	Retired	Electronic / Electrical	General Management	3.53	H	1963
Q	F	Medical Devices	Medical Devices	Design / Development	3.54	H	2003
R	F	Local authority	Civil	Design / Development	3.6	H	1980
S	M	University	Electronic / Electrical	Education	3.84	H	1980
T	F	Electricity	Electronic / Electrical	Design / Development	4.17	H	2002
U	M	Telecommunications	Electronic / Electrical	Design / Development	4.23	H	1984

Table A7-1: Profile of interviewees.

Appendix 7 is organised as follows:

Page number

Engineer A

Gender: Male

Background: A is from an urban background.

Family: A's father is an electrical engineer who provided mathematics "assistance up to 1st year in school when his ability to understand the subject was striped by his inability to exercise the patience to explain it."

Leaving Certificate mathematics level: Higher level, 1990

Education: Chemical engineering degree, UCD [University College Dublin]

Decision to study engineering: A chose to study engineering because he perceived it as a logical progression from what he had done in school. He states that if he hadn't been happy or comfortable with mathematics, he probably wouldn't have picked engineering.

Current work: A is a contract project engineer with a leading pharmaceutical company that produces drug substances. His role is in process engineering whereby he has responsibility for process equipment.

Chartered Engineer: Yes

Leaving Certificate mathematics: A enjoyed school mathematics because he "was good at it." For him, unlike other subjects, mathematics was not retention of information it was more the process of doing mathematics. He claims that "in theory, you probably could do Leaving Cert maths without a teacher." He particularly enjoyed problem solving in the applied mathematics subject. He states that if "you enjoy mathematics it is a good indicator to say that you would enjoy engineering". He had "two excellent maths teachers" and he notes their "ability to explain … teachers need to be absolutely comfortable with something to explain it".

Engineering mathematics: A is of the view that, "if you couldn't do Leaving Cert maths at a higher level, rather than didn't, that you would probably struggle with traditional engineering". He believes that engineering courses contain too much

specialist mathematics and that there is probably "not a necessity for everyone to learn all the mathematics". However it is not possible to anticipate which 10% of engineering mathematics that will be used by individual practising engineers. However an understanding of "statistics is always useful".

Use of mathematics in current job: A states that chemical engineering does not rely heavily on mathematics and that mathematics is not a major element of his job. He believes that if his current job required a high level of mathematics, he "wouldn't have got it [job]". He states that despite common perceptions, mathematics and engineering are not equivalent, "you are not going to go back to first principles in engineering practice". However success in Leaving Certificate mathematics indicates a problem solving ability. "If you can't solve problems, you shouldn't be an engineer but the fact that you can solve problems doesn't mean that you necessarily need to use maths to solve problems". The majority of *curriculum mathematics* that A uses in his current job could be described as numeracy. This he says is at the level of Leaving Certificate ordinary and is used in a reproducing way. However A rates his *thinking* usage, as "quite a lot" given that he is expected to "understand and solve more complex problems faster".

What is engineering? For A, "engineering is so much more than mathematics", he believes that the association with mathematics "is more an association in terms of *thinking*" and that using mathematics develops that *thinking*. Engineering is "pretty much problem solving", usually problems that are generally not well defined. "The people who are natural problem solvers are good … you know good fodder for engineering."

Views on engineering: A is of the view that there is a large degree of interchange in engineering; because the majority of engineers don't work in particularly specialised roles many engineers could fill quite a number of roles within their organisations. According to A, while engineering is a good grounding for management **"**engineering isn't particularly highly valued … an increase in the number of highly technical or specialist roles might improve engineering prestige".

Views on mathematics: A believes that the Leaving Certificate higher mathematics curriculum is not an "efficient way" for a lot of people to get CAO points and the majority of students don't specifically require it.

Engineer B

Gender: Male

Background: B is from an urban background.

Family: B's father was in the banking industry, he was very comfortable with mathematics and from an early age, he gave B a lot of support.

Leaving Certificate mathematics level: Higher level, 1984

Education: Electrical engineering degree, UCD [University College Dublin]

Decision to study engineering: B's interest in understanding things, taking things apart and trying to build new things was born from his uncle's workshop; there were blacksmiths in one part of his family. For B mathematics was the "entrée" into the engineering. B's strongest subjects in school were mathematics and science and he wanted to pursue a career that would have exploited and harnessed that capability. B saw engineering as the most "prestigious way of expressing that in education terms" and for him engineering was a very "natural progression from one education phase into the next education phase". There was also a tradition in his school whereby each year a cohort of boys would have gone on to do engineering courses at UCD and Trinity [Trinity College Dublin].

Current work: B works with a leading telecommunications company and is currently head of operations for one of the company's public sector contracts. He states that it is his experience and maturity rather than any technical qualification that qualifies him for this position.

Chartered Engineer: No, however B is a member of Engineers Ireland and meets the requirements for Chartered Engineer.

Leaving Certificate mathematics: B enjoyed school mathematics because he "was good at it". He had "good teachers" who "explained maths well" and who "challenged" him with "maths problems". At secondary school, he had a peer group that had proficiency in mathematics and who were also targeting an engineering

qualification. This group who studied higher level mathematics, applied mathematics and physics was “a very self-sustaining group” and “so wholesome in terms of a field of study and one thing reinforced the next and there was never an issue”. If they had a difficult problem to solve, they would “share perspectives on that” and there was “an interest in getting a common approach”.

B is concerned about his own son’s mathematics teacher whom he describes as “introverted and neurotic” Consequently his son “has lost maths and he has lost engineering”. B believes that a good mathematics teacher is “enthusiastic to the point where he can foster interest and enthusiasm for the subject with a broad profile of students within the classroom and that he can get past the binary tick [✓] and x system and show, through problem solving and through general exposition of maths concepts and principles and practice, that there is a genuine subject there of relevance for students of all ages”. Applied mathematics gave B a practical realisation of the approach to mathematics and problem solving.

Engineering mathematics: B believes that “a significant achievement in higher level maths at Leaving Cert level” is required for students to be able to “embrace and persevere with the level of maths that was being taught in the engineering course.”

B states that engineering mathematics was “a hard grind” and he felt proud and still feels proud of that achievement and this has instilled great confidence in him in terms of career progression. He states that the “grounding that engineers get, prepares them for any manner of mathematical interpretation, understanding and interpretation”. If B was designing an engineering course, he would aim it at the engineers who are “going to have the highest consequence in terms of their on-going operation, their risk profile, and the consequence of failure” which is only the “top 5 or 10% of engineers”. While the remaining engineers may be lost to the engineering profession, they are not lost to society or to business; in fact they are “infusing organisations, public sector organisations and commercial organisations, with a great deal of rigour and discipline”.

Use of mathematics in current job: B states that, in his current job, he could quite satisfactorily proceed without higher level mathematics. While he has responsibility

for a “highly sophisticated system”, this system “was designed, implemented, tested and brought into service by some technical engineers” and a team of engineers are responsible for the maintenance of the system. In terms of *curriculum mathematics*, B’s use of mathematics is limited to the number domain at Leaving Certificate ordinary level and particularly involves interpreting financial and statistical reports which he classifies as reproducing and connecting type usage.

B rates his *thinking* usage very highly and increasing over time. In particular assimilation skills are important in B’s work; he describes assimilation as “being able to formulate an overall concept of a situation or of a problem”.

What is engineering? “Much of the value of an engineer brings to his job, brings to society, is to be able to do a reasonableness test to conceive a solution and within a good level of probability to be able to say yeah, that will meet the need, but then not being afraid to modify that and evolve that in subsequent observations or in practice”. B claims that engineers ultimately become responsible for “project costing, project expenditure, supplier management and contract management”.

Views on engineering: B believes that engineers get side-tracked in their roles and they get “persuaded for various reasons, not least for financial reward and compensation into project managers, programme managers, commercial managers, contract managers where their reliance on maths degrades very rapidly.” While B maintains that engineering is “badly represented and badly understood”, he puts “engineering on a pedestal as being worthy of being a respected as a third level qualification that was worthy of pursuit”. B stresses the need to get “engineers into positions of power and influence so that they become role models … even more significant role models in society.”

Views on mathematics: B is “very sad that we have these issues in society about maths”, particularly the “dumbing down in society” and the fact that “general academic proficiency has not been lauded or not been acknowledged or affirmed within society”. “There are certain subjects that are in vogue and other subjects that are out of vogue and the focus has been on the points’ race rather than a more holistic approach to education and maths has been the bogey man for so many

generations of students over the years." B wants to be "satisfied that, the engineer is designing to the highest level of rigour and discipline; if that requires, you know, in-depth understanding of maths in all its dimensions then so be it".

Engineer C

Gender: Male

Background: C is from a farming background.

Family: C's father died when C was very young.

Leaving Certificate mathematics level: Ordinary level, 1985; C's secondary school "didn't have the critical mass of students necessary to do honours maths".

Education: Apprenticeship as a Fitter/Turner; Mechanical engineering degree, DIT [Dublin Institute of Technology]

Decision to study engineering: C was the first in his family to attend third level education. It was C's "apprenticeship that opened up the engineering route" and not his feelings about mathematics. Also growing up on a farm, where he had to do "a certain amount of fixing" steered him towards engineering, C states that engineering is perceived as "an acceptable profession for a farmer's son, who is not going farming".

Current work: C is the department manager of the mechanical engineering group in an Irish founded multi-disciplinary engineering firm that develops solutions for complex capital projects serving multinational clients worldwide. As well as managing 28 engineers, C also works as a lead engineer on many projects.

Chartered Engineer: Yes

Leaving Certificate mathematics: C enjoyed school mathematics a lot. He states that "the maths teacher had probably a big influence on that, he had a nice enough manner and possibly too easy going for some, but he suited my style".

C states that "honours maths challenges a certain amount of teachers … if you have a damned good honours maths student, he is not just interested in the curriculum do you know what I mean, he is pushing the boundaries, like you know, and I think very few teachers are comfortable with that".

C believes that mathematics requires a greater understanding than most other subjects, for example “when kids come under pressure” in mathematics, they cannot move on to the next topic.

Engineering mathematics: Mathematics was one of C’s better subjects in college and he believes that the high mathematical component of engineering education is essential. He states than many of the engineering subjects are “closely related to maths, you know, so closely related that if you weren’t doing okay in maths, it was possibly bringing you down in those subjects”.

Use of mathematics in current job: C’s job does not “require a huge level of maths but invariably something will come along”. C states that the mathematics in his job is statistical analysis and geometry. He rates the academic level of his mathematics usage as Leaving Certificate ordinary level and he uses it in reproducing and connecting ways.

C contrasts school mathematics where “there must be one answer” with his current job whereby if he came “to one solution … that would be a disaster”; instead C must look at how his “design fits in” with the other disciplines. For mathematical calculations, C has “set up the computer to do all of that” and for a new calculation, he gets “the graduates to do it because they are closer to college”. When hiring graduates, higher level mathematics is not necessary, instead C looks for “the guy that likes engineering” and “would fit in” with his team, these types usually play Gaelic sports. Good graduates are like a sponge “soaking” up “various different strands of experience”.

In C’s work “thinking is everything” and his clients require him to “think about the alternatives”. C states that being “in the right train of mind” gives him a “certain amount of fulfilment”.

What is engineering? C maintains that “engineering is so broad” that he “could safely switch codes in the morning”. Engineering is about implementing ideas. C defines engineering as “a mind-set of how you go about things”. Engineering is “taking a solution” and “refining your estimate”.

Views on engineering: While C believes that "the engineer has lagged behind other professions", he is "an enthusiastic supporter of engineering" stating that engineering "is different day in and day out". When liaising with local schools, C observes that unlike most other professions, students "have no idea of what an engineer does" and that interest in engineering careers reduces considerably from first year to sixth year in secondary school.

C states that "it's too easy for anybody to be called an engineer" and that if he "became an electrician he "wouldn't have been academically as challenged" and that he "would invariably have had more money". C believes that if the issues concerning engineering "status and the pay" were fixed, more students would be encouraged to pursue engineering careers.

Views on mathematics:

C states that the "the idea of giving extra points for maths will encourage people to do maths but it doesn't necessarily encourage you to do engineering" He also states that "if you don't enjoy maths, you won't probably excel at maths, and if you don't excel at maths you steer away from that because even the career guidance teachers would be shoving you down towards a different route".

Engineer D

Gender: Male

Background: D is from an urban background.

Family: D's father was a Mechanical/Electrical engineer.

Leaving Certificate mathematics level: Higher level, 1966

Education: Mechanical engineering degree, UCD [University College Cork]

Decision to study engineering: D became an engineer because he was "fascinated by ... how things work". He states that mathematics was "the biggest block" to his decision to study engineering.

Current work: D recently retired from an Irish founded multi-disciplinary engineering firm that develops solutions for complex capital projects serving multinational clients worldwide, where he was a project manager in pharmaceutical type jobs.

Chartered Engineer: Yes

Leaving Certificate mathematics: D "was not a fan of maths", he "found maths difficult" He states that due to his "very poor grounding" in mathematics, he was "afraid" of the subject.

D sat the Leaving Certificate in 1966 which was the year of the "new maths" syllabus, which D states "frightened every teacher in the country". D attributes his success in Leaving Certificate mathematics to the similarity between sample exam papers and the exam itself.

D believes that mathematics is more difficult than other subjects. It is "unique, it's precise, there is a right answer and there is a step by step …. It even looks different … You can't bluff it". D states that mathematics teaching in his secondary school was "plain ordinary bad". This gave D an "inferiority complex about maths". In the context of teaching mathematics to Leaving Certificate students, D states that "teachers'

attitudes" and the need "for someone to explain it to them or motivate them" are hugely important.

Engineering mathematics: "That lack of maths caught" D all the way through college, where he "endured the maths". He states that "maths is a major tool for engineers", and that for many engineering concepts, "you can't see them, you can't poke them, you express them some other way … the only way we have is maths or experiments". D explains that when an engineering concept is put into "a mathematical framework, then we can start talking about it … and we understand it better, there is no other way of expressing it". However, D states that "an awful lot of the maths that you learn in engineering education, you never see it applied".

D is "critical of the amount of maths" in engineering education. However he states that following "four years in engineering education, the whole lot, obviously of which maths is an important part, you inevitably end up being logical and reasoning and analytical in your problem solving".

Use of mathematics in current job: At work mathematics, when required, "began to fall into place" for D because he could see "the big picture" but he only used the mathematics that he "was confident about". In fact he was more confident in his work "about having the principles right and conclusions right from a good understanding of the problem with some checking by maths rather than doing a big long calculation". D states that "statistics and probability" at engineering level was the *curriculum mathematics* that was most relevant to his work. He says he "never got beyond connecting" type usage.

D states that while in the course of his work "if the answer comes right, you're happy you got the right answer" but there was always "a nagging fear that I got something wrong".

D states that at work "the whole thrust is to reduce the figuring out to be done mathematically down to the minimum and … dumbing down the process all the time, so that you can shove it down to a less experienced or less qualified person".

D maintains that as one progresses in engineering, less mathematics is required and that his "whole way of analysing things and reasoning and organising got better as time went on; that was just experience".

What is engineering? D states that engineering is the "bigger picture", it "is learning to understand engineering principles, experience, experimentation, the various tools you use, all of the whole lot, maths is in there but maths in only a tool … it comes down to problem solving".

He also states that "an awful lot of what engineers do is very mundane. Very few engineers work in areas where they are challenged you know in engineering things, particularly mathematical".

Views on engineering: D states that "engineering training would be a good grounding for any of type of work", he believes that because engineers have better analytical skills, better reasoning skills, they would be better at defining the outcomes" and "they would probably do a better job than the banker bankers."

However D states that engineers are badly paid, often hired to do technicians' work and that unlike many other professions, engineers are not supportive of each other.

Views on mathematics: D states that mathematics is an extremely important tool in engineering but he rejects the idea that one who is very good at mathematics should do engineering.

D believes that one "can get through life without any maths, other than having to do sums". He singles out statistics and probability as having some "relevance in life".

While D regularly hears that "it pays to do maths", he says "you don't see the teacher conferences at Easter time and the INTO [Irish National Teachers Organisation], you don't see them saying lads we are going to devote a day to teaching maths".

Engineer E

Gender: Female

Background: E is from an urban background. Her "husband is from a farm" and he is an engineer with the same firm.

Family: Family has no other connections with engineering

Leaving Certificate mathematics level: Higher level, 1997

Education: Structural engineering degree, CIT [Cork Institute of Technology]

Decision to study engineering: In secondary secondary school, "there wasn't must emphasis on engineering", E "just happened to do engineering". The fact that E "liked maths did go some way to choosing engineering" however while E likes her work, she "would prefer if there were more maths" in her job.

E believes that "engineering seems boring to "young people" and she says that they probably would prefer "to be high fliers" rather than opt for a "safe" career like engineering. E knows people who opted for actuarial studies partly "because they love maths" and "they think that's where the money is". She believes that if students score 600 points [maximum CAO points], they will choose a career that requires 600 points.

Current work: E is working as a civil engineer with an international multi-disciplinary consultancy firm that provides planning, engineering, environmental and communications services. Her role is a senior design engineer. E designs water collection networks, water distribution systems and flood study measures.

Chartered Engineer: Yes

Leaving Certificate mathematics: E "loved secondary school maths", she "liked the challenge of it and I like getting it right". At primary school E would be "gutted" if she "didn't get 10 out of 10" in her tables test. E believes that unless one enjoys mathematics, one is not "going to stick with doing higher level maths". E attended an

all-girls secondary school and she wasn't aware of any gender issues concerning mathematics, at school it was known that she was "very good at maths".

Compared to her twin sister's mathematics teacher who "didn't have a clue what she was doing", E's teacher was "a super teacher". She "knew the maths and she was able to teach them well", she used "practical examples and things to make you understand and to make it easier to understand". While E's mathematics teacher "was very strict", E says that "it was very rewarding to get something right for her". In particular E notes that her mathematics teacher "waited for you to understand it before moving on".

Engineering mathematics: E was "one of two girls in class of about 40"in college. There were "6 hours per week" of mathematics in E's engineering course. As entry to her course did not require higher level Leaving Certificate mathematics, E had already studied most of the engineering mathematics syllabus in secondary school. E states that the amount of mathematics in her engineering studies was "just tradition" and she hasn't "ever used it since". E would favour "a reduction in some of the maths" in favour of more "more practical solutions".

Use of mathematics in current job: E is disappointed with how little mathematics is required for engineering practice. She describes her use of mathematics at work as "easy sums". She says her mathematics usage at work is Leaving Certificate ordinary level geometry, trigonometry, statistics and probability used in reproducing and connecting type ways. She states that her work follows "the same pattern all of the time" and this she describes as a "logical process". E believes that in civil engineering "an estimate is probably good enough because nobody is going to know if the flow in a pipe is 10% less than what you have estimated" while structural engineering is "a more exact field".

While E likes "to do it the maths way", her mathematics *thinking* usage is greater than her use of *curriculum mathematics* and this "*thinking* usage increases with new projects or with unfamiliar tasks". When E first started her job, she "wouldn't have had such a feel for it" but now she does because she is doing it nine years.

E states that, in the company she work for, the older engineers use more mathematics than the younger engineers because “they wouldn’t have had the tools and now they don’t have the confidence in the tools”. While using the tools, E likes to “use maths just to check that some program” is working correctly.

What is engineering? For E, engineering is much more than mathematics, she knows “people who are successful in engineering but they don’t necessarily do a lot of maths”.

Views on engineering: E is of the view that engineering is not “prestigious” because the entry points to engineering studies have reduced is recent years, she also believes that engineers are badly paid.

E states that many engineers are hired to fill technicians’ roles, that engineers are being educated “in the wrong things” and that technicians are often better than engineers at implementing practical solutions, however financial constraints often override the “better solutions”.

E notes that, for women, engineering is not a family friendly career.

Views on mathematics: E believes that in school, students are branded according to their mathematics ability and that importance is assigned to mathematics performance. C states that “higher level maths probably takes up a fair bit of time” and that people “just dropped back to ordinary level maths, because of a timing issue, they didn’t really have the time to put into that at the sacrifice of something else”.

Engineer F

Gender: Male

Background: F is from an urban background.

Family: Family has no connections with engineering.

Leaving Certificate mathematics level: Higher level, 1985

Education: Mechanical engineering degree, DIT; MBA [Master Business Administration]

Decision to study engineering: From a young age F was interested in "engineering things and mechanical things". Many of F's engineering colleagues came from farming backgrounds and he believes that their early introduction to engineering on the farm led them to a career in engineering.

F asserts that interest in mathematics contributes to success in mathematics which in turn steers people towards a "scientific/ engineering type of career".

Current work: F is currently working as a project manager in a commercial department of a semi-state energy provider.

Chartered Engineer: Yes

Leaving Certificate mathematics: At school F was "drawn to physics, chemistry and maths", however F states that school mathematics "meant nothing and you couldn't relate it really to everyday life".

F says that he "had some good maths teachers" and also "some really bad ones". F's good mathematics teachers interacted well with the class, however F states that school mathematics "should be more applied" and that students should be made aware of its usefulness.

Engineering mathematics: In engineering college F related more to mathematics because he saw it used "in other subjects" and "for practical purposes". He states that while he covered a wide range of topics within the subject of mathematics in

college and that only a fraction of it is relevant to his working career, "it is not wasted doing it". F also asserts that "you develop a logical mind set from having done these types of subjects".

Use of mathematics in current job: F states that in his current role, mathematics "is always there", there is a need "to have had higher level maths at some stage" and that to use mathematics tools "with confidence, you need to know where they came from". F states that in his job he needs to understand the mathematics, that his company uses "to model complex physical problems" on a daily basis, otherwise he might be "hoodwinked". Many of these problems are "versions of issues that have arisen elsewhere" and there is rarely a need to "go back to the first principles", it is more about "plugging in the numbers".

F states that in his work he uses higher level Leaving Certificate statistics in a manner "somewhere between connecting and reproducing".

F states that "crunching numbers would be seen as something you do the first couple of years you are out of college" and that "if you were to be successful and you were to graduate up through the management chain, you wouldn't be using maths on a daily basis but you would be managing people who were using it". While F describes his current mathematical ability as "rusty", he claims that he could easily "pick it up". A few years ago having solved a mathematical problem, F states he "got a bit of a kick out of doing that".

What is engineering? F states that "engineering is not pure science and pure maths", it is "using maths and science and applying them to the real world, engineering". Engineering isn't about expending "resources developing solutions from first principles unless the solutions we have today aren't working".

Views on engineering: F asserts that mathematics is not the reason why students are "not drawn to engineering" and that bonus points in mathematics would have no impact on the demand for engineering careers. He states that engineering is not seen as "as a very glamorous career" and that the engineering profession has "allowed the profession's brand to be watered down over time".

F also states that employers rate engineering experience more highly than engineering qualifications.

Views on mathematics: F states that “mathematics is important” and that one never gets “too far away” from statistics and probability.

Engineer G

Gender: Male

Background: G is from an urban background.

Family: Education was a "big thing in G's home, his father was "always throwing maths questions" at him. Many of G's relatives were engineers.

Leaving Certificate mathematics level: Higher level, 1994

Education: Electronic engineering degree, UCG [University College Galway]; MBA

Decision to study engineering: G chose engineering because he was "good enough at maths … there was a bit of rigour to" it" [engineering]. "High points" and career "credibility" also influenced his decision. G states that while "maths is the real link" to engineering careers it would be helpful for young people to know "that you weren't going to be up to your neck in equations for forty years".

Current work: G works with a semi-state company involved in energy transmission systems where he has responsibility for pricing. G states that he has a "broad remit" and there "is a lot of economics and there is also a lot of technology" in his job.

Chartered Engineer: Yes

Leaving Certificate mathematics: G is of the view that Leaving Certificate mathematics is **"**hard enough" and is "very time consuming." G states that unlike other subjects "you couldn't bluff" mathematics and that instead of "regurgitating stuff" "you had to actually think on the spot". G describes his mathematics teacher as a "tough guy … coach of the soccer team" who "was a very good teacher", "who really knew the maths", who taught "through examples" and who "challenged the lads". G attended "an all-boys school" where "the guys who were good at maths got a lot of respect". G believes that this respect stemmed from "being able to do something other people can't do". Many of G's school friends also went on to study engineering.

G describes mathematics education as “a building block type of a house from the foundation up” and that in order to “get a grasp of it”, it is necessary “to go back in order to go forward”. He believes that many young children who “don’t get a chance to learn the basics” have “very negative experiences of maths”. G calls for “specialist maths teachers” in primary school; he describes these as teachers who are “interested in maths and children” and who will encourage children and also ensure that the advanced children “don’t get bored”.

Engineering mathematics: G states that engineering is a “rigorous” course and that while higher level mathematics “was necessary to get into engineering, it is definitely necessary to get through engineering” studies. Given that engineering knowledge is “readily accessible”, G states that it is important that engineering students have access to engineering experience similar to “clinical time” and “lectures from consultants” as is the case of medical students or “devilling” in the case of law.

Use of mathematics in current job: G states that mathematics makes his job “easier” and that because he did higher level Leaving Certificate mathematics, he doesn’t “have a fear of it”. G says he is “very comfortable with numbers” and when encountering a work problem in work he would initially “try and get a number on it and get a feel for it”. G believes that he “needed maths” to get to his current job and that statistics as used in reliability engineering has always been a “huge part” of his work. G states that throughout his career, there has always been “something new” and that “having the mathematics” makes working on new tools easier. As G moved into more management roles, he has become “less inclined to do things from first principles” and he looks to other people to do that work. G maintains that as his experience increases, “there is a lot more judgement” and he can make decisions “quicker”.

G describes his current *curriculum mathematics* usage as engineering level matrix algebra used in reproducing and connecting ways.

What is engineering? G asserts that other professions “apply a body of knowledge” and that “the only profession that is trained to deal with problems is engineering”. While engineering has moved towards “delivering total solutions” due to the

"economic benefit" of greater levels of integration of "others' work", G believes that "the guys developing the algorithms from first principles are rare" and "that a lot of the engineers don't really know what is under the bonnet". Career advancement in engineering is a "move into the commercial side".

Views on engineering: G is of the view that engineers' work is "new", they "do something that hasn't been done before" and that their work has "massive social benefits" for societies. However while "everything is driven by technology and the best profession to deal with that is engineering", G asserts that engineering is "the most undervalued and under rated profession; in "Irish society … engineers don't feature" and "it is not mandatory to be a member of Engineers Ireland … to be called an engineer". G states that "engineers are so often in the background" and "they lack the emotional intensity that they need to communicate, the impact of what they do, on people's lives" and this is "sometimes exploited by people who do have that emotional ability".

Views on mathematics: G believes that being "good at maths … opens up a huge number of careers". It is a "handy tool" and "if you have a fear of it or it turns you off, it's just like not being able to use your driver in your golf bag". G notes that in some other countries "mathematically based careers are the highest income earners".

Engineer H

Gender: Female

Background: H is from a rural background.

Family: H's father was an accountant and he instilled in H that mathematics is not hard, that it is a challenge and that methodology is more important than getting the correct answer.

Leaving Certificate mathematics level: Higher level, 1997

Education: Civil engineering degree, UCC [University College Cork]

Decision to study engineering: It was H's confidence in mathematics and "the look of the curriculum" that led her to engineering. Given the mathematics orientation of the engineering curriculum H expected that engineering "wouldn't be too much of a struggle". Her father advised her that engineering would be a good general education and that, with an engineering background, she could easily switch to another numerate profession if she wanted to change careers.

Current work: H is a projects manager with a state agency where her responsibility includes design, tender, implementation, and construction of rail traffic infrastructure.

Chartered Engineer: Yes

Leaving Certificate mathematics: H "always found maths real easy to study" because "it wasn't just sitting down trying to remember loads of stuff", instead it was doing mathematics. When she worked out a problem she would be "delighted", she says that she is "very dogged on working stuff out".

H attended an all-girls school that is highly ranked and where approximately one third of the students in her year opted for higher level Leaving Certificate mathematics. H states that with mathematics "you have to be engaged" and she attributes her mathematics success to "30% teacher, 30% area and 30% home". H had an "excellent teacher, she was really interested in us all getting a really good result" she was "quite

interested in teaching" and "never boring." H states that she was "terrified" of her mathematics teacher who "made" her do the work and who was also "delighted" with her when she did it. H describes bad teachers as those who are "not interested and not able to take control of the class" and she maintains that "there is no consequence for bad teaching".

H believes that, unlike other subjects, results in mathematics are not subjective but are directly related to "the effort you put in". However "if you fall behind in it [mathematics], you can get snarled up in it quite quickly and fall behind particularly with honours maths". H states that there is "a huge level of difference between honours and pass maths" and that "pass maths needs to be a bit more challenging".

Engineering mathematics: H states that without higher level Leaving Certificate mathematics, engineering education "could really intimidate you".

H describes engineering as "so wide ranging" that it is not possible to "teach all the theory and application at the same time". When H "first came out of college" she was able to "recognise things" but she didn't "know how to do anything". She says that when an engineer "has about 8 years' experience under their belt" they know "how things actually work".

H notes that "Engineers Ireland are trying to always push engineers to become leaders but if you look at the course, it doesn't really train you for any of that, it is very much kind of left up to individuals".

Use of mathematics in current job: H maintains that "as an engineer you don't sit in front of the computer and do maths all day" and that in her job the "technical solution is the first step in about ten to get things done". H says, while "there are programs that will do a lot of the groundwork" she needs to know "how to use the programs and interpret the results." A major part of H's work is "contracts" and the "commercial implications" of decisions. H states that she is "at the stage where common sense applies more than the maths" and that her "grounding in maths" helps her to "look at the figures very quickly and make decisions". She says that "in

order to have common sense I think you need to understand … the effect of one piece of work on another part of our system".

She rates her current *curriculum mathematics* usage as mainly reproducing type and of higher level Leaving Certificate standard. She uses statistics and probability in a project about "noise monitoring" on a rail line and she uses "basic geometry and trigonometry to work out site levels".

H's work involves "huge amounts of interaction with people" as she has to explain to her colleagues how she reached her conclusions. She says that when one progresses to management "you need to know enough to know when someone is pulling your leg".

What is engineering? According to H, "engineering is more than maths … it is much more, bigger picture thinking". She says that "engineers are expected to be rational and logical and to come up with the correct solution".

Views on engineering: H believes that "money spent on design is money well spent" and that if an engineer "does a good job nobody will notice". H believes that engineering careers "are not lucrative" and that while engineering fees are a "project cost overhead" where the "lowest cost wins", legal and accounting fees "are a corporate overhead" that are not driven by the lowest price. She states that the financial and legal professions are "quite transferable across sectors" whereas engineers are not and that is probably why many engineers pursue MBA qualifications. H states that despite the restrictive nature of engineering, she enjoys her work and that she would "hate to be an accountant … I just think it is so boring".

Views on mathematics: H believes that higher level mathematics opens "up a lot of doors in different careers and that "it isn't as hard" as people think.

Engineer J

Gender: Male

Background: J is from an urban background.

Family: J's father was a mechanical engineer who "was quite good at maths", J says his "mother wasn't". The attitude at his home was always that J should "just enjoy whatever subject" J liked or was good at. There was a lot of "mathematical type game playing going on" in J's home and it was something the family and relatives "did for fun" rather than because it might be "useful".

Leaving Certificate mathematics level: A- level mathematics, 1971

Education: Mathematics and Physics, Queens College Cambridge; PhD, University of Cambridge

Decision to study engineering: J says he "fell into" engineering rather than chose it. In the north of England in the 1970s J was "encouraged to do pure sciences, not engineering" because he was "bright at school". J himself "was always much more motivated to seek out a career from the point of view of the pleasure" rather "anything else, like, the money or the kudos" and his "set of skills" led him to his current career. J asserts that "once you are seeing maths as your best subject, then you are asking yourself what can I do with that and engineering has got to come up strongly".

Current work: J is a Professor and Head of Department of Mechanical and Manufacturing Engineering in one of Ireland's top universities. In addition to lecturing, J engages in research work in conjunction with designers and engineers in Bio-Medical companies.

Chartered Engineer: Yes

Leaving Certificate mathematics: J took mathematics at A-level and while he claims that he was "never top of the class" his group of school friends were all good at mathematics. Being "good at maths" had advantages for J, he felt "useful" when

helping other people with their homework. J had good teachers who made mathematics "interesting" and presented mathematics as a "fun" subject. He believes that teachers "inevitably have an enormous effect in all subject areas" and that the way mathematics is taught makes it more "challenging" and it requires "more brain work" than other subjects. He states that mathematics "gets difficult in a kind of a non-linear way, in an exponential way if you want to go to the next level of difficulty". J asserts that mathematics is unique in that it requires "getting on top of various concepts" and that a "particular teacher" works for you when you find "that you are able to do it". J was attracted to mathematics because he doesn't "have a particularly good memory", he was "more inclined to derive the solution on the spot" which he says "that is the fun of it" and this technique was very successful in exams.

Engineering mathematics: J found university mathematics "much more challenging" than school mathematics and he states that current students with a C grade [≥55%, <70%] in higher level Leaving Certificate mathematics need to work hard to "keep up". He would be "very reluctant to reduce the level and difficulty of maths" that is currently taught in his department. He is of the view that the "types of maths, applied maths, problem solving techniques" used by engineers depend "on what kind of work they do, but there is still quite a lot of engineers who couldn't do their jobs unless they can solve differential equations". According to J, managers in engineering companies need to know what the people in their companies are doing and engineers need to understand the "mathematics underneath" the readymade tools. J maintains that "doing maths is just very good training for the brain". He is of the view that in engineering education "information is now less of a problem" and the focus is about "more generic problem solving skills, like abstraction and choosing different solutions and designing experiments things like that, that would apply to any branch of engineering", which he says are also required for accreditation of their courses by Engineers Ireland.

Use of mathematics in current job: While there are "great chunks of the subject" that J has never needed to use, he states that mathematics is "essential" in his work. In his teaching work, J uses "a few differential or integral equations now and again and a bit of algebra" at a level no higher than higher level Leaving Certificate mathematics.

In his research, J uses statistics, geometry, algebra and functions “quite a lot” at the level of degree and in a mathematising way. He says the academic level of his mathematics usage is between A- level and engineering level. Ideas are critical to J’s research, “the first step in a new area is to try and find the mathematical expression of some ideas and hypotheses”. J states that his “quite simple mathematics ideas” are then “carried on by other people who are better mathematicians”. Statistics, which J describes as “conceptually quite different” to the rest of mathematics, is also important in J’s work because he is constantly “dealing with experimental data and trying to understand it”.

What is engineering? J describes a “typical engineering situation or a company … as being maybe a few people in the company doing maths at quite a high level and … people below them who need to understand and interpret what they are doing and then others who just need to know the big picture”.

Views on engineering: J thinks that “in Ireland engineering always had a better name than it did in England”. He states that “we live in an age dominated by science and technology and that all of things that you use every day have only come about because of science and of maths”. J believes that control theory as applied to engineering processes has a huge potential in systems biology whereby, instead of using “maths after the fact”, mathematical models can be used to describe biological systems and to understand what’s “happening to these cells in the body” during various illnesses. J describes this application as “fashionable”.

Views on mathematics: J states that mathematics gives him “an approach to a problem which is different from somebody who doesn’t have a maths training”. While having an “idea is a creative process” that J would subsequently “develop through maths”, J’s “ideas are constrained by the techniques” he “is able to master”. J believes creativity also includes the “different starting points for the solution” and that his ability “to do certain types of maths … has an effect on the ideas” that he has.

J maintains that it is an “advantage to society that people are aware of maths and what it is” and that mathematics is “important”.

Engineer K

Gender: Male

Background: K is from a farming background.

Family: From a very young age K was counting cattle on the family farm and playing Gaelic sports. His father "remembers being good at maths in school" and his mother ensured that K was vigilant when doing his homework. Throughout school, K was interested in his older brother's mathematics homework. His younger brother is a recent graduate of construction engineering.

Leaving Certificate mathematics level: Higher level, 1995

Education: Electronic engineering degree, UL [University of Limerick]

Decision to study engineering: "Mathematics would have been one of the strongest things that pushed" K towards electronic engineering. K asserts that a career "is an opportunity to do something that you like, something that you are good at". While his teacher encouraged him to study "pure maths in Trinity", K felt that having grown up on a farm where he was "used to touching stuff and manual labour … it wasn't hands on enough". He says his brother studied engineering not for "a love of maths" but "out of love of construction".

Current work: K is an information technology consultant with a multinational organisation.

Chartered Engineer: Yes

Leaving Certificate mathematics: At school, K was "mad for mathematics" which he found it "instantly rewarding". K relished the "ability to stand up in class and answer the question from a very young age and be more correct than everybody else". K also enjoyed "tutoring everybody in class". One of K's mathematics teachers was "excellent", she was "strict as hell" but "she tolerated questioning". K states that "without a little bit of extra challenge" from this teacher, he would have been "bored". K's way of learning was to "figure why it was", he would "ask the teachers to

explain" and if they could not explain" he had "to take them on". If K "wasn't sure of a formula" he "would just go back to first principles and work it out". K believes that mathematics "teaches logical thinking and teaches that everything must follow a particular sequence". His Leaving Certificate mathematics teacher was "poor" because she could not teach maths". She "had no interest in answering questions" and consequently the students jeered her for "not knowing the mathematics". K stays that the class got "very frustrated" and tried "to learn stuff off by rote … without actually understanding it". When K took on a role of "tutoring" other students, he says "they suddenly went aha, that makes sense, that's easy now".

K claims that many students who are good at mathematics feel "isolated because of their abilities and skills", they would be "pushed out of groups". However K's main school friend was good at mathematics and he also became an engineer.

Engineering mathematics: K describes his class in university as "highly competitive" in both sports and mathematics. He says that only a few of the class struggled but only in certain elements of mathematics. They all liked engineering but some "did not like maths".

Use of mathematics in current job: Much of K's current work is "mathematical problem decomposition and restructuring and sequencing". For the 10% of the time that K needs mathematics in his job, "it is very valuable". K relishes mathematics, he sees it as a challenge and he would prefer a role with greater mathematics usage.

K uses statistics and probability, algebra and functions, at a level between higher level Leaving Certificate and engineering mathematics to determine "the most economically advantageous tender" for public sector contracts and to present civil servants with "a rock solid argument". He describes his usage type as mathematising.

K believes that many people in his company have "no interest in presenting an argument or presenting something through mathematics and they would use whatever shortcuts they can or get other people to do it". K states that there is a "confidence" issue attached to using mathematics and that "if you don't use it you

lose it". Also "if you get it wrong it can look very bad" and because his colleagues don't understand mathematics, K has to diligently "double check" his own work.

What is engineering? The "modern focus" on "speed of development" and "design once use many rather than design many use many" has moved engineering towards "written standards" for the "connection and integration of components" between "black boxes".

Views on engineering: For many organisations, engineering is "getting the job done"; there is no need to "understand" how the "black boxes" work.

Views on mathematics: K asserts that "there is a fundamental belief in mathematics more than in written English" and with mathematics, "if you are correct you're great".

Engineer L

Gender: Male

Background: L is from an urban background.

Family: Both of L's parents are teachers. His father, who teaches mathematics and physics, encouraged L to have an interest in these subjects. All of L's siblings did higher level mathematics and his younger brother is also an engineer.

Leaving Certificate mathematics level: Higher level, 1997

Education: Electrical engineering, UCD [University College Dublin]

Decision to study engineering: L states that because of his "high scores in maths" and his enjoyment of the subject, engineering "just made sense". At the time "points for engineering were high and there would have been that perception that it was a good career". At school L was also advised to "do engineering because it is more of a general degree".

Current work: L works in a multinational consulting engineering practice. His work is "mostly project management" and it also includes some electrical design. L was based "on site for two years at Dublin Airport, at the new Terminal 2" development and he has recently returned to his office.

Chartered Engineer: Yes

Leaving Certificate mathematics: L was "just always really good" at mathematics. He states that as far back as primary school he had "a natural ability" for the subject and that "maths was always quite easy". Because L was good at mathematics he "enjoyed" the subject" and in primary school he was "automatically rewarded by the teachers".

In secondary school, L was also interested in mathematics and he states that "the enjoyment of solving a problem was good", and that when doing mathematics, he "would persist" until he reached his "goal" which was to get "a certain answer". L was usually "ahead" of the teacher in the curriculum", he "would be disgusted" with

himself if he wasn't "at the top in mathematics" and he "pushed" himself "as much as he could" in the subject.

L states that his "maths teacher was very good", she made mathematics "very easy", she had "confidence in herself" and "she was patient". L states that "teenagers can be cruel if they see a weakness" in the teacher.

L got "pleasure" from mathematics, particularly when he "could do something so easily that other people couldn't do". He admits to being "completely geekish" and to trying "to hide" his "guilty pleasure of enjoying maths".

Engineering mathematics: L is of the view that students entering engineering education with low mathematics grades "are going to struggle". L states that while the "mathematics element of the degree stood out on its own" in that "it didn't relate to the other elements of the degree", it did however help students to "apply the mathematics in a more logical way". L asserts that in engineering education, the assessment process neglects the skills that are "more beneficial" to "future" engineers.

Use of mathematics in current job: Apart from statistics, L doesn't believe that he "will ever use that level of maths" he studied in university. His current mathematics usage is "statistics at either Leaving Certificate or engineering level, algebra at Leaving Certificate level and functions at Leaving Certificate level". He says the "majority of the usage would be in the type one category, reproducing".

However he does believe that "the sort of person who does honours maths ends up thinking and acting in a certain way" and that is what engineers bring to their work. He notes that while "hand calculations" dominated engineering work "ten or fifteen years ago" that "now, it is all done by computer modelling". L states that familiarity with "computer programming and software" gives engineers "confidence".

When approaching "problems that mightn't be mathematical by nature" L, because he is "comfortable with maths", approaches them with a "mathematical logic".

What is engineering? While engineers "don't use the maths that is taught on the curriculum", L states that it is "the type of person that is capable of doing those maths … who is suited to being an engineer and to think like an engineer". L states that engineering has changed and that engineering is not "writing down equations and working things out", instead engineers "minimise the amount of work that's required in order to deliver an end product".

Views on engineering: L states that it was "nice to be involved in" an engineering project that "a lot of people will see and talk about". He thinks that "there is a bit of ignorance about what exactly engineering is" and that "the status associated with being an engineer has dropped". L further believes that that the student "with an A1 [≥ 90%] in maths" will not opt for engineering careers because of the relatively low points' requirements for entry to engineering courses. He notes that the "quality of graduate that was coming out of college ten years ago, in an engineering discipline , was a lot higher" than recent graduates.

Views on mathematics: L always held mathematics "in high regard". However he argues that the "people who are not good at maths" can "earn a lot more money than people who are good at maths". L's view of bonus points for mathematics is that this incentive would help students "get into medicine" courses and would not impact on engineering courses.

Engineer M

Gender: Male

Background: M is from a farming background.

Family: At a very young age, M counted large numbers of sheep on the family farm. He recalls how, at the time, he would repeat the count until he was confident with his answer. M's mother worked in "accounting" … "she was good at numbers" and she helped M with primary school mathematics.

Leaving Certificate mathematics level: Higher level, 1991

Education: Manufacturing and Production engineering, UL [University of Limerick]

Decision to study engineering: The "only reason" M choose engineering was that he "liked doing honours maths" and he "would like to do more maths". M "just ticked all these boxes for engineering" while admitting that at the time M didn't know "what engineers do".

Current work: M is a "programme manager" with a large U.S. multinational company. His job involves development and acquisitions of tooling and equipment for high volume manufacturing.

Chartered Engineer: Yes

Leaving Certificate mathematics: At school "maths was number one" for M. He states that in primary school, mathematics was "a closed loop of get good results; be happy get good results and be happy". Because M's parents wanted to give him "a chance", M attended a top boys' boarding school. M says his enjoyment of mathematics increased after Junior Certificate as he was "getting strong results in exams that mattered". For M, Leaving Certificate mathematics "turned into this challenge". He recalls mathematics as being "this fun thing" for a group of boys at boarding school, who competed with each other "to see who would be first" in sport, the race to the canteen and mathematics. M says the boys "would be delighted if you caught out the teacher" in mathematics class.

M is of the view that after Junior Certificate "the teacher factor" emerged when the "guys who wanted to do honours maths" were provided with "stronger teaching". M maintains that as the "maths got tougher" he "relied" more on the teacher. M's mathematics teacher was easily identified as a relative of the researcher/author; he is a priest to whom many of the researcher's engineering classmates previously attributed their success in Leaving Certificate mathematics. M states that this teacher was "very strong at maths", he was "a very nice gentle kind of person", he "was just genuine", he was able to "connect with people through maths" and "there was discipline" in his class.

M maintains that mathematics is about "trying to work it out" and that for him "if it's maths, it has to be the right answer". M notes that mathematics is "a mixture of a hard subject and a huge amount of time". He found it difficult not to spend his entire study period doing mathematics and he is of the view that managing his study time taught him "discipline".

Engineering mathematics: M admits that he "lost" his "love for maths as soon as" he "went to college" but he "still enjoyed the engineering". He asserts that while school mathematics teaching takes place in "two directions", in college mathematics "was all just thrown to you". M states that college mathematics was "a bit more theoretical" and more difficult to apply and to internalise" than school mathematics. M also missed the social element of school mathematics.

Use of mathematics in current job: M uses Leaving Certificate ordinary level "numbers, statistics and probability and probably algebra" in a connecting way in his work. He says that while "higher level Leaving Certificate maths isn't necessary" in his work, he has brought the "discipline" he established from doing higher level Leaving Certificate mathematics into his "working life". M's work involves "looking at data, making decisions and giving directions". M uses "mathematical templates" to assist him "make the best decision for the business" and to "stand over the decisions" he makes; these mostly involve using "Excel". While M chooses the "quickest way to solve that problem", a mathematical approach is often required in complex cases otherwise he might choose "the wrong solution". Much of the data used in high

volume manufacturing is “outputs from the machines, it is pre-done for you” and has the advantage that “everybody is using the same system”. Statistics and probability is a big part of the production process. M estimates that only “10% of the engineers on site would need some of the learning from higher level Leaving Certificate maths”

What is engineering? M describes engineering as a “tool box” of “approaches” used to solve complex issues.

Views on engineering: M is of the view that engineering has been “dumbed down.” Companies are finding “cheaper ways of doing” engineering by relying on short-term “contract” engineers and by promoting people who “wouldn’t have a primary engineering degree” to engineering positions. Information technology (IT) tools are “dropped” into companies allowing many other disciplines to do engineering type work. People involved in “more high value added tasks” such as “outsourcing” are regarded much more highly than those in technical roles. M regrets choosing engineering as “engineering is not a high earning job”.

Views on mathematics: M asserts that most “people can avoid the heavy maths discipline”. He states that there is a risk associated with developing anything from first principles in that you are “putting your neck on the line” and that if “you try to present the maths behind it, you would probably see people nodding off”. However M is of the view that mathematics has many advantages over the use of “templates”, for example mathematics develops the ability to “think” and an “ability to figure it out for yourself” which is necessary when there are no readymade solutions available.

M calls for bonus points for higher level Leaving Certificate mathematics given the huge study time demanded by the subject. M is of the view that students need to “understand the practical applications” of mathematics early in school.

Engineer N

Gender: Male

Background: N is from an urban background.

Family No family interest in engineering or related activity.

Leaving Certificate mathematics level: Ordinary level, 1981

Education: Civil engineering diploma; Civil engineering degree, The Open University

Decision to study engineering: N says he chose engineering because he "loved building things" and that it "wasn't necessarily a love of maths, maths was just a part of it". Also, at that time, "engineering was seen as a good career prospect". N asserts that "the kind of people that go for applied mathematics rather than people who go for the pure maths in their choice of subjects" are more suited to engineering.

Current work: N is an executive engineer for drainage with a city council; he has responsibility for "a crew of twenty people" who maintain the drainage network in the city.

Chartered Engineer: Yes

Leaving Certificate mathematics: While N enjoyed Leaving Certificate mathematics, he did not enjoy Intermediate Certificate [Junior Certificate] mathematics because he "had a very poor teacher". At Leaving Certificate, N's mathematics teacher was good, he made sure that the class "understood something before moving on to the next topic". N is of the view that a good mathematics teacher would "show students the relevance of maths and try to encourage them into maths". N had a particular difficulty with functions, he "could never see the point" of "mapping f"; he says "it turned us off". N says that it took him "ages" to get his "mind around" mathematics, but when he "saw the point of it … it clicked" and it "wasn't that difficult then". N says his technical drawing teacher "who made him feel important" had the class "hooked" on trigonometry. N is of the view that there "are some areas of maths that

need to be applied as opposed to just straight studied". For example, "statistics and probability would need to have an application".

Engineering mathematics: N asserts that in his engineering education "maths followed" the engineering problems and that while he hasn't used this level of mathematics since finishing college his engineering education gave him the "mentality to think." N is of the view that engineers are "not trained for the real world situation that they end up in, they only pick it up after their education."

Use of mathematics in current job: N's current mathematics usage comprises algebra, geometry and trigonometry at engineering level used in a connecting way. N estimates that mathematics is only about 10% of his job and this is mostly "working from software or Excel spread sheets that somebody else had created". The majority N's work is "dealing with people" and "finance". N states that while he enjoys mathematics, and "it is always there at the back of" his mind, "all the decent work is done by consultants" engaged by the council.

N asserts that mathematics is not good for career progression as "there is a greater need for the practical application of day to day stuff". Graduates are relied on to meet any high level mathematics requirement while senior engineers "progress towards management".

N notes that "it's not the actual maths" that he takes from his mathematics education, rather "it's the logical format that you go through".

What is engineering? N maintains that engineering is "a problem to be solved" and that "the maths is secondary". Engineering is "a way of thinking". Engineers are "formed" by "solving maths problems", their "brain gets triggered in these logical deductions".

N is of the view that there are two ways to solve problems: one is "to represent the problem using formulae and symbols and it automatically ends up being maths"; and the other way is to use "a software program".

Views on engineering: N states that “engineers are being side-lined” and that much of engineers’ work has become “technician work”. “Administrators are taking over” engineering functions even when though “they don’t know what the consultants are telling them”. N is of the view that engineers “don’t promote themselves enough”, for example, “the architect sells the beauty of the bridge more than the engineer sells the strength of the bridge” and there is “no mention of the engineer until a problem happens”.

Views on mathematics: N states that “other subjects seem to take precedence over maths” and that “how we value things” is “a societal issue”. N asserts that mathematics should be recognised for its “its usefulness” and not as an “elitist clique that excludes people”. N is also of the view that mathematics “doesn’t help with creativity”; instead mathematics is a “basic toolset”.

Engineer O

Gender: Male

Background: O is from an urban background.

Family: O's family had no great interest in mathematics. O remembers his older brother telling him about calculus when he was very young.

Leaving Certificate mathematics level: Higher level, 1979

Education: Civil engineering degree, UCC [University College Cork]; M.Sc. (mathematics)

Decision to study engineering: O's choice of engineering was "driven by maths", he "always loved maths" and he went for a career that he "thought was maths related" However, O states he "outmanoeuvred" himself in that he "really wanted maths for its own sake but not for engineering". After a few years as a civil engineer, O switched to computer science.

Current work: O is a manager with a major multinational software organisation. O manages a team of four engineers and three testers who have responsibility for software localisation.

Chartered Engineer: Yes

Leaving Certificate mathematics: O says he "went from being this average student to being someone who was in the top five in the school" at mathematics. O attributes his love of mathematics to his Leaving Certificate mathematics teacher, who was a famous author of mathematics text books. O maintains this teacher "transformed" him "from being someone who didn't like maths or didn't care about it to someone who loved it". O describes his teacher as "legendary" and a "fabulous man and a fabulous teacher". This teacher "was just full of encouragement", he "could tell a good story" and his "history of maths just captured" O's "imagination". O states that this teacher showed him "how the solutions were so wonderful and beautiful and just cool" and that "solving a problem in that sort of way … is fantastic", O wanted "to

think like that". O recalls that as mathematics "got more difficult" he "started to enjoy it more" because he "found" he "was good at it". O is of the view that when "you understand" it, "maths is so much easier" and that "you don't forget" it. O is still hugely interested "in the history of maths" and he says that "it's frightening" to think that without this teacher, his "life would have been different".

O was part of a group all of who loved mathematics in school. O recalls that, in school, he wouldn't have expressed his love of mathematics to the same degree as he is doing now.

O is concerned about his own daughter's mathematics teacher and that despite his own love of mathematics, he states "it is the teacher that has to be the one" who inspires his daughter to become someone who loves mathematics otherwise "maths may well fall off". O believes that children are lost to mathematics early in their school years because the better teachers are assigned to senior classes.

Engineering mathematics: O maintains that one wouldn't survive engineering education without higher level Leaving Certificate mathematics.

Use of mathematics in current job: O is of the view that "Leaving Certificate ordinary level is enough maths for me to get by". He describes is current mathematics usage as "a lot of implicit number work … a very basic bit of algebra … some statistics". His usage type is between type 2 connecting usage and type 3 mathematising usage.

O states that while ordinary level Leaving Certificate mathematics is "plenty" for his work, he does "need the thought process". He states that the "practice" of getting the "brain going in different ways" is "good" and this gives him the ability "to reason out problems" outside of mathematics. Most of O's work concerns "human interaction problems" and budgeting. He states that "estimating" is "powerful" when "a reasonably good answer" is required "quickly".

O is of the view that, in the software industry, there is an emphasis on creating value that "can be re-used" and the interconnection of "software building blocks" is "where things go wrong".

While O likes his work, he states that he "became a manager for the wrong reasons" namely career progression. He "would have liked to have stayed actually doing the work instead of managing it." In his current role O uses Excel at an intermediate to advanced level, while if he "was a software design engineer" he would use higher level mathematics to write the code for Excel. O previously worked in search engine development whereby designers required PhD level statistics to "try and figure out ultimately what users mean when they type in something to search for". O says there aren't many software designers based in Ireland; the majority of the higher mathematics users are based in the United States. In Ireland a level 8 degree and "an aptitude for computers" is sufficient to work in the software industry.

What is engineering? O is of the view that in engineering is very broad and that in engineering "mathematics is just a tool".

Views on engineering: O states that due to his love of mathematics, engineering was "a bad choice for him".

Views on mathematics: While O is of the view that the "percentage of mathematicians in the world is always going to be small enough", he is also concerned about the general acceptance by many adults of negative perceptions of mathematics particularly given that "its usages are everywhere". O argues that mathematics is "fundamental", and that mathematics is "a tool that enables one to do really powerful things in other disciplines".

O says that "persistence" is important in mathematics due to the nature of mathematical problems. However he is "nervous" about making the mathematics curriculum "easier", this he believes would result in kids being "utterly unable to cope when they eventually get to work or even when they hit college". O believes that there is a need to demonstrate "how good or how beautiful a subject" mathematics is and "how important it is in life".

Engineer P

Gender: Male

Background: P is from a rural background.

Family: P was the first one in his family to go to university, his parents were happy that he went to university and there was no importance given to mathematics in his family.

Leaving Certificate mathematics level: Higher level, 1963

Education: Electrical engineering degree, UCD [University College Dublin]

Decision to study engineering: Having studied physics, chemistry and mathematics in school, P originally opted for a B.Sc., however having talked to some engineering students, P switched to engineering. While P "understood that maths was a very important element in the engineering curriculum" he states that "it was the more practical nature of engineering that appealed" to him.

Current work: P retired four years ago. Initially, P worked "as an engineer" for six years after graduating, he then "moved into marketing" and he subsequently moved "into general management". P worked "for a variety of mainly U.S. companies" in European countries.

Chartered Engineer: Yes

Leaving Certificate mathematics: P states that he "was far brighter than any other kid" in his class and "fairly precocious". He was interested in mathematics because he was good at it. P believes that "the quality of teaching in many respects is as important as the ability of the child". His mathematics teacher was good and he encouraged him. For P, mathematics was "a pleasant intellectual exercise, it was learning and solving problems" and he "always tended to read ahead".

P also got great pleasure from learning physics; his physics teacher "challenged" him with physics problems "at a level way beyond that of honours Leaving Certificate".

It was “obvious” to P “that maths was easy for some people and difficult for others”. P states that he was “happy” with his “innate ability” and he “didn’t feel any need to demonstrate it in any particularly public way”.

Engineering mathematics: P believes that “the academic approach to mathematics is very important in the formation of engineers”, he states that engineering mathematics “serves as a platform on which one can undertake the kind of reasoning that is necessary when confronted with technical challenges”.

P notes the difference in the approach to the education of engineers in Ireland compared to the U.S., where he states the curriculum is “highly specialised”. P questions if this Irish “generalist” approach is relevant to current technology and engineering practice.

Use of mathematics in current job: While P spent six years “working at the cold face” he spent “twenty eight years moving away from the cold face”. P believes “that a good grasp of maths is essential to being a good engineer” and that engineers have varying “degrees of involvement with mathematics”. He is of the view that as engineers develop “the relevance and importance of mathematics” declines to the point where “experience replaces mathematics” and “for most engineering problems there is a myriad of strategies”.

P says he had “stopped using functions” by “the time he was four years out of college”. Subsequently when managing “quality” in a manufacturing plant, P required higher level Leaving Certificate statistics and probability “to understand the solutions other people were implementing”. P says that he used “algebra, functions, numbers, statistics and probability” at a minimum level of higher level Leaving Certificate in his career. Early on in his career the usage would have been type 3, mathematising.

Over time P’s work was “primarily about decision making”, this included representing “the available information” mathematically or making “the best possible estimate”. P states that “there is always an acceptable level of imperfection” and that unlike school mathematics, “there is very seldom a unique right answer in engineering

challenges". P rates "problem solving against a background of incomplete information" as "one of the biggest challenges in engineering".

What is engineering? P is of the view **"**that engineering is primarily applied mathematics in one shape or another". He states that "there is tremendous diversity in what engineers wind up doing". P believes that "problem solving and logical thinking are essential to not just the everyday practice of engineering but to the everyday practice of management and to a large extent engineers are managers".

Views on engineering: P states that "it is easy to forget that you went through an iterative process of learning in order to arrive at the point where you had enough experience to make certain decisions without having to spend a lot of time worrying about the nitty-gritty and the background detail". He states that in engineering practice, "there is a balance between the amount of time you can spend on problem solving and the degree of certainty that you can have that the solution you've come up with is the ideal solution" P adds that "it is much more important to have a working solution than to have the ideal one".

Views on mathematics: P states that mathematics is "an extremely useful tool" and because most people use mathematics "in one way or another" throughout their careers, "society needs to set certain expectations for kids coming out of school" and mathematics teachers need to be accountable for achieving those expectations.

Engineer Q

Gender: Female

Background: Q is from an urban background.

Family: Q's father was an engineer and is proud of his daughter's high mathematics grades.

Leaving Certificate mathematics level: Higher level, 2003

Education: Mechanical and manufacturing engineering, TCD [Trinity College Dublin]

Decision to study engineering: Q's "feelings about maths and science" steered her towards engineering. She says that when choosing a career she looked at careers associated with mathematics because she enjoyed mathematics and school mathematics was her "strength". At the time of choosing her career, Q was aware of the universal career benefits of "numeracy and problem solving" and that engineering could lead to careers in management.

Current work: Q works for a multinational medical devices company. She is a quality engineer working in both process development and design of products used to repair and reconstruct joints and skeletal injuries. She has just four year engineering experience.

Chartered Engineer: Chartered Engineer application in progress

Leaving Certificate mathematics: Q "always liked maths". Q says she is competitive; in primary school, mathematics was "like a race" to "get the right answer". Q attended an all-girls secondary school where twelve girls from a class of one hundred took higher level Leaving Certificate mathematics, the same girls studied physics and chemistry. Q says her secondary school mathematics teacher was "unpopular" and she was "on a different wavelength" to most of her mathematics students because she was "so smart that she couldn't dumb things or explain things enough".

Q liked mathematics because she could "do a sum in half a page" and "still get full marks" whereas in subjects such as English she "didn't want to write three pages of

an answer" and get a lower grade compared to mathematics. For Q, mathematics homework was "always first" and it required two hours each day. Q says she was "diligent", "methodical" and she "wanted neat handwriting". She maintains that "understanding" and "checking the answer" were important in mathematics and she would also "go back" over her work and she "filled in units" to verify that equations were correct. She says that getting the "wrong" answer "feels bad".

Q "wanted to do well" at mathematics because she thought she could do well. Q says that she "clicked" with her mathematics teacher who would sit with her and explain concepts. Q was also inspired by some older "female role models" who were good at mathematics.

Q enjoyed getting full marks for getting the "right answer" and she states that she hid her enjoyment of mathematics in school. She believes there is a "stigma" associated with school mathematics and she recalls writing that she didn't like mathematics in her French homework because "everyone else was saying it". Her father quickly dispelled that notion.

Engineering mathematics: Of the two hundred students in Q's engineering class, forty were girls. In addition to an engineering degree, her class were awarded a B.A. in mathematics. Q says she "didn't always realise the application of mathematics in university". She has a view that lecturers are more "passionate about doing research" than lecturing.

Q maintains that engineering education would be "an uphill battle" for students who didn't have higher level Leaving Certificate mathematics. She believes that engineering education is not difficult; it is the time requirement and the greater workload compared to other third level courses that was "tough".

From her undergraduate summer work experience, Q developed an interest in bio-medical work and she says that having "read some validation procedures" while in work practice, she "got an idea where the maths comes in".

Use of mathematics in current job: Q maintains that there are two types of engineers: "mathematical engineers", who "need to be strong in maths to understand

processes" and "tool box" engineers who are equipment experts and who are not mathematical. In her industry, validation testing is critical and this is primarily mathematics. Q maintains there "is quite a lot of number crunching" in her job. Statistics and probability is a huge part of her work and she is a confident user of both Excel and Minitab. She describes her current mathematics usage as "statistics and probability and numbers, I do loads of that and that's up in mathematising … geometry and trigonometry, I would say at least connecting, we have product drawings with geometric dimensioning and tolerances". Q says much of her mathematics usage in work is at engineering level.

In addition to using mathematics as a "tool", Q states that the "logical stuff" is in "everything" she does, this includes: "looking at something and gathering the information"; solving a problem; getting "something done in the quickest way" and "setting milestones". Q states that as a new engineer she initially she learned from people at work and that with her four years' experience she has recently become "an independent thinker".

On one occasion, when Q "just took a minute too long" to complete a calculation and a work colleague ridiculed her which made her feel "really stupid". Q says she would not normally be so sensitive to negative remarks but that in this situation she felt that she "needed to be quicker".

What is engineering? Q states that "engineering makes everything work really".

Views on engineering: As an engineer, Q is often associated with "cars" and "dishwashers". She is of the view that, in her work, the roles of engineers and technicians are often intermixed. She is also of the view that membership of Engineers Ireland is primarily for civil engineers.

Q is of the view that modern students do not "choose careers", instead they choose "college courses" and they particularly choose "high points courses". She states that engineering education requires a "points' boost" to improve the attractiveness of the profession.

Views on mathematics: Q asserts that “people who can’t do mathematics call you a nerd and the people who are just amazing at it just put you down”. She is of the view that many “middle of the road” students are lost to higher level mathematics because of “a vicious circle” of people claiming they “can’t do maths”. Q “strongly” believes that “everyone can do mathematics”. Q states that the “perception” of difficulty is the greatest obstacle to higher level mathematics. She is also of the view that mathematics “tests understanding” more than other subjects and therefore mathematics teaching “requires explanation”. She states that there is a need to “pass on an appreciation” of mathematics, “to make it interesting”, to stimulate “discussions in class”, to “demonstrate an understanding of the applications” and to show “that it is useful.”

Engineer R

Gender: Female

Background: R is from a farming background. She has a view that people from farming backgrounds have a greater "feel for engineering" compared to people from urban backgrounds. Also farmers are "non-sexist" in the context of "who does the work". She believes that "what you grow up with" has a huge influence on your decisions in life.

Family: If R's "mother got her way", R would have become "a primary school teacher". R parents tried to dissuade her from studying engineering so much that R had to pay her own university fees.

Leaving Certificate mathematics level: Higher level, 1980

Education: Civil engineering, UCD [University College Dublin]; MBA

Decision to study engineering: R "always wanted to build bridges". Her "emotions towards maths was only for the purpose of getting into UCD to do engineering". When R commenced engineering studies, the entry points for engineering were on par with medicine and there was an "ego" associated with engineering, R felt she was "up there at the top".

Current work: R states that her career has been a "jack of all trades", she started off in consulting engineering, designing and building water and sewerage treatment works. R is currently a senior area manager with a local authority with responsibility for unfinished housing estates.

Chartered Engineer: Yes

Leaving Certificate mathematics: R knew that she required higher level mathematics by "hook or by crook" for engineering education. She says she studied higher level Leaving Certificate mathematics by "slight rote" and that she couldn't relate the mathematics to real life uses. She was one of four students in an all-girls school run by nuns taking mathematics at higher level. She describes her teacher as "manic

depressive" and who told the class that mathematics is "hard" and persuaded them to change to ordinary level. R says her "teachers never trusted" her to "to get anything". Prior to the Leaving Certificate exam, R begged her parents to switch to a grind school [private tuition]; there she found that "maths was easy". Her new teacher was a "revelation", he had "a smile on his face" and he "explained the problems".

R states that mathematics was "ok" in school but she "preferred history". She was interested in "great designers" and read about their "calculations and drawings".

Engineering mathematics: R found that engineering mathematics was "extremely hard". Her engineering class was predominately boys, most of whom had studied mechanical drawing and applied mathematics, R had never heard of applied mathematics prior to university and she believed that the boys were better than girls at mathematics because that was what she was told in school. In University, R felt completely at a disadvantage and she had to work really hard to keep up. It wasn't until third year that R could relate the mathematics to engineering applications. R believes that her engineering education would have benefitted from engineering experience, she says she "wasn't ready" for some aspects of engineering education, which she maintains become "more relevant" with "experience". In university she learned about individual units but only discovered the concept of "the whole system" when she started working in engineering practice.

Use of mathematics in current job: For about eight years of R's engineering career, there was "very little" mathematics, she says her "brain was so unutilised because of the repetitive nature" of "the parish pump politics". Following further education, her work moved back to mathematics, equations and designs. She states that while she is "in a senior management role", she is the only one in her staff of fifty two people "that can actually do something from first principles". She states that she has "taken on extra jobs and not got a consultant to do it" because she "had the higher level Leaving Cert maths".

R uses functions, geometry and trigonometry when designing storm water pipes. Statistics and probability is essential in "traffic management" and numbers are

required for “managing budgets”. R states that her mathematics usage is mostly at engineering level and the usage type varies from reproducing to connecting and to mathematising.

R is of the view that engineering is “diverse and forever changing”. An example of this view is that the design of “a water sewerage treatment plant requires civil, mechanical, electrical, structural and geotechnical applications.

R is currently working on unfinished housing estates, in addition to the water, sewerage and pyrite design considerations; R’s “main mode of *thinking*” is how to “get two hundred housing estates completed”. This she describes as “horse trading” with estate developers, where “you have to give something, get something, threaten something, make a stand but whatever you do say, you have to be able to stand over it”. She says her *thinking* is how to “figure out what is the optimum” she can get from the €82 million developer bonds she retains. R says this is “not straight black and white, it is a logical analysis”.

R is of the view that “during the tiger economy” she “did not think at all because the money kept flowing”. However, now with “reduced staff” and a lot of recent floods, there is “a completely different mode of thought”. She says that while her employers “demand the answer” and an answer that “works”, that due to her orderly personality she always goes “back to first principles” and she likes “breaking everything down and building it back up again”. She “would always have a get out clause on everything”, this she learned on the family farm.

She maintains that, due to her experience, she has acquired an “automatic thinking” capability whereby she could produce “a solution immediately”. She says she has “a feel for what’s going” on but she would do a quick calculation just to make sure” her answer was correct.

In managing people, R describes this role as “getting other people to think and getting other people to develop the solutions”.

What is engineering? R notes the similarity between Lego and engineering in that “you are just using everything you have and sticking them together”. She also likens

an engineer to “a social worker” because of her previous job of “sorting out everybody’s problems”.

Views on engineering: R is of the view that engineering could be done “today using just computers” and she states that many “engineers are working in technician’s roles” because “everybody wants to be an engineer”. R sits on many interview boards and she asserts that the “better” engineering graduates come from the university system [direct entry into level 8 engineering degree courses where higher level Leaving Certificate mathematics is an entry requirement] rather than from the diploma route [progression from level 6 diploma to level 8 degree] where the entry requirements, including mathematics, are much lower.

R believes that many students who choose higher level Leaving Certificate mathematics are also “highly motivated and very brainy … in their other subjects”. She is of the view students who are “highly motivated money wise” opt for careers in medicine and actuary. She states that “engineering hasn’t got the same appeal” to “a really smart person” because it has been “dumbed down seriously through the intervention of the Institute of Technology route [progression from level 6 diploma to level 8 degree]”. Also the “anorak brigade [name given to someone who has an obsession with a particular hobby similar to a nerd] of engineers” are much “more sort of problem solving orientated than money orientated”.

Views on mathematics: R believes that she never had “a maths teacher that trained as a maths teacher” and she argues that “primary school teaching should be changed”. She maintains that it is the “swots [people who engage in intensive learning prior to an examination] of the Leaving Cert”, who become primary school teachers and many of these teachers “have no concept how any subject relates to anything”. R criticises her own interview for entry to primary school teaching training where “playing the tin whistle” got more attention than mathematics.

R is of the view that society labels people; because her own son is good at mathematics in school, it is assumed that he would be no good at sport and in his school the students who are good at mathematics are excluded from the football team.

R believes that “there is a skill in communicating maths.” She asserts that if one doesn’t “bring the problem and the solution to people in their language”, mathematics becomes “elitist”.

Engineer S

Gender: Male

Background: S is from an urban background.

Family: S says his "mathematical bent came from" his father who "left school at fourteen years" and who "had this fascination with maths as being a great thing". His father also instilled in S a "work ethic", which he believes "can be applied anywhere".

Leaving Certificate mathematics level: Higher level, 1980

Education: B.Sc. (Electronic engineering), DIT [Dublin Institute of Technology]; MSc; PhD

Decision to study engineering: "Maths was everything" to S in school and "it was the key to the career" he wanted. S viewed engineering as "the way to make a living out of maths". S knew that maths, applied maths and physics were the "way to get" to engineering. At the time "the public perception of" engineering was higher that what it is now.

Current work: S describes his current role as "educator, university lecturer and researcher".

Chartered Engineer: Yes

Leaving Certificate mathematics: S "was a real problem student in primary school", but with good teachers in an all-boys secondary school S progressed from the "lowest of the six classes" to the top class. S "loved" Leaving Certificate mathematics. It was the subject he "put most into". "One of the disappointing things about maths" for S, was "the Leaving Cert paper being so **** easy". His Leaving Certificate mathematics teacher was "famous, simply because of the number of A's that his students used to get". S says this teacher "loved teaching maths" and he was "on top of his subject". He "kept throwing … interesting examples … and … interesting problems" at the students and he would present the class with a weekly "shock test" where the students got no advance warning. S was competitive. He got a "great buzz" from

"difficult homework" as it created "real competition" within the class and sometimes when he was "the only one in the class who got it right", the teacher would praise him, S would be "on cloud nine". There was a stigma attached to school mathematics; S says that his class were "too geeky" to discuss mathematics and in the context of his own love of the subject S labels himself as "a sad individual" and a "weirdo".

Engineering mathematics: S is of the view that engineering education "needs to move towards teaching people how to learn for themselves". He also believes that there is a need to create an awareness of the "the importance of certain skills" in engineering.

Use of mathematics in current job: Prior to working in academia, S worked in research and development with a large Japanese electronics company where his work was "absolutely maths". While in Japan, S recalls solving a design problem where the mathematics "wasn't rocket science" and the way S applied the mathematics was "one of the most rewarding things" he has done in his career. Similarly, the mathematics in S's PhD research was not "ground breaking", there he applied mathematics in a "new way" that proved quite "useful".

In his current role S uses functions, algebra, numbers, geometry and trigonometry in reproducing and connecting ways when educating students. S's mathematics usage in research is more of a mathematising type. The academic level is at "higher level Leaving Certificate and above". S was "never mad into statistics, which he describes as "vague", he prefers "concrete" problems that have an "exact answer".

S states that "a good rigorous mathematical ability is an advantage" in engineering especially when "trying to push frontiers". However he asserts that there is a "broadness" associated with engineering roles and that many engineers work in roles "where maths isn't central to their everyday activity". S maintains that engineers need an "ability to think" and he believes that "mathematical training is good for your brain". S also argues that "while the maths is very useful for elements of problems particularly in engineering, it is not necessarily the full solution" and that some problems "mightn't need maths".

What is engineering? Without wishing to give "the impression that engineering is elitist", S asserts that "engineering should be about problem solving" and not someone "carrying a spanner". He states that "real life" engineering problems are "bigger" than mathematics.

Views on engineering: S is of the view that engineers "who grew up loving maths, are probably more in danger of being the ones less focussed on what the customer really wants." Very often engineers come up with a "mad sophisticated solution" that is not related to any real problem" or they might "shy away from a question which can't be formulated mathematically". S maintains that "engineering should be about trying to identify the right question". He presents that "real world" engineers "have to frame the problem correctly and maybe express it in maths, then they have to solve it and then they have to interpret the solution and communicate that to the decision maker". S maintains that without this full solution "the decision makers" might "ignore the engineer" and instead they "use their own intuition".

S is of the view that the current poor demand for engineering courses is points related; he maintains that "there is a lot of evidence of people picking a course consistent with the number of points that they feel they are going to get".

Views on mathematics: S asserts that mathematics is "not the be all and end all". Instead it "is the tool or the means towards a particular end". There is a need to communicate "the outcomes or findings in a language which their target audience can relate to". S is of the view that mathematics students would benefit from "better enjoyment" and "interest" in the subject. He says that "the single most important piece of information that a teacher can have about a student is their level of prior knowledge in the topic that you are trying to teach them" and that mathematics "learning happens when the student manages to make that little extra step".

Engineer T

Gender: Female

Background: T is from a farming background.

Family: T is from a farming background and her father is also an engineer. She states that farming is similar to engineering; both are "practical", they each involve "technology", "efficiency" and "hard work". T states that there was "a certain level of competition in the family about maths", her older sister "got an A" so T "wanted to get an A". One of her brothers is currently "doing a degree in maths" and another brother is studying engineering.

Leaving Certificate mathematics level: Higher level, 2002

Education: B.E. (Electrical and electronic), UCC [University College Cork]

Decision to study engineering: Medicine was T's first choice of career, this was based on her ideas of "being successful" and "using the points to full effect". T now believes that "engineering was the best thing" for her. A number of factors contributed to T's decision to become an engineer. The primary factor was that while T knew her choice of engineering course was "a hard core", she felt confident that with "good grades in maths", she would "be able to do it". T also had an interest in "how things work", this she says stemmed from her father who is an engineer and a farmer.

Current work: T is a "sub-station designer" with a major energy provider. She designs power "transmission and distribution stations around the country" and also abroad.

Chartered Engineer: Chartered Engineer application in process

Leaving Certificate mathematics: T always had an interest in "playing with numbers", particularly car registration plates. She found mathematics "enjoyable" and "challenging" and she got a lot of "satisfaction" from it. T is competitive and she "would be very annoyed if someone got better than" her in mathematics. She liked the fact that mathematics had either a "right or wrong answer" unlike English about

which she states “no matter what you do you will always get a C in English, so what is the point”?

T’s “primary school maths teacher” was good; he was “very logical” and “when he was explaining maths problems”, “he would relate it back to practical examples”, there were “a lot of little tests” and he would encourage the children to do better in the next test. With good mathematics results, T “realised this is something that I could be good at”.

T did not attend mathematics classes in her Leaving Certificate year; she “just didn’t like being taught maths”, the teachers were not organised and she got “bored” when the weaker students were “driving the pace of the whole course”. T “dropped applied maths” because the “teacher hadn’t got the course done five weeks before the Leaving Cert”. T says that mathematics “is a personal thing and it is easier to work through it yourself”. Instead of learning to “regurgitate”, T preferred to derive formulae from first principles in exams, she says “it made so much more sense” that way. T didn’t “see the point of statistics and probability” and she omitted this section from her Leaving Certification preparation.

T is of the view that Leaving certificate mathematics “has nothing to do with thinking” and that it is more about getting points. She also asserts that, in a recent attempt to improve grades, the standard of the higher level Leaving Certificate exam has dropped considerably.

Engineering mathematics: T describes mathematics in university as “faster” and “more challenging” than school. She labels her engineering course as a “classical degree” with “a mix of everything” and which was also known as “four years of hell”. In her engineering class of ninety students, there were fifteen girls, T says that “the girls always got higher marks in exams and the boys always got higher marks in the projects”.

While T understood mathematics and was able to apply it, she “didn’t understand its application in a real life situation until” she went to university.

Use of mathematics in current job: T says that "engineering is such a varied profession" and that while "a lot of engineers end up working in the social side" of engineering and do not require higher level Leaving Certificate mathematics, she "definitely" requires it in her job. T describes her work as a mixture of "design" and "project management". She says that while "she could do ninety per cent of her job without maths", engineering is that extra ten per cent she gets paid for. In her job, T uses algebra, geometry, "a lot of calculus" and "very little statistics" at engineering level in reproducing, connecting and mathematising ways.

T states than in addition to "doing direct mathematics" there is also indirect usage which she describes as "a logical way of thinking" and a "way of working" that come "from having done maths". She describes mathematics as "clean", "logical", "totally transparent" and "a good way to justify an argument" because "nine out of ten times" she is "dealing with engineers" who "understand the logical approach".

What is engineering? T defines engineering as "more about getting the basics right and building from there than an extremely high level of maths."

Views on engineering: T asserts that engineering is not an attractive career choice for many young people. Instead students want the "course with the highest points". She asserts that there is ignorance about engineering; it is associated with "factory floor" tradesmen who were "paid more than engineers", "dowdy girls" and engineers who work as "project managers".

Views on mathematics: T asserts that the "logical thinking" benefit of mathematics education is relevant to many occupations outside of engineering and that "it is not actually the maths that's important it is how you use it". While it is acceptable to society that many Junior Certificate students "drop to ordinary level", T is of the view that bonus points would make "maths more of an elitist subject" and she believes that "the level of teaching maths is very bad".

Engineer U

Gender: Male

Background: U is from an urban background.

Family: U's father was a shop-keeper. The whole family worked in the shop and from a very young age U "had to be able to do sums quickly" in his "head in front of the customers". The children enjoyed working in the shop and U is of the view that the mathematics they learnt there "rubbed" off on them as "three out of four" of them became engineers.

Leaving Certificate mathematics level: Higher level, 1984

Education: Electronic engineering, UCD [University College Dublin]

Decision to study engineering: U states that from "around Junior Certificate", engineering was on his mind and his Leaving Certificate subjects were chosen based on that career path. It was very clear to U that he enjoyed "the maths, the applied maths and some of the physics" and he states that "engineering followed on from that". U's "two older brothers had done engineering" and he says that "they were definitely an influence".

Current work: U works with a major telecommunications company where he manages a team of ten engineers who "design the transmission network in Ireland." U says that his job is "on the line between the design and the senior management".

Chartered Engineer: Yes

Leaving Certificate mathematics: Compared to other subjects, U states that there "were more numbers and less learning" in his two favourite subjects; mathematics and "applied maths". He liked the "investigative" nature of applied mathematics and the notion that as well as solving a problem, he had to first define the problem.

U says that he had "an aptitude" for mathematics and he got "a buzz from doing" mathematics. He had "good teachers … right the way through from primary school". He defines a good mathematics teacher as "a teacher who is able to get the message

across to you". His own school principal, a Presentation brother and "a very nice guy", had "clearly a love of mathematics", he taught U that "presentation and showing how you got the right answer" was important. In order to get the "most students across the line", U's mathematics teacher omitted the statistics option from his Leaving Certificate preparation. U believes that statistics is "perceived to be harder" by both students and teachers.

Engineering mathematics: U is of the view that "because technology is moving at such a rapid rate, most of what was available" from his engineering education "has been long swept away". His work ability comes from "an awful lot of experience". U is of the view that "finance training" is required in engineering education. He also believes that engineering education is responsible for the declining numbers of engineers managing engineering companies.

Use of mathematics in current job: U says he requires "an understanding of mathematics and a mathematical view" in "everything" he does at work and very often he needs to be able to do mathematics "at speed". Every day, U uses statistics, geometry, trigonometry, numbers, algebra and functions and sometimes these domains are required at engineering level and in reproducing, connecting and mathematising ways. U says his company is "riddled" with "black box software solutions", some of which he made himself. These software solutions standardise solutions across groups of engineers.

When designing networks or solving "synchronisation" problems, U needs to "convert boxes and widgets into euros", turn "things like man hours into megabits per second" and create documents for the "finance people to provide" the money. These documents have to be "double" checked and while mathematically based they have to be put into "a form that a non-engineer will understand". U states that because "there are so many different layers in telecommunications networks" eight of his team of ten engineers are continuously "thinking and problem solving". When managing the "capacity in the network" U himself has to make decisions "based on problem solving and logical thinking". He has to do a "certain amount of estimation" to predict future network usage, for this he relies on both his "experience" and

knowledge of “statistics”. U maintains that as his career progresses he is “doing a lot more management orientated as opposed to problem solving oriented or design orientated” tasks and he has “to apply the maths” not just to engineering but to all the aspects of his company”.

What is engineering? U is of the view that an engineer progresses from “solving individual problems for individual sites” to “looking at the bigger picture” and to “areas such as finance”, capacity management, design and strategy. He is also of the view that “a huge amount of knowledge used” in engineering is “experience gained from” earlier years.

Views on engineering: U notes that engineers in his company go “into widely different disciplines” and the experience they gain in one area “is nearly always useful in another area”. In his team of ten engineers, there are mechanical engineers, electrical/ electronic engineers, one civil engineer and one B.Sc. graduate, none of whom are identifiable by their qualifications. U notes that Engineers Ireland’s concentration on civil engineering has “alienated too many other engineers”. U asserts that, in the context of career progression, “it is best not to be painted as an engineer” as chief executives tend to select their “very senior management” team from “marketing and accounting disciplines”.

Views on mathematics: U states that because his audience might not understand the mathematics and they are “afraid to ask”, he has “a certain amount of licence to get away with things as well”. He notes that reports “can be very biased” because “people are not going into the details behind the headline”.

APPENDIX 8: INTERVIEW CODING AND IDENTIFICATION OF THEMES

Included in this appendix are 107 descriptive codes and 10 themes identified in the interview data analysis. The descriptive codes were identified in the first cycle of coding and following subsequent coding cycles, 10 overarching themes, were identified. These are organised as follows:

Page number

1st cycle coding	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	T	Th	Theme
Functions													✓	✓	✓			✓	✓		1
Gender					✓		✓	✓							✓	✓	✓		✓		1
Geometry			✓				✓				✓										1
Hard work														✓			✓	✓			1
Learning mathematics	✓						✓	✓	✓	✓			✓		✓	✓	✓	✓	✓	✓	1
Leaving certificate mathematics curriculum	✓								✓					✓		✓			✓		1
Leaving certificate mathematics workload	✓		✓		✓		✓	✓						✓		✓		✓	✓	✓	1
Mathematics is … an easy subject					✓						✓									✓	1
Mathematics is … different	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓				✓			✓		1
Mathematics is … diverse																			✓		1
Mathematics is … one solution			✓	✓		✓					✓	✓				✓					1
Mathematics is difficult							✓		✓			✓									1
Mathematics teachers / teaching	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	1
Precision									✓												1
Pure mathematics														✓					✓		1
School								✓				✓						✓			1
Understanding is essential in mathematics learning			✓	✓	✓			✓			✓	✓	✓	✓		✓					1

Table A8-1: Theme 1: School mathematics.

1st cycle coding	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	T	U	Theme
Additional support for mathematics				✓				✓			✓										2
Applied mathematics	✓	✓								✓		✓	✓		✓		✓	✓	✓	✓	2
Background	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	2
Competitive person			✓									✓				✓	✓	✓	✓		2
Confident using mathematics	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓	2
Creativity									✓				✓								2
Engineering education	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓			✓	2
Engineering mathematics - workload	✓		✓	✓				✓													2
Engineers' enjoyment of school mathematics	✓				✓						✓	✓									2
Enjoy school mathematics	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	2
Enjoy using mathematics	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	2
Family background	✓		✓	✓	✓		✓	✓	✓	✓	✓					✓	✓	✓	✓	✓	2
Family constraints								✓													2
Feelings about mathematics	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓		✓		✓	2
History of mathematics														✓			✓				2
Image of student who is good at mathematics					✓		✓		✓	✓	✓				✓	✓			✓		2
Improve young people's affective engagement with mather	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	2
Mathematics and elitism													✓				✓		✓		2
Mathematics and isolation													✓				✓				2
Mathematics and politics																				✓	2
Mathematics and society	✓	✓		✓					✓								✓				2
Mathematics is … a tool	✓			✓			✓		✓				✓	✓	✓			✓			2
Mathematics is important					✓	✓			✓		✓			✓							2
Mathematics self-efficacy	✓			✓			✓		✓		✓					✓				✓	2
Mathematics usage "varies from job to job"	✓														✓				✓		2
Minority														✓							2
Motivation to study mathematics					✓						✓										2
Need higher level LC mathematics for engineering studies	✓	✓		✓	✓		✓				✓				✓						2
Negative experience with mathematics	✓	✓		✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		2
Numbers			✓		✓											✓				✓	2
Peers		✓					✓		✓	✓		✓		✓		✓		✓		✓	2
Perceptions of school mathematics	✓	✓		✓				✓	✓					✓	✓				✓		2
Persistence														✓							2
Personality															✓	✓	✓				2
Role models															✓	✓					2
Value of mathematics	✓	✓		✓	✓	✓	✓	✓	✓			✓	✓	✓		✓		✓	✓	✓	2

Table A8-2: Theme 2: Motivation to engage with mathematics.

1st cycle coding	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	T	U	Theme
Decision to become / study engineering	✓		✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	3
Engineering at second level						✓	✓														3
Feelings about mathematics influence engineering career ch	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	3
Young people's career choices					✓	✓	✓				✓										3
Young people's interests							✓		✓		✓										3
Engineeers' communication skills								✓										✓			3
Engineering achievements									✓				✓								3
Image of engineer															✓	✓	✓		✓		3
Ireland														✓					✓		3
Value of engineering	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓			✓	✓	✓	✓	✓	3

Table A8-3: Theme 3: Factors influencing engineering career choice.

1st cycle coding	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	T	U	Theme
Association between engineering and mathematics	✓		✓	✓	✓		✓	✓		✓	✓		✓			✓			✓	✓	4
Breadth of engineering	✓		✓	✓		✓		✓	✓				✓	✓	✓		✓	✓	✓	✓	4
Contract law is important								✓													4
Engineering is ... good grounding for management	✓																				4
Engineering is … a mindset			✓				✓														4
Engineering is … a tool box												✓									4
Engineering is … implementing ideas			✓																		4
Engineering is … interpreting data								✓													4
Engineering is … like Lego																	✓				4
Engineering is … more than mathematics				✓				✓										✓	✓		4
Engineering is … not first principles	✓			✓		✓	✓			✓					✓				✓		4
Engineering is … practical application				✓	✓	✓							✓				✓				4
Engineering is … problem solving	✓			✓			✓										✓	✓			4
Engineering is … taking constraints into account								✓													4
Engineering is … the bigger picture				✓				✓										✓			4
Engineering is … thinking											✓		✓								4
Engineering skills			✓	✓					✓												4
Finance is important in engineering		✓	✓	✓	✓	✓	✓				✓		✓	✓		✓		✓		✓	4
Managing people		✓	✓				✓							✓							4
Problem solving	✓	✓		✓					✓				✓	✓	✓	✓	✓		✓	✓	4
Real world										✓	✓							✓			4
Resources that assist job	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓			✓	4
Teamwork is important								✓													4

Table A8-4: Theme 4: Engineering practice, roles & activities.

1st cycle coding	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	T	U	Theme
Engineering career progression	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓		5
Engineers are … managers															✓						5

Table A8-5: Theme 5: Career development paths in engineering practice.

1st cycle coding	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	T	U	Theme
Curriculum mathematics usage	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓		✓	✓		✓	✓	6
Simple mathematics	✓				✓																6
Use of higher leaving certificate mathematics in job	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	6
Visibility of workplace mathematics		✓	✓				✓														6

Table A8-6: Theme 6: Engineering practice, *curriculum mathematics* usage.

1st cycle coding	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	T	U	Theme
Curriculum vs. thinking usage	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	7
Engineering is … understanding	✓			✓				✓													7
Estimation of solution	✓		✓	✓	✓				✓					✓	✓		✓			✓	7
Mathematical thinking	✓	✓																			7
Mathematical thinking is … problem solving	✓					✓															7
Solution confirmation	✓	✓		✓	✓				✓	✓	✓	✓	✓			✓	✓		✓	✓	7
Statistics	✓	✓	✓	✓	✓	✓			✓			✓	✓	✓	✓	✓		✓	✓	✓	7
Thinking usage	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	7

Table A8-7: Theme 7: Engineering practice, *thinking* usage.

1st cycle coding	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	T	U	Theme
Communicating mathematics	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓		✓		✓	✓		✓	8

Table A8-8: Theme 8: Engineering practice, communicating mathematics.

1st cycle coding	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	T	U	Theme
Mathematical approach necessary	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓		✓	✓	✓	9
Seek mathematical approach	✓	✓	✓		✓		✓	✓	✓	✓	✓				✓	✓		✓	✓	✓	9

Table A8-9: Theme 9: Engineering practice, *engaging* with mathematics.

1st cycle coding	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	T	U	Theme
Academics																		✓			10
Engineering - learn by experience	✓		✓	✓	✓	✓	✓	✓			✓		✓		✓	✓	✓			✓	10
Recollection of engineering mathematics	✓							✓	✓												10
School mathematics vs. engineering mathematics	✓																				10

Table A8-10: Theme 10: Relevance of engineering education to engineering practice.

APPENDIX 9: INTERVIEW DATA ANALYSIS

Included in this appendix are: a profile of interviewees; profile of engineers' mathematics teachers; engineers' motivation to engage with school mathematics; feelings about engineering mathematics; feelings about mathematics in engineering practice; feelings about mathematics outside of engineering; engineers' feelings about mathematics; engineers' path to engineering education; engineers' job descriptions; engineers' views about engineering practice; engineers' *curriculum mathematic*s usage; engineers' *curriculum mathematics* usage by discipline and role; engineers' views about and usage of mathematics in engineering practice; the need for a mathematical approach in engineering practice; and the value of mathematics education in engineering practice. This appendix is organised as follows:

Page number

Profile of Interviewees							
Name	Company Sector	Gender	Engineering Discipline	Engineering Role	Mathematics Usage	Mathematics Level	Leaving Certificate (LC) Year
A	Pharmaceutical	M	Chemical	Design / Development	1.28	H	1990
B	Telecommunications	M	Electronic / Electrical	Technology Service Sales Manager	1.52	H	1984
C	Project engineering	M	Mechanical	Design / Development	1.76	O	1985
D	Project Engineering	M	Mechanical	Project Management	1.88	H	1966
E	Project Engineering	F	Civil	Design / Development	2.04	H	1997
F	Energy distribution	M	Mechanical	Project Management	2.08	H	1985
G	Electricity distribution	M	Electronic/ Electrical	Commercial	2.09	H	1994
H	Project Engineering	F	Civil, Rail, Water	Design / Development, Resident Engineer	2.33	H	1997
J	University	M	Biomedical	Education, Research	2.67	A-level	1971
K	IT consultancy	M	Electronic/ Electrical	Information Technology Consultancy	2.68	H	1995
L	Project Engineering	M	Electronic/ Electrical	Design / Development	2.90	H	1997
M	Consumer electronics	M	Manufacturing / Production	Design / Development	2.91	H	1991
N	Local authority	M	Civil	Maintenance	3.34	O	1981
O	Software	M	Software	Design / Development	3.51	H	1979
P	Retired	M	Electronic/ Electrical	General Management	3.53	H	1963
Q	Medical Devices	F	Medical Devices	Design / Development	3.54	H	2003
R	Local authority	F	Civil	Design / Development	3.60	H	1980
S	University	M	Electronic/ Electrical	Education	3.84	H	1980
T	Electricity	F	Electronic/ Electrical	Design / Development	4.17	H	2002
U	Telecommunications	M	Electronic/ Electrical	Design / Development	4.23	H	1984

Table A9-1: Profile of interviewees.

Engineers' Mathematics Teachers					
Name	**Gender**	**Maths usage**	**LC level**	**LC year**	
A	Male	1.28	H	1990	• "Two excellent maths teachers" in secondary school
B	Male	1.52	H	1984	• "Good teachers" in secondary school
C	Male	1.76	O	1985	• "Easy going" teacher in secondary school
D	Male	1.88	H	1966	• "Plain ordinary bad" teacher in Leaving Certificate
E	Female	2.04	H	1997	• "Super teacher" in secondary school
F	Male	2.08	H	1985	• "Some good maths teachers" and also "some really bad ones"
G	Male	2.09	H	1994	• "Very solid" teacher for Leaving Certificate
H	Female	2.33	H	1997	• "Excellent teacher" for Leaving Certificate
J	Male	2.67	A-level	1971	• "Very good teachers"
K	Male	2.68	H	1995	• Primary school teacher "had a strong focus on mathematics" • "Excellent" teacher for Junior Certificate • "Poor" Leaving Certificate mathematics teacher
L	Male	2.90	H	1997	• "Very good" Leaving Certificate mathematics teacher
M	Male	2.91	H	1991	• "Excellent" teacher for Leaving Certificate
N	Male	3.34	O	1981	• "Very poor" teachers in Junior Certificate • "Good" teacher for Leaving Certificate mathematics
O	Male	3.51	H	1979	• "Fabulous teacher" in secondary school
P	Male	3.53	H	1963	• "Good teacher" in primary school • Physics teacher and mathematics teachers were a "big influence" in secondary school
Q	Female	3.54	H	2003	• "Unpopular teacher" in secondary school
R	Female	3.60	H	1980	• "Manic depressive" teacher in secondary school • "Revelation" in grind school
S	Male	3.84	H	1980	• "Brilliant teacher"in secondary school
T	Female	4.17	H	2002	• "Very good" teacher in primary school • "Self-taught" for Leaving Certificate
U	Male	4.23	H	1984	• "Good teachers … right the way through from primary school"

Table A9-2: Profile of engineers' mathematics teachers.

Engineers' Motivation to engage with School Mathematics	
A	
Feelings	• A "enjoyed maths all the way through" school because he "was good at it". • Knowing he had "the right answer" was "very direct gratification" for him.
Views/ beliefs	• A's view is that mathematics is "a hard grind",
Self-efficacy	• A says he "was good at problem solving" and the "sense" of getting "the answer right" and knowing that he had "the right answer" was "very direct gratification".
Value	• A is of the view that there is little value in taking higher level mathematics in the Leaving Certificate if it consumes "almost all of the two years". • For A the "value" of higher level Leaving Certificate mathematics is the ability to get "through engineering studies". • A wasn't "particularly comfortable" with statistics. However he believes that statistics and getting "a feel for data is very important".
Effort	• A says "I was determined to work out every maths problem that came my way".
B	
Feelings	• B enjoyed school mathematics because he "was good at it". • B still feels "proud" of his Leaving Certificate mathematics achievement.
Views/ beliefs	• B is of the view higher level Leaving Certificate mathematics is "a hard grind".
Self-efficacy	• B says mathematics was "a reliable subject" for him from the point of view of success".
Value	• Higher level mathematics was required for engineering education
Peers	• The most "notable feature" of B's engagement with secondary school mathematics was his "peer group" of friends, who also "had proficiency in maths and were targeting an engineering qualification". B recalls that a group of "six or ten guys that were sparking off each other in terms of those subjects". B says that within the group there "was an interest in getting a common approach" in mathematics and applied mathematics problem solving. He describes the group as "a very self-sustaining group" as they would "share perspectives" when presented with a difficult problem. Because the group was "so natural" and "so wholesome" in the context of doing mathematics, there "was never an issue" with mathematics. B states that the "comfort and positivity" of the group towards numerate subjects was "hugely important" at the time.
Effort	• B's teachers "challenged" him with "maths problems" and he "persisted" until he worked out the answer.
C	
Feelings	• C says he enjoyed school mathematics. He is of the view that success and enjoyment are necessary in mathematics learning and he says that "there is certain amount of fulfilment" in getting the correct answer while in subjects such as English, if you "think you have done a damn good job" you might only get "fifty per cent".
Value	• C states that his secondary school "didn't have the critical mass of students necessary to do higher level maths" and it would have "been

	too much" to do outside of school.
Effort	• C states he was competitive in primary school and that he did the mathematics as fast as the teacher "could dole out the maths".
D	
Feelings	• D sates that he was not a "fan of maths" in school. • D is of the view that his feelings about mathematics impacted not just his education but also his career.
Views/ beliefs	• He was "prejudiced that maths was hard and he states that consequently he "just wasn't good at maths". • D believes that mathematics is more difficult than other subjects. It is "unique, it's precise, there is a right answer, there is a step by step …. It even looks different … you can't bluff it".
Self-efficacy	• D says that he developed an "inferiority complex about maths" and a "blockage" to learning mathematics in secondary school.
Value	• D knew that higher level Leaving Certification mathematics was a "career requirement" and his interest in engineering as a career motivated him to continue with the higher level option.
Peers	• D states that he relied on some of his peers who "used to give tutorials" to the rest of the class in preparation for mathematics exams.
E	
Feelings	• In primary school, E had "good feelings" about mathematics, she "enjoyed it", she "liked the challenge of it" and she "liked getting it right". • E also "loved secondary school maths". She says it was "very rewarding" to get something right for her mathematics teacher.
Self-efficacy	• E knew she was good at mathematics and if she got something wrong in a mathematics test, she would ask herself "why didn't I get 100% when I could have".
Value	• E states that in her school mathematics was perceived as "a measure of your ability as a student" and that "once you were good at maths that was what was important". E believes because mathematics was assigned such importance this is why she "put more work into maths rather than other subjects".
Effort	• E says the "praise" she got from her mathematics teacher in primary school egged her on and she "would be gutted" if she "didn't get 10 out of 10" in her "tables test every Friday". • She was very motivated to do well in Leaving Certificate mathematics in that she "wouldn't drop a difficult mathematics problem", instead she would "wait and stick it out".
F	
Feelings	• In school F was "drawn to physics, chemistry and maths" but mathematics wasn't his favourite subject in school.
Value	• F says his Leaving Certificate mathematics "meant nothing" as he "couldn't relate it really to everyday life". He is of the view that "nobody" knows what "differential and integral calculus" is for and that teachers do not explain "how it is actually used".
G	
Feelings	• G says he enjoyed mathematics and he was "very comfortable with numbers".
Views/ beliefs	• G is of the view that Leaving Certificate mathematics is **"**hard enough" and is "very time consuming."
Self-efficacy	• G says he became confident in mathematics and "very comfortable

	with numbers".
Value	• G says that he wasn't interested in mathematics prior to secondary school. In secondary school he became interested and he attended "maths competitions" every Saturday morning. He recalls learning "a lot of number theory stuff" and "patterns" which he found "quite interesting". • G believes that there is something special about "being able to do something other people can't do" and the boys in his school "who were good at maths got a lot of respect".
Effort	• G's mathematics teachers in school "challenged" him and he says he was "very motivated to do well in maths".
H	
Feelings	• H rates her enjoyment of school mathematics as "a very great deal". "Maths would be the first" subject H chose when doing her homework. She found it "nicer study than the other subjects" as "it wasn't just sitting down trying to remember loads of stuff" instead it was doing mathematics. H says that once she grasped a particular mathematics methodology, she could re-use it. This was in contrast to "learning stuff off by rote" which H says was "too inefficient".
Views/ beliefs	• H attended a particularly good all-girls school where a third of her class took the higher level Leaving Certificate mathematics exam. She says that these girls were branded as being good at mathematics. H believes that higher level mathematics is "seen as quite prestigious" and that this perception "needs to be wiped out". • H is of the view that there is "a huge level of difference between honours and pass maths" and that "pass maths needs to be a bit more challenging" rather than reducing the higher level standard.
Self-efficacy	• She says she was confident in her ability to solve difficult problems.
Value	• H was interested in mathematics. She says her teacher was "never boring", she engaged the students and in class they had "to do the maths to learn".
Effort	• H states that with mathematics "you have to be engaged" • H describes mathematics as an "active" subject in which one has to be "engaged" in to do well. She says that she was "very dogged on working stuff out" and when she did solve a mathematics problem she was "delighted" with herself. • H believes that unlike other subjects, results in mathematics are directly related to "the effort you put in".
J	
Feelings	• J says he was "always attracted" to mathematics because he didn't "have a particularly good memory". He says the "fun" of mathematics was "to derive the solution on the spot". He says that this methodology worked for him as "the deriver would always be successful and the learner might not be".
Views/ beliefs	• J believes that the way mathematics is taught makes it more "challenging" and it requires "more brain work" than other subjects. • J argues that there is a "them and us culture" associated with mathematics. He is of the view that mathematics "cut-off" happens at quite an early age when "people decide that they can't do it" and "that the people who do it are somehow different from them".
Self-efficacy	• J says that while he was good at mathematics he was "never top of the class" and he asserts that the key to mathematics learning is "finding that you are able to do it" and this "unique skill doesn't come up much in any of the other subjects".
Value	• According to J, "being good at maths had almost as much of a cache

	about it as being good at football". J says that the other students "could see that the geeks had their uses" and J "got some brownie points for" helping other students with their mathematics homework.
Peers	• J's group of friends were all good at mathematics and they collaborated over homework. They also "played football together because nobody else would play football" with them.
K	
Feelings	• K says that he was "mad for mathematics" in school and he found it "instantly rewarding". • K says that he found "maths easy and very enjoyable" and consequently "people were always deferring" to him and copying his homework.
Views/ beliefs	• K believes that many young people have a negative perception of those who are good at mathematics. They do "not to want to stand out by being good at something like maths", instead they "want to fit in more" with their peers. • K notes that some of his secondary school class mates were "very much more isolated because of their abilities and skills in maths and they would have been pushed out of the groups". He said he never felt such pressure in school and that he used to "hop from one group to another".
Self-efficacy	• K knew he was good at mathematics.
Value	• K says that he was "mad for mathematics" in school and he found it "instantly rewarding". K recalls at a very young age "getting the maths questions right" and "being rewarded for it and getting a gold star". • K says that as a child he was "very shy" and the "instant recognition" he got for being "good" at mathematics helped him come out of his "shell". The "instant gratification" K got from mathematics helped him to develop the "ability to stand up in class and answer the questions, from a very young age and be more correct than everybody else". He says that mathematics has "an instant answer" and "if you are correct you're great". • K was interested in mathematics. His Junior Certificate mathematics teacher made mathematics "interesting"; she "would talk about other elements where maths could be used". • About mathematics, K says he "always thought of it as an important subject probably because" he "was a bit of a nerd". • K says he knew "that maths always had a part to play in science and technology" and thus mathematics always had a "value" for him. • K is of the view that school students currently value mathematics from a points perspective rather than from an applications perspective.
Peers	• One of K's school friends, who also became an engineer, was good at mathematics and they studied together.
Effort	• K admits that "without a little bit of extra challenge" in mathematics from his secondary school teachers he "would have been bored". • K 's way of learning was to "figure why it was", he would "ask the teachers to explain" and if they could not explain" he had "to take them on". • If K "wasn't sure of a formula" he "would just go back to first principles and work it out". • In the context of mathematics problems, K says "when you can solve it, it is a sense of achievement and it spurs you on to do more and when you can't, you get a sense of failure and this 'disincentivises' you from learning anymore".
L	

Feelings	• In primary school L says that because he was "good at maths and enjoyed it, it became easy" and he recalls being "automatically rewarded by the teachers". • L rates his enjoyment of secondary school mathematics between "quite a lot" and "a very great deal". He says it was "definitely the easiest" subject in school.
Views/ beliefs	• In school L was branded as being good at mathematics, he says he was "angry" when "put "into a certain group who would be the geeks". He says tried to hide "the guilty pleasure of enjoying maths" and that he "let on that it took" extra time to answer a mathematics question. • L asserts that current school students do not enjoy mathematics as much as he did. He is of the view that "the level of maths has actually decreased" since he did his Leaving Certificate exam.
Self-efficacy	• He says he always had a "natural ability" in mathematics and he "always had that confidence and that kind of ability from a young age".
Value	• For L, mathematics "was always important" and he "held it in high regard". • L says because he found mathematics "so easy, it was always relaxing to do something that to other people was very challenging. He says there was "that level of satisfaction" and he got "pleasure" in the fact that he "could do something so easily that other people couldn't do".
Effort	• He recalls "the enjoyment of solving a problem" in secondary school when he says he "would persist and try and work it out". • He says had a "goal to get a certain answer". • L "pushed" himself in mathematics because he would be "disgusted" if he "wasn't at the top in mathematics" class. • L "would have always gone ahead of the teacher in the maths curriculum".
M	
Feelings	• M says that if he was to rank his school subjects "maths was number one". M says he enjoyed "solving problems and getting the right solution". • M says he "got good results in primary school maths" and "if you were getting good marks you were happy, that was a closed loop of get good results, be happy, get good results and be happy". • M says his good mathematics results continued through to secondary school. M says he "definitely enjoyed maths more from Junior Cert on because I was getting strong results in exams that mattered". M says that as "the maths got tougher" he "relied more on the teacher".
Views/ beliefs	• He says that higher level Leaving Certificate mathematics is "a mixture of a hard subject and a huge amount of time".
Self-efficacy	• M says his good mathematics results continued through to secondary school. In the first and second years of secondary school strong and weak students were mixed and M felt relatively strong in mathematics. From Junior Certificate onwards, the students were "graded" and the "honours classes" were given the "better teachers". • M says that "he worked very hard at maths for the Leaving Certificate" and "if I couldn't get an A and be the best at it, I would not be confident at it".
Value	• M says that Leaving Certificate mathematics took up more than half of his allocated three hours of study time. He recalls that sometimes he risked passing his Leaving Certificate exam when he did "an extra maths question" and skipped the other subjects.
Peers	• M says that "Leaving Certificate maths just turned into this challenge, this fun thing as I said a few of us doing the maths together". He said

	that the boys were all "fiercely competitive" they all played Gaelic football and "if we were going down the canteen to eat, we would race down there, to see who would be first". • M recalls that in preparation for his Leaving Certificate he worked on mathematics problems with a group of four other boys.
Effort	• M maintains that mathematics is about "trying to work it out" and he says "I kept at it until I got the right answer". • M found it difficult not to spend his entire study period doing mathematics and he is of the view that managing his study time taught him "discipline".
N	
Feelings	• N's feelings about school mathematics are mixed. He says that trigonometry and algebra were his favourite subjects and he was "hooked" on them. • While N enjoyed Leaving Certificate mathematics, he did not enjoy Intermediate [Junior] Certificate mathematics because he "had a very poor teacher"
Views/ beliefs	• N is of the view that there "are some areas of maths that need to be applied as opposed to just straight studied".
Self-efficacy	
Value	• He says he couldn't "relate" to the subject and that "it didn't matter" to his teachers whether "we learned it or not". • He says that he knew that "algebra, trigonometry and numbers were essential" but that he found other areas of mathematics "totally abstract", he "couldn't see the point" of them and they "turned us off". • N says that he saw statistics as "such a narrow field" that he could never see himself using. • N asserts that the real value of school mathematics for current students is "just for points in the Leaving Certificate".
O	
Feelings	• O says he loved school mathematics "because it is so beautiful I guess." He says his teacher "transformed me from being someone who didn't like maths or didn't care about it to someone who loved it" • O says that as mathematics "got more difficult" he "started to enjoy it more" because he "found" he "was good at it". • O is of the view that "maths is so much easier" than other subjects and that "you don't forget" it when "you understand" it.
Views/ beliefs	• O says that he would not be comfortable declaring his "love for mathematics" in school because he feared that he would have been branded the "school geek". He adds that he is "a reasonably rounded person enough and that maths wouldn't be the sole and abiding thing". • He says that the problem solving approach of the Project Maths "is a good idea but not at the expense eliminating part of the curriculum".
Self-efficacy	• O says that in school he "found I was good" at mathematics.
Value	• In school the "history of maths" just captured O's imagination. O says the teacher "held our attention, he could tell a good story and he did tell a good story". • O says he would "have been seen as someone who was very good at maths" and he was "in demand" by other students who needed help with their homework.
Peers	• O's school friends also loved mathematics. He says that a core group of "six or seven friends formed" as a result of them attending extra maths

	classes after school and "that helped with the maths".
Effort	• O says his teacher gave him "a love of maths … he showed me how the solutions were so wonderful and beautiful and just cool … I wished I could think like that, I wanted to think like that … I wanted to find out all about the history of maths … I read every maths book I could find".
P	
Feelings	• P is of the view that he was "interested in maths" because he was "good at mathematics" and because it "came easy" to him, he "enjoyed it".
Views/ beliefs	• P says it was "obvious" to him "that maths was easy for some people and difficult for others" and he "would also have been aware that in general terms girls didn't do higher level maths". • P is of the view that while he never "felt the urge to outshine other people he "would have been regarded as something of a phenomenon" in school due to his "innate" mathematical ability. He says he "tried not to alienate other students with mathematics".
Self-efficacy	• It was "obvious" to P "that maths was easy for some people and difficult for others" and he was "happy" with his "innate ability" in mathematics.
Value	• P was interested in mathematics; he says "you were almost for ever learning something new". • For P "maths was a pleasant intellectual exercise". • P was aware "that mathematics would have been an important subject" for him
Effort	• For P "maths was a pleasant intellectual exercise". He says mathematics was about "learning and solving problems … there is a lot of discoveries that one makes about mathematics as one progresses up the tree and I found learning pleasant … I always tended to read ahead."
Q	
Feelings	• Q recalls that in primary school mathematics was about getting "the right answer, it was "like a race or a game". • She says that getting the "wrong" answer "feels bad". • Q attended an all-girls secondary school where she says she "always liked maths" and she looked forward to "maths class". • She says she always did her "maths homework" first and often spent two hours each day doing Leaving Cert mathematics homework. • Q liked mathematics because she could "do a sum in half a page" and "still get full marks" whereas in subjects such as English she "didn't want to write three pages of an answer" and get a lower grade.
Views/ beliefs	• Q says that there "was kind of a stigma associated with school maths". She says in her school "maths was nerdy" and "the same twelve girls did honours maths, physics and chemistry". • She says that in school when she "would be the only one in the class" who got a particular mathematics question correct, the other students would look at her, she says she felt "like a closet nerd". Q says she was "probably a closet nerd" because she felt alone in her enjoyment of mathematics and she wouldn't readily "come out" and says 'maths is my favourite subject'". • Q says she wasn't aware that "maths is only for boys" until her middle to late secondary school years. • She says her sister did ordinary level mathematics possibly because she "didn't have the right teachers" and for "the amount of work she would have had to put in to it, wasn't really worth it".
Self-efficacy	• I wanted to do well because I thought I could do well".

Peers	• Q sought out and "found a few female role models who had got As in Leaving Certificate maths". She says that these "mentors or role models" helped motivate her and they helped her realise that she could get an A in Leaving Certificate mathematics. Q says she now wants her younger brother "to know that he too can get an A".
Effort	• Q says that sometimes mathematics "required a lot of effort" and if "I didn't get it I would go and move on and come back to it". • Q says she was "diligent", "methodical" and she "wanted neat handwriting". She says that "understanding" and "checking the answer" were important in mathematics, she would also "go back" over her work and she "filled in units" to verify that equations were correct.
R	
Feelings	• R says she enjoyed mathematics in school but that she "preferred history". She was interested in "great designers" and read about their "calculations and drawings". • The mathematics teaching in the convent school was poor and out of fear of failing mathematics R and two other girls switched to a grind school. • R says her new mathematics teacher "totally revitalised her feelings of what maths was about".
Views/ beliefs	• In secondary school, R says she believed that "it was only boys who had the ability to grasp most of higher level Leaving Certificate maths." • R is of the view that there is a "stigma associated with being good at maths" and that "if you're brainy you can't be good at anything else … a swot can't be an all-rounder". She says that her own son and his five friends who are all very good at mathematics are excluded from the football team.
Self-efficacy	• In the grind school, R began to feel more confident in her ability to do higher level Leaving Certificate mathematics.
Value	• R says "I knew that I needed honours maths for engineering and I had to do it by hook or by crook in whatever way I could remember it to get a C in the honours exam". • R says she "couldn't relate the maths to anything".
Effort	• R says she learnt mathematics "by slight rote and by default and by memory and everything else because of the poor teaching practices". • The mathematics teaching in the convent was poor and out of fear of failing mathematics R and two other girls switched to a grind school. • R says she was competitive in school and that she was determined to "find the solution" to mathematics problems.
S	
Feelings	• S says he loved mathematics in secondary school and he got a "great buzz" from "difficult homework.
Views/ beliefs	• When asked if he got a buzz from doing mathematics S replies "yeah, I am such a sad individual". • S attended an all-boys school where he says "the competition was fierce" in the "top maths class in the school … with the top teacher". S says the boys were "too geeky" to work together, he says "our maths homework was a competition to see who would get it out … when you went home there was no communication with the outside world, it was your problem and you would try and work it out … because the following day Batty [mathematics teacher] would ask who got it out".
Self-efficacy	• S became confident when he progressed to the top mathematics class.
Value	• He says that "maths was what I was interested in doing at the time, I

	just loved it". • When S was "the only one in the class who got it [difficult homework] right", the teacher would praise him; S would be "on cloud nine".
Effort	• S says "it [mathematics] was the subject that I put most into … it is said the more work you put into something the more you get out of it, so I used to do one hour of maths a day religiously, whether I needed to or not" • He says he got "a certain buzz out of being able to get to a solution in a smaller number of lines … there was probably an element of arrogance in this as well … if it was really important you would go back and verifying every step" He adds "I warmed towards problems that in my mind were more concrete … I liked problems where you could get your teeth into the problem and work out the exact answer … I was obsessed with quantifying things to the n^{th} degree".
T	
Feelings	• T found mathematics "enjoyable" and "challenging" and she got a lot of "satisfaction" from it. • She liked the "reasoned ways of thinking out a mathematical problem". • She liked the fact that mathematics has either a "right or wrong answer" unlike English about which she states "no matter what you do you will always get a C in English, so what is the point"? • T says "I would be very competitive when it came to maths … I would be very annoyed if someone got better than me, it used to really rattle me … it was just about maths not the other subjects".
Views/ beliefs	• T says "there is a very negative view towards maths" and that people who "were good at maths in school would have been deemed to be geeks". She feels that because of her personality and appearance she wasn't branded a geek even though she was good at mathematics. • T is of the view that Leaving Certificate mathematics "has nothing to do with thinking" and that it is more about getting points. • T feels that "an A in maths is considered to require double the study time compared to many other subjects". • She also asserts that, in a recent attempt to improve grades, that the higher level Leaving Certificate mathematics exams have got "progressively easier since 1990".
Self-efficacy	• T says while in primary school, "I got confidence in the fact that I was getting good results in mathematics and then I realised this is something that I could be good at". • She adds "I was always proud of the fact that I was good at maths".
Value	• T is of the view that "an honour in maths is actually worth something … it is worth more than an honour in Irish or English". • T says "you only need to get one good grade in secondary school and the teachers will leave you alone". • T didn't "see the point of statistics and probability" and she omitted this section from her Leaving Certification preparation. • T asserts that the current value of mathematics to most secondary school students is from a "points" perspective. • T did not attend mathematics classes in her Leaving Certificate year because the weaker students were "driving the pace of the whole course".
Effort	• T says "I worked harder at maths than probably any other subject because I liked it … I liked the challenge and I liked being good at maths, it was easy to be good at it and it just felt natural. • T says that mathematics "is a personal thing and it is easier to work

	through it yourself". Instead of learning to "regurgitate", T preferred to derive formulae from first principles in exams, she says "it made so much more sense" that way.
U	
Feelings	• U says he got "a buzz from doing" mathematics in school and working out the correct answer. • U says that "out of the seven subjects I did mathematics was either my favourite or my second favourite subject". U "slightly preferred applied maths compared to maths … because it was more problem solving, more let's say investigative … in other words, you are given a, b and c and work out d, but don't even know what d is in all the questions and you have to go and find out, what do they want me to get here … and that was a challenge".
Self-efficacy	• U states that he had "an aptitude" for mathematics and he "never had to worry about it thank God".
Peers	• U recalls when in secondary school, the school principal who was "a Presentation brother" and who "clearly had a love of mathematics" helped the mathematics teacher by giving a "free grind" to students every Saturday morning. U says that "everybody" in sixth year attended because "it was too good to miss".
Effort	• I had to do that a lot less in maths than I did in other subjects and indeed a lot less than my fellow pupils … I know some of my fellow pupils were spending twice maybe three times as much time as I was studying maths".

Table A9-3: Engineers' motivation to engage with school mathematics.

Feelings about Engineering Mathematics	
A	If one "couldn't do maths at higher level", then one "would probably struggle with traditional engineering". The "value" of college mathematics was for the purpose of passing an exam at the end of the year.
B	Without higher level Leaving Certificate mathematics, one would "struggle" in engineering education. Engineering education should "aim the course for the top five or ten per cent of engineers that are going to bear that design responsibility". People who pursue less numerate careers as these people benefit from the discipline and rigour of learning mathematics.
C	Mathematics was one of C's best subjects "all through his degree".
D	In engineering education "you're up against it" and a "good standard of maths" is necessary. D "endured the maths, to get through college". D's "blockage to learning mathematics" and his "lack of maths caught" him "all the way through college". Mathematics teaching in universities is "bad". D says that the "take it or leave it" approach to teaching mathematics in universities does not work. He believes that, in universities, there is a need for teachers who demonstrate a "willingness to teach rather than just throw" the mathematics at the students. Many engineering subjects "are taught through mathematics" and students thus need a "very high standard of maths" to "grasp" subsequent engineering concepts.
E	Engineering students will "not stick" engineering courses unless they enjoy mathematics and they have higher level leaving certificate mathematics.
F	As F went through college, he got to like mathematics as he "could see it applied". In college F "used maths in the other subjects", particularly thermodynamics and fluids. He says that while he did "not develop a love of maths", he was able "to relate to it more" in college than in school.
G	In university G "wasn't bad "at mathematics but he "wasn't brilliant" either. He said that he was confident enough not to "shut down when maths was mentioned" in an engineering context. He says that higher level Leaving Certificate mathematics was "definitely necessary to get through engineering" education.
H	Higher level Leaving Certificate mathematics was "necessary" for H's engineering education. While she always "found maths real easy to study", she says that there was "so much of it for the first two years" of college. H maintains that in university "lecturers don't teach, they lecture", "they tell you where the information is" and you "are very much left working it out for yourself". She says that without confidence in her mathematics ability, engineering education would "intimidate" her.
J	J found mathematics much more challenging at university than school, in university he says there were "a lot of us putting our heads together trying to get solutions". J believes that students who enter engineering courses with a grade C in higher level Leaving Certificate mathematics need to work "hard to keep up what we are teaching".

	He describes his university mathematics as "applied maths" and "certainly not pure maths". J says that the lecturer's job is to let the undergraduate engineering students out of university "with a level of maths that we think is appropriate for a professional engineer, a Chartered Engineer, which of course is a very high level of engineering". J asserts that students need "to understand how important maths is in the engineering world". He says that students who become engineers and managers of "other people who are using maths" need to "understand the language of mathematics and the importance of it for the engineering field".
K	K notes that while his engineering class were all "quite strong" at mathematics, a few students "really struggled at certain elements" of engineering mathematics.
L	L is of the view that mathematics was not as easy in college compared to school. He believes that "anybody who goes into engineering with low marks in mathematics …is going to struggle". L says that his engineering mathematics "didn't relate to the other elements of the degree". It was "taught by the mathematics department and most of the other subjects were done through the engineering school".
M	M says "I lost my love for maths as soon as I went to college … it was hard, it was complicated …I would have to blame the lecturers … it was a completely different way of doing maths than the leaving certificate … in school the teacher interacted with a class of twenty five of us and there were two directions with the maths … however in college when you are getting lectured on maths it's one direction only … it was all just thrown to you". M admits that "while it was sad to be talking about maths" he missed the "banter" of "the group that studied together" in school. He says that he "wasn't a nerd but the social element of the maths was gone" in college. M says that in college "maths was the one subject that I found the most difficult in transition". He says that college mathematics was "very theoretical" and that it was "difficult to apply and to internalise".
N	While N says his engineering education gave him the "mentality to think", he is of the view that engineering mathematics is "a means to an end". He says that apart from "report writing, problem solving and spatial awareness" the purpose of engineering mathematics is to pass the engineering exams.
O	O says that higher level Leaving Certificate mathematics was necessary for civil engineering education and that "you won't survive without it".
P	P asserts that "one needs the higher level maths to get through an engineering course" P says he wasn't a diligent student in university. Having failed a mathematics exam, he says he was "highly insulted" and "to have someone question my ability in mathematics, it challenged what I believed about myself and I took umbrage and decided to show him". P says that engineering mathematics "serves as a platform on which one can undertake the kind of reasoning that is necessary when confronted with technical challenges or situational challenges of any sort".
Q	Q says that engineering "was tough … the hours were a lot longer than you know the arts block … it was just the workload" when compared to other courses. Q said that she had to "turn off" the students in her course "who weren't very studious". She said that she "would not dare ask a question out loud in a lecture" while in tutorials "the post-grads would come and just talk to you". She says she studied with her boyfriend up to third years when he took the civil engineering option and she chose mechanical.

	Q says that there is "still a lot of maths" that she studied in college that she doesn't "know the application of".
R	R says she would not have been able to do engineering mathematics without higher level Leaving Certificate mathematics. She says she found her engineering course " very difficult" as she was in a class "with male colleagues who had done mechanical drawing, who had done applied maths, who had been told because they were male that they were probably better at maths than the girls". R says she had "never heard of applied maths" until she was in university. She says "everybody else had applied maths … they had a greater comprehension of what they were doing". R says she felt "completely disadvantaged" from the start of university and she also "found maths in university extremely hard". R says that it wasn't until third year that she "started relating" to the mathematics in the course, she says "it kind of came to me … that's what dy/dx means, finite element analysis was a huge eye opener, I thought it was marvellous … nobody ever related maths to me ever".
S	
T	T says she enjoyed mathematics much more in college than in secondary school because it was at a level that was "faster and a bit more challenging" than school. T says her interest in college mathematics was primarily in the applications of the subject. She says she is into the "practical use of maths … what can you use that for, why is that any good to you".
U	U is of the view that students would find engineering education a lot harder if they didn't like maths". He notes that from his college experience, part of which he shared with civil and mechanical engineering students that "some" engineering students "didn't like maths but they liked the engineering aspects of the course". U says the "civil students definitely gave me the impression they weren't that interested in maths, whereas the mechanical, the electrical and the electronic students were all very into maths".

Table A9-4: Feelings about engineering mathematics.

Feelings about Mathematics in Engineering Practice	
A	• A's job does not require higher level Leaving Certificate mathematics. • A believes that when "trying to fix something" in engineering practice that "having a feel for an answer or solution is more useful" than having an answer "correct to eight decimal places".
B	• B enjoys working with numbers. • Mathematics did instil "great confidence" in B in terms of career progression • B says that "so much of the value an engineer brings to his job and brings to society is to be able to do a reasonableness test to conceive a solution and within a good level of probability to be able to say yeah, that will meet the need, but then not being afraid to modify that and evolve that in subsequent observations or in practice".
C	• C does not think that "it is necessary for engineers to have honours maths". • C enjoys using mathematics in work. • C also recognises the security associated with a mathematical answer and he likens mathematics to "a safety valve" in his work.
D	• Due to "the very poor grounding" D "got in maths" he "was afraid of some of" the mathematics he encountered in engineering practice. D says that when using mathematics he has "a nagging fear that" he has "got something wrong". He notes that following college, he focused on engineering and when he encountered a mathematics problem, he would "refer" to his colleagues. • D says he is "much more confident" in his work about "having the principles right and conclusions right from a good understanding of the problem with some checking by maths rather than doing a big long calculation, coming up with the answer and saying bang, there's the answer".
E	• E is of the view that engineering practice requires "basic maths" rather than "college maths". • In her work, E likes "a maths way to do something", she likes getting an "exact solution". She likes "to be able to prove that something is right with maths", she is not comfortable working with "an in between solution". • E says she would "prefer to use maths more" in her work. She says she is more confident in her work when using mathematics compared to when she doesn't use mathematics.
F	• F is of the view that one "would need to have had higher level maths at some stage" to do his job. • He considers any job that uses mathematics as "interesting". • He likes "mathematical solutions" and "the concept of solving problems using models and modelling using mathematics". He recalls "getting a bit of a kick out of doing spread sheet analysis". • He states that in his work, he uses "models" and "black box solutions" to do various computations such as gas flow rates. While he doesn't "have to develop the models" he notes the "need to know where they came from" if he is "to use them with confidence" and have "an appreciation of the limitations" of the models.
G	• G says mathematics "is necessary" for his job and it makes his job "easier". He adds "if you have a fear of it or it turns you off it's just like not being able to use your driver in your golf bag, it's just going to handicap you". • G enjoys using mathematics in his work and he has "always found numbers to be the most interesting" part of his work. • G says that as engineers move "onto to more management roles", there is much less "exposure to maths".
H	• H says the need for higher level Leaving Certificate mathematics varies in her company. The engineers who do "modelling of drainage or water systems" need to know mathematics. She says that some engineers who didn't do higher level Leaving Certificate mathematics may be "less confident" but "probably every bit

	as good" compared to those with higher level Leaving Certificate mathematics. • H enjoys using mathematics in work. She says that due to her "good grounding" in mathematics, she is confident using mathematics in work.
J	• J says that mathematics is "essential" to his research work. • He says he "absolutely" enjoys using mathematics as he is "exercising a skill" that he has. He says that mathematics "coincides with the way" his "brain works" and consequently he "finds pleasure in doing" mathematics just like a "fit and strong" person would find it "a pleasure to lift heavy weights". • J often finds that he is "so engaged" when "solving a mathematical problem" that he would hardly notice when "hours and hours have gone by". • He says that he "would like to be better at maths" because he is "always coming upon the limitations" of his own mathematics. He says he gets "frustrated" when the answers aren't apparent. • J is of the view that while few engineers need "certain types of maths, applied maths and problem-solving techniques" in their work, there "are still quite a lot of engineers who couldn't do their jobs unless they can solve differential equations". He is also of the view that managers in engineering companies require an "appreciation of mathematics" and that if the managers never learnt the mathematics themselves they cannot properly manage engineering work. J asserts that "doing maths is just very good training for the brain and teaches you concepts, like abstraction which you know make you a better thinker in general".
K	• K says that mathematics is "valuable" in the ten per cent of his work where he uses mathematics. He says he sees "circumstances where others in the company would be better" if they had mathematics and that "when they don't have that level of mathematical ability it restricts them in terms of analysing situations". • K says he is confident about using mathematics at work and he relishes the "challenge". However he is of the view that his confidence reduces when he "is not using mathematics regularly". He says he has to "double check" the mathematics before presenting his mathematical solution to his co-workers. • K is of the view that because many engineers "bypass the maths", "you have to stand on your own two feet" and "if you get it wrong it can look very bad".
L	• L asserts that "in this day and age" engineers don't need to write down equations" to do their work. • However he does say that engineers because of their education and because they are "comfortable with maths and using maths" when "analysing problems that mightn't be mathematical by nature" they "still approach them with a kind of mathematical logic". • He says he enjoys "working with mathematics" and he has the "confidence" necessary to solve engineering problems he encounters in his work.
M	• M is of the view that higher level Leaving Certificate mathematics usage "depends on engineering roles". He says that only "ten per cent of the engineers on site here would need some of the learning from higher level maths" and that "ninety per cent of us could do our roles without honours maths". • M says he has "taken more from the discipline of maths than from the actual academic side of it". He says that while "higher level Leaving Certificate maths isn't necessary" in his "day to day work", the "discipline that comes with it is a requirement". • M says that while he enjoys his job, he doesn't enjoy using mathematics in his work. He says he prefers the "buzz of working with people solving problems, working with teams and giving direction to teams" rather than "doing the maths which is working on your own." • M says that while he is confident "using Excel to run graphs, standard deviations, CPKs (process capability) that type of stuff" but "if you threw some honours maths type stuff in front of me now, I would probably fall off the chair". • M is of the view that "if you were doing or using some maths for your solutions

	… where nobody has done it before and you can't copy a template … , you are putting yourself up, putting your neck on the line … you don't want to be the guy that puts something in place that goes wrong or is fundamentally flawed".
N	• N is of the view that "maths tends to stifle the engineering profession". He says that in engineering practice "you don't have to be good at maths; you have to be good at problem solving". • N says he enjoys maths and "I do appreciate it for itself … I have gone to study maths in university at higher level again and I am good at it … it is always there at the back of my mind just because I enjoy doing it." • While N enjoys using mathematics, he is of the view that there is an "isolation" associated with using mathematics as "maths is usually more of an individual activity than a team effort".
O	• O says that in his current role as a manager, he "would absolutely not need higher level Leaving Certificate maths". He is of the view that while engineering managers generally wouldn't be using higher level Leaving Certificate mathematics "in their day to day jobs" that "they may need to understand certain parts of it". O says that he doesn't require his team to "to have an awful lot of mathematical knowledge coming in here". • O enjoys any mathematical challenges he encounters in his work. He says that he is confident enough in his own mathematics ability to know when he should use it and he "would be very confident that maths will deliver a better way of doing something". He says "if the maths works out … it's a faster way of doing something".
P	• P asserts "that a good grasp of maths is essential to being a good engineer" and that he wouldn't hire the "guys who have struggled through engineering school". • P believes that "mathematics is an extremely useful tool … early on one learns how useful it is and simply continues to use it in one way or another as one progresses through one's career". • In his work P says "if you're faced with a problem which you can define mathematically, your knowledge of maths helps you come up with what seems to be an effective solution, there is a feel good factor in that." • P also notes that "in engineering there is very seldom a unique solution, there is a balance between the amount of time you can spend on problem solving and the degree of certainty that you can have that the solution you've come up with is the ideal solution, it is much more important to have a working solution than to have the ideal one".
Q	• Q says "I do feel I am able to cope with things better because I have a grasp of the kind of maths and figures, particularly statistics required in my industry". • Q is of the view that there is "a need for mathematical engineers, because engineers need to be strong in maths to understand processes". • Q says that she is known to be "kind of good" at statistics and people are often referred to her for advice. • Q recalls a time in work when she "just took a minute too long" to predict a mathematical solution, she was "put down by a colleague" who was "just a step ahead" of her. She said that she felt "just stupid" but determined "to be a bit more on the ball" from the on.
R	• R is of the view that higher level Leaving Certificate mathematics is necessary for engineering practice because "in engineering you need to go into maths in a great depth". • R says she enjoys using mathematics in work. She says that once "I achieve something that is kind of difficult then I will get bored at it". • She says that when using mathematics she is "a lot more confident" than her work colleagues.
S	• S is of the view that mathematics in general is "a real useful tool" in engineering. • S says that "to get the real buzz out of maths it has to be a real problem". He

	recalls a previous job when working in research and development for Sony in Japan when he came up with "a minimal tweak" that made one of Sony's products "comply with an international standard" which put him "on cloud nine for weeks". • S says that he enjoys using mathematics and he says "that's why I turned out to be such a weirdo". S says that while he would like to formulate all his problems mathematically, he only feels confident using the mathematics he is "comfortable" with. He adds that he is "really good at only a few small branches of mathematics" and that he has experienced "a lot more negatives than positives" when using mathematics particularly "when you get the wrong answer … more so when you've identified a problem and you just can formulate it mathematically … if only I had the maths to formulate this problem and go and solve it". • S is of the view that some academics "are really interested in this mad sophisticated solution that there might not be a real problem out there looking for that solution, but they love the solution".
T	• T is of the view that she couldn't do her job without higher level Leaving Certificate mathematics. She says "I just think you can do certain aspects of it [her job], but I don't think you understand the fundamental aspects unless you have a good grasp of maths". • She says she enjoys using mathematics in work because "it is clean … it is completely logical, … it is totally transparent and basically once you are happy with it yourself, no one else can really question the validity of it".
U	• U says that he "simply wouldn't been able to do" his job without mathematics. • U enjoys using mathematics at work and he says he is confident using mathematics. However U says "I thought I knew basic statistics but I didn't know enough and I had to go away and learn it". • U says that he has had "very few negative experiences" using mathematics but that he did get "something wrong and I got caught out". He says he mostly trusts mathematical software, "but not one hundred per cent and he adds "I just don't have the time for check it all but I found that there is times where simply the software is wrong … but at least I know where it is wrong now". • U is of the view that "there is a certain respect for mathematics" in his company "but that seems to change as the management changes and I have seen that over the years where the CEO was an engineer there was a very large amount of respect for mathematics, whereas the current CEO currently is very much a marketing man and so definitely the emphasis is on sales and marketing and away from the maths right now".

Table A9-5: Feelings about mathematics in engineering practice.

	Feelings about Mathematics Outside of Engineering
A	• A is of the view that while "a grasp of statistics always useful" and that society requires "numeracy" skills, not everyone requires "the ability to do high level calculus from first principles".
B	• B is of the view given that "only 16% of any given school year is taking higher level maths" that mathematics has been on "a sliding trend" for a number of generations. • B states that "generations of students" have shown general disaffection with mathematics resulting from "a general dumbing down in society". • B states that in his "life", proficiency in mathematics "generated so much confidence" and he "would like the next generation of children coming through to have that same opportunity". B asserts that because many students who get good grades in higher level Leaving Certificate mathematics do not become engineers, their mathematics learning is not a "waste". He states that "we lose them to the engineering profession, but we don't lose them to society or to business".
C	• C notes that society use "maths every day".
D	• D is of the view that one "can get through life without any maths, other than having to do sums" and that people can count money without knowing mathematics. • While "geometry and trigonometry, numbers, algebra and function" comprise of "xs and ys, funny graphs and funny symbols", D singles out statistics as being "a bit different". He is of the view that statistics and probability "has a bit of relevance in life".
F	• F enjoys "TV programmes" on the subject of "the history of maths".
J	• J's research work involves working with "teams with people who have degrees in biology or in medical qualification." He says it "is a big problem to work with these people because, not only do they not know any maths, they are scared of it, and their whole approach to solving a problem doesn't include maths". He says people with biological backgrounds approach problems differently to people with mathematical and physical science backgrounds. J outlines his own mathematical approach as "abstracting a problem to a general type of problem which you can express mathematically and then coming back down to the particular case that you're dealing with". He says that "the biologists and the medical people" tend to "use maths after the fact" in that "they collect all their data and then they use statistics to try and see what they have got" for example when exploring the question "does smoking cause cancer?" J believes that using "maths at the beginning of the problem" is required in "systems biology" which is "applying maths to try and describe biological systems" for example "what is this drug doing to your bones?" Systems biology involves making "a model about what might be happening to these cells in the body" which J says "is basically control theory". J believes that the difficulty in this field is that "almost no biologists can do maths". He says that "people who are interested in science but don't like maths at school, tend to do biology". • J asserts that thinking skills developed from mathematics education are useful when solving "problems that are not essentially mathematical problems". He says that "the ability to think logically" would be very useful in many jobs outside of engineering and mathematics. • J is of the view that mathematics invites creativity. He says that while the first step in creativity is "to have the idea" he believes that if he "went back and studied or re-studied some of those parts of mathematics" he has stopped using, he "would probably start having different ideas as well", because he says "I have got a tool that I can use" to develop the ideas. • J states that "it would be good" if people "are aware of maths and what it is even if they are not using" and if "they understood that maths is important" for

	society.
L	• L is of the view that "there are almost two types of people, the people who are good at maths and the people who aren't good at maths". He says that most work is now done by computers and that people don't associate computer programming with mathematics. • L says that because "things are changing" there is "a huge difference between a teenager now and when I was a teenager and that's only 10 years ago". L remembers when he was a young teenager, he would have "taken apart a radio or a Walkman … out of curiosity … because there was nothing else to do … but now there is so much choice".
N	• N is of the view that society does not value "maths and engineering enough". He says that "other subjects seem to take precedence over maths". N calls this a "disconnect" … "it's a societal issue … it's how we value things". • N says that "a lot of people are wary of maths, they think it stifles creativity". N blames "rote learning" for the loss of "the creative side of maths", he says that a consequence of rote learning is to "force a particular way of doing things when there may be a better way". This he says "is stifling and restrictive and I don't think you can restrict any part of the creative process".
O	• O says that while "the whole engineering thing wasn't" for him, he loves "the beauty of numbers". O recently "did a Masters in pure maths" where he studied number theory. He doesn't use this mathematics in his work but he says that "cryptography and things like that" would be useful if he was to become a software "coder". • O is concerned with "the number of adults that you meet who say that they hate maths, they are afraid of maths, maths is very hard and who would have negative experiences of maths at some level". O says this this attitude is accepted "because there are enough people to form a quorum who can feel not left out by being that way". However he says this attitude is "wrong" and that if higher level Leaving Certificate mathematics was "made easier", it would be "detrimental to more than just engineering". O asserts that "maths is a tool that enables you to really do powerful things in other disciplines".
P	• P is of the view that mathematics is "an extremely useful tool" and that most people use mathematics "in one way or another" throughout their careers."
Q	• Q says that mathematics makes many people "shut down". She says that many of these people "go on and they become parents and primary school teachers … and then their kids, are from a family who could never do maths … is a vicious circle". • Q says that she believes strongly that "everyone can do maths". She says "if someone says they can't do something, they are never going to be able to do it … they just need the belief, they need either a pace that suits them … everyone can do a certain level and I am not going to say that everyone is going to get PhDs in maths, but everyone can do maths". • Q asserts that that mathematics is one of those subjects where "people who can't do mathematics call you a nerd and the people who are just amazing at it put you down". She believes that students "in the middle are probably the ones who are probably going down into ordinary level, but would be capable of doing higher level" if they got support and encouragement to do so. Q adds "I don't think there should be 16% doing it, I think it should be 60% doing" higher level Leaving Certificate mathematics.
S	• S is of the view that there is a "general feeling that maths is important" but that "it's not the be all and end all". He also suggests that there is "anecdotal evidence from older people who try and push themselves to do Sudoku" that "mathematical training is good for developing the mind".
T	• T believes that many people have "a very negative" of mathematics and she adds that it is "perfectly acceptable to drop to pass maths whereas if you drop to pass English you will never be able to write a letter". T is of the view that

	"society is at a loss" because of so few students taking higher level Leaving Certificate mathematics. She says that apart from engineering "maths helps other occupations as well … the whole logical thinking training would help pretty much any occupation".

Table A9-6: Feelings about mathematics outside of engineering.

Summary of Engineers' Feelings about Mathematics														
Name	Gender	Mathematics usage in engineering practice	Leaving Certificate level	Leaving Certificate year	Family support in mathematics learning	Good teachers	Bad mathematics teachers	Enjoy school mathematics	Social problems associated with being good at mathematics	Confident in school mathematical ability	Put big effort into school mathematics	Positive contribution of mathematics education to engineering practice	Engineers enjoy using mathematics in their work	Teachers key to young people's affective engagement with mathematics
A	M	1.28	H	1990	✓	✓		✓		✓	✓			✓
B	M	1.52	H	1984	✓	✓		✓		✓	✓		✓	✓
C	M	1.76	O	1985		✓		✓			✓		✓	✓
D	M	1.88	H	1966			✓							✓
E	F	2.04	H	1997		✓		✓		✓	✓		✓	✓
F	M	2.08	H	1985		✓	✓					✓	✓	✓
G	M	2.09	H	1994	✓	✓		✓		✓	✓	✓	✓	✓
H	F	2.33	H	1997	✓	✓		✓	✓	✓	✓	✓	✓	✓
J	M	2.67	A-L	1971	✓	✓		✓	✓	✓	✓	✓	✓	✓
K	M	2.68	H	1995	✓	✓		✓	✓	✓	✓	✓	✓	✓
L	M	2.90	H	1997	✓	✓		✓	✓	✓	✓	✓	✓	✓
M	M	2.91	H	1991	✓	✓		✓		✓	✓	✓		✓
N	M	3.34	O	1981		✓	✓						✓	✓
O	M	3.51	H	1979	✓	✓		✓	✓	✓	✓	✓	✓	✓
P	M	3.53	H	1963		✓		✓	✓	✓	✓	✓	✓	✓
Q	F	3.54	H	2003	✓	✓		✓	✓	✓	✓	✓	✓	✓
R	F	3.60	H	1980		✓	✓		✓	✓	✓	✓	✓	✓
S	M	3.84	H	1980	✓	✓		✓	✓	✓	✓	✓	✓	✓
T	F	4.17	H	2002	✓	✓		✓	✓	✓	✓	✓	✓	✓
U	M	4.23	H	1984	✓	✓		✓		✓		✓	✓	✓

Table A9-7: Summary of engineers' feelings about mathematics.

Engineers' Paths to Engineering Education										
Name	Gender	Mathematics usage in engineering practice	Leaving Certificate level	Leaving Certificate year	Family support with mathematics learning	Bad teachers	Feelings about mathematics was main influence in choosing engineering career	Interest in practical side of engineering influenced career choice	Primary engineering qualification	Engineering college
A	M	1.28	H	1990	✓		✓		Chemical engineering degree	UCD
B	M	1.52	H	1984	✓		✓	✓	Electrical engineering degree	UCD
C	M	1.76	O	1985				✓	Fitter/turner apprenticeship and mechanical engineering degree	DIT
D	M	1.88	H	1966		✓		✓	Mechanical engineering degree	UCD
E	F	2.04	H	1997			✓	✓	Structural engineering degree course in	CIT
F	M	2.08	H	1985		✓		✓	Mechanical engineering degree	DIT
G	M	2.09	H	1994	✓		✓		Electronic engineering degree	UCG
H	F	2.33	H	1997	✓		✓		Civil engineering degree	UCC
J	M	2.67	A-L	1971	✓		✓		Mathematics and physics degree	Queens Cambridge
K	M	2.68	H	1995	✓		✓		Electronic engineering degree	UCD
L	M	2.90	H	1997	✓		✓		Electrical engineering degree course	UL
M	M	2.91	H	1991	✓		✓		Manufacturing and production engineering degree	UL
N	M	3.34	O	1981		✓		✓	Civil engineering diploma and civil engineering degree	Open University
O	M	3.51	H	1979	✓		✓		Civil engineering degree	UCC
P	M	3.53	H	1963				✓	Electrical engineering degree	UCD
Q	F	3.54	H	2003	✓		✓		Manufacturing engineering degree	TCD
R	F	3.60	H	1980		✓		✓	Civil engineering degree	UCD
S	M	3.84	H	1980	✓		✓	✓	Electronic engineering degree	DIT
T	F	4.17	H	2002	✓		✓	✓	Electrical and electronic engineering degree	UCC
U	M	4.23	H	1984	✓		✓		Electronic engineering degree	UCD

Table A9-8: Engineers' paths to engineering education.

Engineers' Job Descriptions									
Name	Gender	Maths Usage	LC Mathematics	LC Year	Company Sector	Product	Engineering Discipline	Engineering Role	Job Description
A	M	1.28	H	1990	Pharmace-utical	Pharmace-utical drug substances	Chemical	Design / Development	Process Engineer - making the process equipment do what it is supposed to do
B	M	1.52	H	1984	Telecomm-unications	Telecomm-unications	Electronic / Electrical	Technology Service Sales Manager	Sales manager - management of the commercial side of the public sector telecommunications contract
C	M	1.76	O	1985	Project Engineering	Engineering design projects	Mechanical	Design / Development	Department manager - management of team of mechanical engineers who develop capital projects for clients, also lead engineer on many projects
D	M	1.88	H	1966	Project Engineering	Engineering design projects	Mechanical	Project Management	Project manager - management of mechanical engineering side of pharmaceutical design projects
E	F	2.04	H	1997	Project Engineering	Engineering consultancy	Civil	Design / Development	Senior design engineer - analysis of water collection and distribution systems. Writing flood study reports and designing flood study measures
F	M	2.08	H	1985	Energy distribution	Gas supply	Mechanical	Project Management	Project manager - managing cost benefit analysis and risk analysis in the commercial department
G	M	2.09	H	1994	Electricity distribution	Electricity transmiss-ion	Electronic / Electrical	Commercial	Commercial manager - management of pricing for the wholesale electricity market in Ireland
H	F	2.33	H	1997	Project Engineering	Dublin light rail system	Civil, Rail, Water	Design / Development	Projects manager - design, tender, implementation and construction of projects on the rail line
J	M	2.67	A-L	1971	University	Education and bio-medical materials	Biomedical	Education, Research	Lecturer and researcher - lecturing "bio mechanics" to engineering students and research into bio-medical materials
K	M	2.68	H	1995	IT consultancy	Informat-ion technology	Electronic / Electrical	Information Technology Consultancy	Information technology consultant - determining the most economically advantageous tender for public sector contracts
L	M	2.90	H	1997	Project Engineering	Engineering consultancy	Electronic / Electrical	Design / Development	Project manager and electrical designer

									- managing and electrical design of major engineering projects e.g. Terminal 2 Dublin Airport
M	M	2.91	H	1991	Consumer electronics	Consumer electronics	Manufact-uring / Production	Design / Development	Programme manager - development and acquisitions of tooling and equipment for high volume manufacturing
N	M	3.34	O	1981	Local authority	Maintenance of city drainage network	Civil	Maintenance	Executive engineer - management of team who maintain the city drainage network and deal with any problems that occur
O	M	3.51	H	1979	Software	International version of Office software for iPhone and iPad	Software	Design / Development	Software senior testlead - management of people and projects with responsibility for software localisation
P	M	3.53	H	1963	Retired	Electrical/ electronics	Electronic / Electrical	General Management	Retired - career included engineering, marketing and general management with a variety of mainly US companies
Q	F	3.54	H	2003	Medical Devices	Hip and knee replace-ments	Medical Devices	Design / Development	Quality engineer - process development and design and quality of products
R	F	3.60	H	1980	Local authority	Local authority services	Civil	Design / Development	Senior area manager - responsibility for unfinished housing estates
S	M	3.84	H	1980	University	Education	Electronic / Electrical	Education	Educator, university lecturer and researcher
T	F	4.17	H	2002	Electricity	Electricity transm-ission and distribution	Electronic / Electrical	Design / Development	Sub-station designer - design of power transmission and distribution stations around the country and also abroad
U	M	4.23	H	1984	Telecomm-unications	Telecomm-unications transm-ission network	Electronic / Electrical	Design / Development	Head of synchronise digital hierarchy (SHD) design - management of team of engineers who design the telecommunications transmission network in Ireland and who also manage the capacity in the network

Table A9-9: Engineers' job descriptions.

Engineers' Views about Engineering Practice											
Name	Gender	Maths usage in engineering practice	Leaving Certificate level	Leaving Certificate year	Family support in mathematics learning	Bad teachers	Feelings about mathematics was main influence in choosing engineering career	Primary engineering qualification	Job description	Engineering practice is much more than mathematics	Use of resources in engineering practice
A	M	1.28	H	1990	✓		✓	Chemical engineering degree	Process Engineer - making the process equipment do what it is supposed to do	✓	✓
B	M	1.52	H	1984	✓		✓	Electrical engineering degree	Sales manager - management of the commercial side of the public sector telecommunications contract		✓
C	M	1.76	O	1985				Fitter/ turner apprenticeship and mechanical engineering degree	Department manager - management of team of mechanical engineers who develop capital projects for clients, also lead engineer on many projects		✓
D	M	1.88	H	1966		✓		Mechanical engineering degree	Project manager - management of mechanical engineering side of pharmaceutical design projects	✓	✓
E	F	2.04	H	1997			✓	Structural engineering degree	Senior design engineer - analysis of water collection and distribution systems. Writing flood study reports and designing flood study measures	✓	✓
F	M	2.08	H	1985		✓		Mechanical engineering degree	Project manager - managing cost benefit analysis and risk analysis in the commercial department	✓	✓
G	M	2.09	H	1994	✓		✓	Electronic engineering degree	Commercial manager - management of pricing for the wholesale electricity market in Ireland		✓
H	F	2.33	H	1997	✓		✓	Civil engineering degree	Projects manager - design, tender, implementation and construction of projects on the rail line	✓	✓
J	M	2.67	A-L	1971	✓		✓	Mathematics and physics degree	Lecturer and researcher - lecturing "bio mechanics" to engineering students and research into bio-medical materials	✓	✓
K	M	2.68	H	1995	✓		✓	Electronic engineering degree	Information technology consultant - determining the most economically advantageous tender for public sector contracts		✓
L	M	2.9	H	1997	✓		✓	Electrical engineering degree	Project manager and electrical designer - managing and electrical design of major engineering projects e.g. Terminal 2 Dublin Airport	✓	✓

M	M	2.91	H	1991	✓		✓	Manufacturing and production engineering degree	Programme manager - development and acquisitions of tooling and equipment for high volume manufacturing		✓
N	M	3.34	O	1981		✓		Civil engineering diploma and civil engineering degree	Executive engineer - management of team who maintain the city drainage network and deal with any problems that occur	✓	✓
O	M	3.51	H	1979	✓		✓	Civil engineering degree	Software senior test lead - management of people and projects with responsibility for software localisation	✓	✓
P	M	3.53	H	1963				Electrical engineering degree	Retired - career included engineering, marketing and general management with a variety of mainly US companies	✓	
Q	F	3.54	H	2003	✓		✓	Manufacturing engineering degree	Quality engineer - process development and design and quality of products	✓	✓
R	F	3.6	H	1980		✓		Civil engineering degree	Senior area manager - responsibility for unfinished housing estates		
S	M	3.84	H	1980	✓		✓	Electronic engineering degree	Educator, university lecturer and researcher	✓	✓
T	F	4.17	H	2002	✓		✓	Electrical and electronic engineering degree	Sub-station designer - design of power transmission and distribution stations around the country and also abroad	✓	✓
U	M	4.23	H	1984	✓		✓	Electronic engineering degree	Head of synchronise digital hierarchy (SHD) design - management of team of engineers who design the telecommunications transmission network in Ireland and who also manage the capacity in the network	✓	✓

Table A9-10: Engineers' views about engineering practice.

Engineers' *Curriculum Mathematics* Usage				
Name	**Maths Usage**	**Domain**	**Level**	**Type**
A	1.28	"Numeracy"	Leaving Certificate ordinary level	Reproducing
B	1.52	"Numbers"	Leaving Certificate ordinary level	Reproducing and Connecting
C	1.76	"Statistical analysis" and "geometry"	Leaving Certificate ordinary level	Reproducing and Connecting
D	1.88	"Statistics and probability"	Engineering level	"Never got beyond connecting"
E	2.04	"Geometry, trigonometry, statistics and probability"	"No higher than Leaving Certificate ordinary level"	Reproducing and Connecting
F	2.08	"Statistics and probability"	Leaving Certificate higher level	"Somewhere between connecting and reproducing"
G	2.09	"Matrix algebra" and "statistics"	Engineering level	Reproducing and Connecting
H	2.33	"Statistics" and probability and "basic geometry and trigonometry"	Leaving Certificate higher level	Reproducing
J	2.67	"Statistics", "geometry, algebra and functions"	"Either A-level or something I learned during my degree"	Mathematising
K	2.68	"Statistics and probability and some algebra and functions"	"Between higher level Leaving Certificate and engineering level"	Mathematising
L	2.90	"Statistics", "Algebra" "Functions"	"Statistics at either Leaving Certificate or engineering level, algebra at Leaving Certificate level and functions at Leaving Certificate level	Reproducing
M	2.91	"Numbers, statistics and probability and probably algebra"	Leaving Certificate ordinary	Connecting
N	3.34	"Geometry, trigonometry and algebra"	"Some of this is at engineering level"	Connecting
O	3.51	"A lot of implicit number work … a very basic bit of algebra … some statistics"	Leaving Certificate ordinary	"Somewhere between type 2 connecting usage and type 3 mathematising usage"
P	3.53	"Algebra, functions, numbers, statistics and probability"	"Minimum level of higher level Leaving Certificate"	"Early on in my career the usage would have been type 3, mathematising"
Q	3.54	"Statistics and probability and numbers" "Geometry and trigonometry"	Engineering level	"Statistics and probability and numbers, I do loads of that and that's up in mathematising". "Geometry and trigonometry, I would say at least connecting"
R	3.60	"Functions would be used every single day… geometry and trigonometry … statistics and probability … algebra … numbers"	"Usage of statistics and probability and geometry and trigonometry is at engineering level, algebra and numbers is at higher level Leaving Certificate and functions is at Junior Cert level".	"Usage type varies from reproducing to connecting and to mathematising"
S	3.84	"Functions, algebra, numbers, geometry and trigonometry but not so much statistics and probability"	"Higher level Leaving Certificate and above"	"Getting the students to reproduce the mathematics and make connections". In S's research work, the usage type would be connecting and "trying to express problems in maths or formulate then into maths with a view to solving them (mathematising)"
T	4.17	"Algebra, geometry … a lot of calculus … and very little statistics"" in her work.	Engineering level	"Reproducing and connecting … some mathematising but not at a very high academic level"
U	4.23	"Statistics, geometry, trigonometry, numbers, algebra, functions are all	"Leaving Certificate and engineering level maths".	"Reproducing is the major function … there is a good part of connecting … mathematising is a lot more rare and

		equally important … I can honestly say that in the last month I've used all of those in some way"		it's more about solving problems that our field crews cannot solve"

Table A9-11: Engineers' *curriculum mathematics* usage.

Engineers' *Curriculum Mathematics* Usage by Discipline and Role						
Name	**Discipline**	**Statistics & Probability**	**Geometry & Trigonometry**	**Number**	**Algebra**	**Functions**
A	Chemical			✓		
B	Electronic / Electrical			✓		
C	Mechanical	✓	✓			
D	Mechanical	✓				
E	Civil	✓	✓			
F	Mechanical	✓				
G	Electronic / Electrical	✓			✓	
H	Civil, Rail, Water	✓	✓			
J	Biomedical	✓	✓		✓	✓
K	Electronic / Electrical	✓			✓	✓
L	Electronic / Electrical	✓	✓	✓	✓	✓
M	Manufacturing / Production	✓		✓	✓	
N	Civil		✓		✓	
O	Software	✓		✓	✓	
P	Electronic / Electrical	✓		✓	✓	✓
Q	Medical Devices	✓	✓	✓		
R	Civil	✓	✓	✓	✓	✓
S	Electronic / Electrical		✓	✓	✓	✓
T	Electronic / Electrical		✓		✓	✓
U	Electronic / Electrical	✓	✓	✓	✓	✓

Table A9-12: Engineers' *curriculum mathematics* usage by discipline and role.

Engineers' Views about and Usage of Mathematics in Engineering Practice												
Name	Gender	Maths usage in engineering practice	Leaving Certificate level	Leaving Certificate year	Family support in mathematics learning	Bad teachers	Feelings about mathematics was main influence in choosing engineering career	Primary engineering qualification	Job description	Engineering practice is much more than mathematics	Use of higher level Leaving Certificate or engineering mathematics in work	Use of connecting or mathematising type mathematics in work
A	M	1.28	H	1990	✓		✓	Chemical engineering degree	Process Engineer - making the process equipment do what it is supposed to do	✓		
B	M	1.52	H	1984	✓		✓	Electrical engineering degree	Sales manager - management of the commercial side of the public sector telecommunicat-ions contract			✓
C	M	1.76	O	1985				Fitter/turner apprentice-ship and mechanical engineering degree	Department manager - management of team of mechanical engineers who develop capital projects for clients, also lead engineer on many projects			✓
D	M	1.88	H	1966		✓		Mechanical engineering degree	Project manager - management of mechanical engineering side of pharmaceutical design projects	✓	✓	✓
E	F	2.04	H	1997			✓	Structural engineering degree course in	Senior design engineer - analysis of water collection and distribution systems. Writing flood study reports and designing flood study measures	✓		✓
F	M	2.08	H	1985		✓		Mechanical engineering degree	Project manager - managing cost benefit analysis and risk analysis in the commercial department	✓		✓
G	M	2.09	H	1994	✓		✓	Electronic	Commercial		✓	✓

								engineering degree	manager - management of pricing for the wholesale electricity market in Ireland			
H	F	2.33	H	1997	✓		✓	Civil engineering degree	Projects manager - design, tender, implementation and construction of projects on the rail line	✓	✓	✓
J	M	2.67	A-L	1971	✓		✓	Mathematics and physics degree	Lecturer and researcher - lecturing "bio mechanics" to engineering students and research into bio-medical materials	✓	✓	✓
K	M	2.68	H	1995	✓		✓	Electronic engineering degree	Information technology consultant - determining the most economically advantageous tender for public sector contracts		✓	✓
L	M	2.90	H	1997	✓		✓	Electrical engineering degree course	Project manager and electrical designer - managing and electrical design of major engineering projects e.g. Terminal 2 Dublin Airport	✓	✓	
M	M	2.91	H	1991	✓		✓	Manufacturing and production engineering degree	Programme manager - development and acquisitions of tooling and equipment for high volume manufacturing			✓
N	M	3.34	O	1981		✓		Civil engineering diploma and civil engineering degree	Executive engineer - management of team who maintain the city drainage network and deal with any problems that occur	✓		✓
O	M	3.51	H	1979	✓		✓	Civil engineering degree	Software senior test lead - management of people and projects with responsibility for software localisation	✓		✓
P	M	3.53	H	1963				Electrical engineering degree	Retired - career included engineering, marketing and general management with	✓	✓	✓

									a variety of mainly US companies			
Q	F	3.54	H	2003	✓		✓	Manufacturing engineering degree	Quality engineer - process development and design and quality of products	✓	✓	✓
R	F	3.60	H	1980		✓		Civil engineering degree	Senior area manager - responsibility for unfinished housing estates		✓	✓
S	M	3.84	H	1980	✓		✓	Electronic engineering degree	Educator, university lecturer and researcher	✓	✓	✓
T	F	4.17	H	2002	✓		✓	Electrical and electronic engineering degree	Sub-station designer - design of power transmission and distribution stations around the country and also abroad	✓	✓	✓
U	M	4.23	H	1984	✓		✓	Electronic engineering degree	Head of synchronise digital hierarchy (SHD) design - management of team of engineers who design the telecommunications transmission network in Ireland and who also manage the capacity in the network	✓	✓	✓

Table A9-13: Engineers' views about and usage of mathematics in engineering practice.

The Need for a Mathematical Approach in Engineering Practice													
Name	Gender	Maths usage in engineering practice	Leaving Certificate level	Leaving Certificate year	Family support in mathematics learning	Bad teachers	Feelings about mathematics was main influence in choosing engineering career	Primary engineering qualification	Job description	Engineering practice is much more than mathematics	Use of higher level Leaving Certificate or engineering mathematics in work	Use of connecting or mathematising type mathematics in work	Mathematical approach is necessary?
A	M	1.28	H	1990	✓		✓	Chemical engineering degree	Process Engineer - making the process equipment do what it is supposed to do	✓			"No"
B	M	1.52	H	1984	✓		✓	Electrical engineering degree	Sales manager - management of the commercial side of the public sector telecommunications contract			✓	Doesn't see job "in maths terms"
C	M	1.76	O	1985				Fitter/ turner apprentice-ship and mechanical engineering degree	Department manager - management of team of mechanical engineers who develop capital projects for clients, also lead engineer on many projects			✓	Work "doesn't require a specifically mathematical approach".
D	M	1.88	H	1966		✓		Mechanical engineering degree	Project manager - management of mechanical engineering side of pharmaceutical design projects	✓	✓	✓	"Very little"
E	F	2.04	H	1997			✓	Structural engineering degree	Senior design engineer - analysis of water collection and distribution systems. Writing flood study reports and designing flood study measures	✓		✓	"Just basic maths to do some things
F	M	2.08	H	1985		✓		Mechanical engineering degree	Project manager - managing cost benefit analysis and risk analysis in the commercial department	✓		✓	Doesn't "have to actually use mathematics" in job
G	M	2.09	H	1994	✓		✓	Electronic engineering degree	Commercial manager - management of pricing for the wholesale electricity market in Ireland		✓	✓	Mathematics "isn't usually necessary"
H	F	2.33	H	1997	✓		✓	Civil engineering degree	Projects manager - design, tender, implementation and construction of	✓	✓	✓	"No"

									projects on the rail line				
J	M	2.67	A - L	1971	✓		✓	Mathemat-ics and physics degree	Lecturer and researcher - lecturing "bio mechanics" to engineering students and research into bio-medical materials	✓	✓	✓	Couldn't do work without mathematics
K	M	2.68	H	1995	✓		✓	Electronic engineering degree	Information technology consultant - determining the most economically advantageous tender for public sector contracts		✓	✓	Mathematics is necessary in less than ten per cent of work
L	M	2.9	H	1997	✓		✓	Electrical engineering degree	Project manager and electrical designer - managing and electrical design of major engineering projects e.g. Terminal 2 Dublin Airport	✓	✓		"No"
M	M	2.91	H	1991	✓		✓	Manufactur ing and production engineering degree	Programme manager - development and acquisitions of tooling and equipment for high volume manufacturing			✓	"A little"
N	M	3.34	O	1981		✓		Civil engineering diploma and civil engineering degree	Executive engineer - management of team who maintain the city drainage network and deal with any problems that occur	✓		✓	"A little"
O	M	3.51	H	1979	✓		✓	Civil engineering degree	Software senior test lead - management of people and projects with responsibility for software localisation	✓		✓	Mathematics isn't specifically necessary
P	M	3.53	H	1963				Electrical engineering degree	Retired - career included engineering, marketing and general management with a variety of mainly US companies	✓	✓	✓	"Very much" necessary
Q	F	3.54	H	2003	✓		✓	Manufactu-ring engineering degree	Quality engineer - process development and design and quality of products	✓	✓	✓	Between "quite a lot" and "a very great deal"
R	F	3.6	H	1980		✓		Civil engineering degree	Senior area manager - responsibility for unfinished housing estates		✓	✓	"Maths is essential in job"
S	M	3.84	H	1980	✓		✓	Electronic engineering degree	Educator, university lecturer and researcher	✓	✓	✓	"Necessary but not sufficient"
T	F	4.17	H	2002	✓		✓	Electrical and electronic engineering degree	Sub-station designer - design of power transmission and distribution stations around the country and also abroad	✓	✓	✓	"Could do ninety per cent" of job without mathematics but "couldn't possibly do the other ten per cent

													without it"
U	M	4.23	H	1984	✓		✓	Electronic engineering degree	Head of synchronise digital hierarchy (SHD) design - management of team of engineers who design the telecommunications transmission network in Ireland and who also manage the capacity in the network	✓	✓	✓	"Quite a lot"

Table A9-14: The need for a mathematical approach in engineering practice.

The Value of Mathematics Education in Engineering Practice				
Name	**Maths Usage**	**Engineering Role**	**Views on relevance of mathematics education to engineering practice**	**Value of mathematics in engineering practice**
A	1.28	Process engineering /equipment performance	Too much "specialist maths" in engineering education	A estimates that engineers in general use just ten per cent of the mathematics learnt in university
B	1.52	Commercial/ head of public sector contract	B supports the high level of mathematics in engineering education curricula	Courses should be aimed at the graduates who take on "the highest consequence" of mathematics in their work Engineers who pursue less numerate careers benefit from the "rigour and discipline" of learning mathematics
C	1.76	Project design/ costs estimates for capital projects	Amount of mathematics in engineering education doesn't do "any harm to engineers".	Security associated with mathematics, a mathematical answer is like "a safety valve"
D	1.88	Project Management/ capital projects	Mathematics in engineering education does not need to be as high as academia seems to think	Good grounding for "logical, reasoning and analytical" skills
E	2.04	Design/ flood study measures	Engineering practice requires "basic maths" rather than "college maths".	Engineering mathematics is only necessary if "you wanted to go back to first principles and know the background behind how some programs work"
F	2.08	Project Management/ cost benefit analysis	"Would need to have had higher level maths at some stage" to do F's job	Higher level mathematics gives F confidence to use "models" and "black box solutions" gives him "an appreciation of the limitations" of the models
G	2.09	Commercial/ electricity transmission pricing	Engineering mathematics "is necessary" for G's job	Makes his job "easier"
H	2.33	Design and management / minor projects for rail line	Need for higher level mathematics varies in H's company	Mathematics required for "modelling of drainage or water systems"
J	2.67	Lecturing and research/ bio-mechanics and bio-medical materials	Lecturer's job is to let the undergraduate engineering students out of university "with a level of maths that we think is appropriate for a professional engineer, a chartered engineer, which of course is a very high level of engineering"	Few engineers need "certain types of maths, applied maths and problem-solving techniques" in their work quite a lot of engineers "couldn't do their jobs unless they can solve differential equations". managers in engineering companies require an "appreciation of mathematics" "Doing maths is just very good training for the brain and teaches you concepts, like abstraction which you know make you a better thinker in general"
K	2.68	Consultancy/ procurement analysis for public sector contracts	Mathematics is "valuable" in ten per cent of K's work	Without a high level of mathematical ability engineers are restricted "in terms of analysing situations"
L	2.9	Electrical design and project management/ capital projects	"Maths should be part of any engineering curriculum no matter what the degree is or no matter what College is teaching it"	The skill of "applying mathematics in a logical way" is necessary in engineering practice
M	2.91	Programme manager/ tooling development and acquisitions	"Higher level Leaving Certificate maths isn't necessary" in M's "day to day work"	"Discipline" that comes with higher level mathematics is a requirement"
N	3.34	Semi-management/ maintenance city drainage network	"The amount of math that you use afterwards is never matched by the amount of maths you do in college"	"Engineering training is too academically based" By including so much mathematics in the engineering subjects, universities are making engineering "elitist"

O	3.51	Management / software localisation	O does "absolutely not need higher level Leaving Certificate maths" in his job	While engineering managers generally wouldn't be using higher level Leaving Certificate mathematics "in their day to day jobs" that "they may need to understand certain parts of it If higher level Leaving Certificate mathematics is made easier "kids will be utterly unable to cope when they eventually get to work"
P	3.53	General Management	"A good grasp of maths is essential to being a good engineer"	"Mathematics is an extremely useful tool … early on one learns how useful it is and simply continues to use it in one way or another as one progresses through one's career"
Q	3.54	Quality engineering /process and research and development	"Need for mathematical engineers, because engineers need to be strong in maths to understand processes"	"I do feel I am able to cope with things better because I have a grasp of the kind of maths and figures, particularly statistics required in my industry"
R	3.6	Manager/ un finished housing estates (incl. water, sewerage, pyrite etc.)	Mathematics is essential in R's job	"In engineering you need to go into maths in a great depth" "sometimes things are not in a straight line … everything you look at is in the third dimension" in engineering
S	3.84	Lecturing and research / electronic s and education	"Engineers' use of mathematics "depends a lot exactly on what area of engineering you are in"	Mathematics is "an advantage" in engineering practice and "a really useful tool"
T	4.17	Design /power transmission and distribution systems	T couldn't do her job without higher level Leaving Certificate mathematics	T cannot "understand the fundamental aspects unless you have a good grasp of maths"
U	4.23	Management and design / telecommunications network	"Simply wouldn't been able to do" his job without mathematics	U uses mathematics "in a financial sense behind "the simple pie chart" in his financial reports there are calculations such as "turning things like man hours into megabits per second" Also to "guess trends or calculate statistically"

Table A9-15: The value of mathematics education in engineering practice.