15 Observations and conclusions

This survey of activities of numeracy in Further Education has been a personal one, shaped by the authors' areas of knowledge and experience as tutors, and by the range of case studies generously contributed by our students and teaching colleagues. Tutors carrying out surveys in other colleges would observe very different ranges of numeracy activities, though the mathematical techniques involved would probably be equally extensive. This summary therefore focuses on general principles, rather than advocating any particular teaching activities.

Our starting point was an investigation of the views of employers on the numeracy skills required in their staff, and the extent to which these requirements were being met.

It is apparent that the skills required by employers go well beyond a simple application of standard mathematical methods. Aspects of wider numeracy which were frequently mentioned include:

- problem solving, particularly in non-routine situations.
- gathering data, either by direct measurement or from documents and other published material.
- working effectively as a member of a team, including the ability to communicate mathematical concepts clearly.
- use of information technology systems, electronic equipment and computer software.
- ability to select appropriate levels of accuracy for tasks.

Above all, employers want all staff to confidently handle numbers, demonstrate mathematical awareness, and be able to make estimates and quickly identify unusual results or errors. In most occupations, an appreciation of finance is needed, so that employees work within budgets and make cost-effective decisions.

In terms of actual mathematical techniques, a series of important topics were identified:

- application of number, particularly in handling percentages.
- conversion between different units of measurement.
- algebra, particularly in the use of formulae in the workplace.
- spatial awareness and the ability to handle shapes in two- and three-dimensions.
- statistical techniques and an appreciation of probabilities.

The mathematical skills required of employees will vary greatly between different occupations. It is often the case that new staff will need to receive specialist training, for example: in operating a particular machine or using a particular software package. However, ***Further Education tutors can help their students by providing realistic, up-to-date training in real or simulated work tasks***, including the numeracy skills required to fully understand and carry out the tasks.

We now move on to consider how numeracy training can be effectively delivered as part of a Further Education course. Students and tutors interviewed during the project were in agreement that it is preferable to provide numeracy education in a way which simulates real workplace problems and projects, so as to motivate students and give realistic and relevant training experiences. However, there may be situations in which the standard of mathematics of a student is so poor that they cannot cope. It may then be necessary to provide remedial support with basic concepts. In this situation, Carl Rogers' humanist approach to identifying the ***requirements for an effective tutor*** are particularly relevant:

- valuing the student as an individual, irrespective of any problems they may be causing, so that a friendly and supportive working relationship is developed.
- honesty, in identifying both the strengths and weaknesses in the student's work, so that areas for improvement can be agreed and progress monitored.
- empathic understanding of the reasons why the student is experiencing difficulties, so that help can be given at an appropriate level.

As with all learning, ***students need to be well motivated to want to improve their numeracy skills***. Motivation is a complex issue, but a number of principles have emerged from research:

- Students will be motivated by realistic numeracy activities which are clearly related to the vocational areas in which they wish to work.
- Students will be more motivated if they have autonomy in their learning. Where possible, tutors should allow their students to make choices about the design of numeracy tasks, the data to be collected, and the ways in which results will be analysed and presented. This allows students to take ownership of the task, with a vested interest in a successful outcome.
- Weaker students can become demotivated if the classroom culture becomes excessively competitive. This can be avoided by promoting cooperation, perhaps by grouping students for tasks in ways that allow individuals with different skills to work together for better overall outcomes.
- Students are motivated by completing tasks successfully. Tutors should try to ensure that activities are of a suitable level of complexity that they can be completed successfully within the available time and with the available resources.
- Students are motivated by creating a product of which they can feel proud. This might be an actual artefact, such as the timber play structure described in the previous chapter, a piece of computer software, or a set of interesting results which can be presented in a professional manner in writing or using PowerPoint.

A useful theoretical framework relating to motivation is the ***MeE model of Munns and Martin***. This describes stages in encouraging students to develop a commitment to learning a subject.

- Students will become motivated (shown as ***M*** in the model) if an interesting and worthwhile learning activity is presented.

- The student will engage with the activity (small ***e*** in the model) if they find the activity enjoyable and they are achieving success in producing results.
- It may be necessary to repeat the cycle a number of times, presenting interesting and motivating learning activities in which the student engages successfully. It is hoped, however, that the student reaches a point where they engage with the subject as a whole (big ***E*** in the model). From this point onwards, the student becomes self-motivating. They value the subject overall and are keen to learn more.

The key message from the MeE model is that the most interesting activities should be presented right at the beginning of a course, so as to draw in the students and show that the course will be valuable and enjoyable. In numeracy, there is a temptation to teach in a bottom-up manner, beginning with such topics as arithmetic operations, fractions and percentages. This approach can be demotivating, especially if the students have previous poor experiences of being taught in a similar way. A more successful approach might be to present a complex problem, such as planning a new business venture, then allow opportunities for developing arithmetic skills to arise naturally in the course of analysing data.

Another useful theoretical structure is the ***teaching triad of Jaworski***. This identifies three components which interact to produce a successful learning activity:

- Mathematical challenge, in which an interesting and worthwhile task or problem is presented to students, which will generate enthusiasm.
- Management of learning, in which the tutor structures the learning activities to allow the students to work effectively and complete the task successfully. This might involve organising the students into groups or allowing them to work individually as appropriate, arranging any necessary equipment or computer access which is needed for data collection and analysis, and agreeing the format for the presentation of results verbally or as a written report.
- Sensitivity to students. The tutor carefully monitors the progress of the learning activity, intervening only when necessary in an advisory role. This might be to provide information on mathematical techniques, advise on data collection methods, or resolve problems which arise at the analysis stage.

In this book, the structure for developing numeracy which we have advocated is a ***top-down approach***, in which real world problems in the students' vocational fields are identified and investigated. These problems may, in turn, require the tutor to deliver training in particular mathematical techniques. However, these techniques will be seen by the students in context and their importance will be apparent.

A top-down approach to numeracy is in contrast to the bottom-up structure often used in mathematics courses, where the initial focus is on learning mathematical techniques without specifying any real world context. This can cause difficulties, particularly for weaker students. From our own interviews, students coming from school mathematics courses often commented that they could see no point in learning algebra and this topic had been a waste of time.

In this book we have taken a ***broader definition of numeracy***, in agreement with the views of employers about the range of skills required by their staff. We would define numeracy as including:

- The mathematical techniques appropriate to the particular vocational area covered by the course. This may only involve simple arithmetic, or might include quite advanced topics such as statistical methods in psychology or calculus in engineering.
- Data collection. According to the context, students may need to collect primary data by measurements or surveys, or collect secondary data by research in publications or on the Internet.
- Planning, in which students have some freedom in deciding the way in which the investigation will be conducted. Different possible solution methods should be evaluated, and appropriate levels of accuracy decided.
- Use of technology. Students should have opportunities to use appropriate state of the art technologies where possible, as an effective preparation for the modern workplace. This might involve the use of computer controlled workshop machinery, the use of specialist software for data analysis, or familiarity with general purpose calculators and spreadsheets for solution of numeracy problems.
- Problem solving, in which students are able to analyse their results, draw conclusions, and perhaps decide that further investigation is necessary in order to reach a convincing solution to the problem.
- Communication, in which students are encouraged to develop their abilities to explain mathematical concepts to others, at a technical specialist level or at a more general level as appropriate for the audience.

We realise that individual tutors may not have the range of skills or experience to deliver all of these components within a single learning activity. It can be valuable for tutors with different skill sets to work together on a project, perhaps with a mathematics tutor assisting with computer aided design and analysis and a workshop tutor supervising practical construction, as in the case of the wind turbine project described in an earlier chapter.

There is currently a focus on students developing their numeracy through re-sitting GCSE Mathematics or related examinations where necessary. Many opportunities do, however, still remain for students to undertake realistic real world numeracy projects in their fields of vocational interest. The individual project components of a range of A-level courses can include a substantial numeracy content, such as the trigonometry required for solid modelling in computing or the statistical analysis techniques required in geography and psychology. Mathematics modules of many vocational courses, such as Engineering and Construction, allow tutors to plan realistic extended numeracy tasks based around practical activities carried out in the workshop or on site. Even where tutors are constrained by an examination syllabus, it may be possible to create challenging real world tasks which introduce students to the theoretical topics in a more interesting and motivating way than formal classroom teaching.

We have found that the ***framework proposed by Tang, Sui & Wang*** can help in the planning of numeracy tasks for integration into vocational courses. Tasks can be developed at a series of levels, progressing from applications set by the teacher, through increasing student involvement in the solution of real world problems, to totally independent project work. The approaches proposed are:

> ***Extension.*** After studying a mathematical topic, students are presented with an ill-defined real world problem and must seek out additional data for its solution.
>
> ***Special Subject.*** Students who have studied a vocational topic are given the opportunity to investigate the topic further through a quantitative project specified by the teacher.
>
> ***Investigation Report.*** Students gather their own primary data through surveys, laboratory or fieldwork measurements, then process the data using appropriate mathematical methods.
>
> ***Paper Discussion.*** Students are presented with an interesting and challenging vocational mathematics task, then provided with resources from books, journal articles or the Internet. The students are encouraged to teach themselves the necessary quantitative techniques for solving the problem.
>
> ***Mini Scientific Research***. This represents the maximum level of student involvement in the planning, investigation and analysis of data for a substantial numeracy project related to their vocational area.

Examples of activities which we have carried out with our students at each of these levels were given in Chapter 3.

A substantial numeracy project can often be developed around ***activity planning***, as in the examples of holiday planning, house renovation, or garden design in Chapter 5. An approach which works well is to structure the project as a sequence of stages:

> ***Analysis***, finding out the exact requirements for the project, and the questions which need to be answered.
>
> ***Design***, deciding on suitable techniques of data collection, processing and analysis.
>
> ***Implementation***, carrying out the practical activities of collecting and processing the necessary data, then calculating results.
>
> ***Evaluation***. Interpreting the results and presenting them in formats appropriate for decision making.

In a large and complex project, this set of activities may be repeated as a cyclic process. Initial results form the basis for the next stage of planning and implementation.

Practical measurement and data collection in realistic work situations can be interesting, motivating and an enjoyable aspect of numeracy for students. A range of general numeracy skills may be required:

- Careful planning of practical activities should be carried out to ensure that all of the required data is collected.

- It is often necessary to choose appropriate units of measurement, and select suitable equipment for measurement and data recording.
- It may be necessary to choose data from a wider set of possible measurements, and in these cases the selected data needs to be representative of the overall pattern.
- It will be necessary to determine an appropriate level of accuracy for the results which are presented.

These skills will be important in real work situations when students enter employment. Students can be highly motivated through collecting data which provide important insight into interesting problems.

In many numeracy tasks, we are interested in the behaviour and properties of shapes. Working with shapes can increase ***spatial awareness in two- and three-dimensions*** and can develop mathematical skills in geometry and trigonometry. In addition, there may be opportunities for applying wider mathematical techniques, such as: ratios for converting scales, or algebra for transforming shapes. Projects may be developed in a wide range of real world contexts, from surveying land surfaces to representing components of buildings and machinery. Shape and space projects fit well into the scheme of broader numeracy training, providing interesting and motivating challenges for students.

An important skill in numeracy is the ability to move easily between ***numeric, algebraic and geometric representations*** of data sets. Patterns in the data may be identified by plotting graphs, and we may then be able to represent the patterns as algebraic expressions for use in solving similar problems. Algebra can be a difficult subject for some students, who may have poor experiences from mathematics lessons at school. However, algebraic techniques have become so important in modern data processing that it would be well worth making a fresh start through working with formulae in realistic vocational contexts.

Statistical analysis provides a powerful range of techniques for assessing the significance of data which has been collected. Statistical techniques are regularly used to answer a wide range of questions, from the quality of goods produced in a factory, to the most effective medical treatments, or the likelihood traffic congestion in a city. Lists of the numeracy skills which employers would like their staff to possess often include a familiarity with the principles of statistics.

Mathematical modelling is another important numeracy skill sought by employers. For students, mathematical modelling can provide an exciting opportunity to investigate real world problems in a similar way to professional users of mathematics. Modelling usually involves the analysis of ill-defined real world systems, requiring students to use a high level of problem solving skill in determining which factors are of central importance and how these factors are related to one another.

Calculus is often seen as a complex and advanced area of mathematics, but is based around some very simple and useful concepts which have immediate uses in a variety of subject areas. Many students can benefit from a basic knowledge of calculus techniques relevant to their vocational fields. The complicated algebra required in analytical calculus can often be avoided by using simpler numerical methods which give acceptable accuracy. This then allows students to focus on interpreting the results produced.

In many workplace situations, complex tasks are controlled or implemented using sequences of instructions in the form of ***algorithms***. The design of efficient algorithms can require a range of broader numeracy skills, including problem solving in a vocational context, the ability to work with information technology systems, and an ability to convert between different representations of quantitative data using numbers, diagrams or algebraic expressions as appropriate. Again, it will be of benefit for students to be introduced to working with algorithms as a preparation for employment.

At the end of this review of numeracy training, we must acknowledge the extent to which ***assessment has a controlling influence on the delivery of Further Education courses***. The requirements for assessment may structure all the teaching activities of a course, leaving relatively little flexibility for teachers to vary the course content.

For an effective assessment strategy which supports learning, a number of components need to work together. We must create a course which is motivating for students through having relevance in their chosen vocational area. Numeracy tasks during the course need to be real or realistic simulations of workplace activities, providing students with opportunities to develop both their mathematical techniques and their wider numeracy skills in areas such as problem solving, measurement and working with information technology systems. At the core of the strategy must be a capacity to make fair assessments of the abilities of candidates.

This all presents a major challenge. As tutors, we continue to work as effectively as we can within the constraints of syllabuses to prepare our students for the increasingly complex numeracy demands of their future careers.