Summary

In this HE STEM-funded project we created a learning environment that raises statistical awareness among STEM employers and employees and:

a) shows the need for employers to audit employees’ statistical skills and act on the evidence provided by the audit;

b) builds an understanding of the role of statistical skills in developing a fully competent workforce;

c) develops an appreciation of how statistical skills can be improved.

We created a web-based tool for employers to audit their employees’ statistical skills. We investigated and identified:

a) statistical issues that STEM graduates should be able to discuss on the basis of what they know, but not necessarily be able to do;

b) the statistics-related areas that STEM graduates should be able to critically evaluate.

We also identified a useful statistical topic applicable to a range of STEM contexts, which can be taught to STEM employees using distance learning web resources. We give an example for teaching this topic to STEM employees through a problem-solving approach.

Background

In June 2011 the Advisory Committee on Mathematics Education (ACME) published the report ‘Mathematical Needs: Mathematics in the workplace and Higher Education’ (ACME, 2011). As part of their research for this report ACME interviewed “… employers and employees from about 25 companies” to investigate staff involvement with mathematics in the workplace. As a result of these interviews a number of case studies on the use of mathematics in the workplace were developed along the following six themes:

- Mathematical modelling (5 case studies)
- Use of software packages and coping with problems (3 case studies)
- Costing (including allocating costs and managing disputes – 4 case studies)
- Performance indicators and the use of ratios (3 case studies)
- Risk (4 case studies)
- Quality control and statistical process control (5 case studies)
While it is clear that the last two of these themes clearly involve statistical awareness and/or competence, in fact the majority of the case studies developed involved obtaining relevant data, creating graphical representations of results and carrying out some statistical analysis/processing of the data. In Appendix 3 of their report (ACME, 2011) they present specific mathematical topics that were encountered in different industries. For six of the eight industrial sectors they considered they present verbal evidence from managers that statistics at varying levels of complexity is required knowledge for some members of the workforce. Unfortunately their research did not extend to populating a curriculum in the manner that we have done in this project.

The Sector Skills Council for Science, Engineering and Manufacturing Technologies (Semta) is currently undertaking work to inform Further Education and Higher Education institutions and other ‘supply-side’ training providers of the detailed skills and knowledge required for technician and engineering posts within their sector. Semta has produced job profiles and tables of specific Mathematics skills ‘enabling, applied, doing technical and practical activity to get the job done’ for each of the following job descriptions:

- Technician (Design & Manufacturing);
- Engineer (Systems Designer);
- Senior Engineer (Product Owner and Support);
- Principal Engineer (Manufacturing Engineering Manager);
- Chief Engineer - Electrical Systems

For example a Senior Engineer (Product Owner and Support) is expected to have adequate knowledge of and make frequent use of Statistical Methods together with adequate practical experience in applying their knowledge. However they might be expected to require some guidance, advice and/or supervision when using Statistical Methods. Engineers in the remaining four posts are expected to make frequent use of at least two of: Statistical Methods; Statistical Techniques; Applications of Statistics; and Probability. In addition they are expected to have expert knowledge of these topics with a comprehensive level of practical experience and achievements in the subject.

While the information proved extremely informative in the way in which the skills have been classified it does not provide the topic-by-topic guide to specific statistical skills that are explored in detail by this project.

Course materials ideally needed to be tailored for each of the STEM disciplines (and subjects within those disciplines). But this project did not have enough funding to be able to create individualised materials that are suitable for biologists, physicists, chemists, technologists, engineers, mathematical scientists and so forth. Instead, for illustration, the project created exemplar resources in one subject area within a Moodle environment.

Activities

Our work concentrated on the following four activities.

a) Running discussion workshops at up to four selected STEM employers

These workshops addressed the statistical needs of companies and their employees. We designed a feedback form for employers and employees and wrote an online competency survey. We modified the audit questionnaire in the light of these meetings and piloted the survey in selected companies.

b) Running a conference to engage with STEM employers

This proved impossible to organise owing to the fact that companies were not able or willing to travel to attend a conference in the available timescale. Instead we discussed a range of possible statistical awareness topics remotely with our selected employers and identified the most useful. The finally agreed curricula are collected together on the web site.

c) Designing and writing a web site to host the new curriculum in Moodle

We have done this (www.rss sce-ed.org.uk) and populated it with the curriculum agreed with the employers. We provide links to examples and good practice material for providers:

- the IASE gateway to statistics educational resources from around the world: (http://www.stat.auckland.ac.nz/~iase/links/start);
- http://onlinestatbook.com/;
- http://www.freebookcentre.net/SpecialCat/Free-Statistics-Books-Download.html;

d) Determining the Curricula

An important aspect of the project was to determine what, if any, statistical curricula were required by STEM professional bodies as part of their accreditation or certification of individuals. A telephone survey was conducted by the project team to determine the extent and content of any such curricula. The learning environment is Moodle-based and is freely available for auditing statistical competencies. It also contains a curriculum in statistical awareness which was agreed with the STEM employers we met. We created a curriculum that enables STEM employees to study material so that they can acquire statistical awareness, knowledge and skills that will help their employers improve productivity.

The following professional bodies were contacted to investigate the extent to which they prescribe a statistics content for their professional qualifications:
Using a web search the project team also contacted a range of universities to explore the undergraduate statistics curriculum in STEM subjects. The following universities that offer study in at least one of biology, chemistry and physics were contacted: Plymouth, Imperial College, Bath, Birmingham, Manchester, Newcastle, Durham, Glasgow, Cardiff and Bristol.

We reviewed the online syllabus content for statistics modules on STEM science degrees at this sample of universities to investigate the extent to which statistics may be taught as part of a first degree in the subject. The results indicate that, as with the engineering professions, there is no clear consensus even within individual disciplines. In biology the requirements for the institutions sampled range from an optional study of statistics, through basic statistics and core skills to experimental design. The requirements in chemistry for the sampled institutions, where they could be identified, appear to be low level basic statistics with one notable exception of statistical mechanics. This same pattern of subject requirements also appeared among the physics courses.

**Outputs**

The following resources are available for colleagues to view and use on the RSSCSE web site [www.rsscse-edu.org.uk](http://www.rsscse-edu.org.uk).

(a) A freely available web-based tool for auditing statistical competencies. This is available in pdf format and the online version can be accessed at [www.rsscseedu.org.uk](http://www.rsscseedu.org.uk) by following the link to ‘A Statistical Awareness Curriculum for STEM Graduate Employees’ or by accessing the online questionnaire directly at [http://bit.ly/hestemc](http://bit.ly/hestemc). We created training example survey-type questions that we discussed with employers. They agreed that these should be inserted to help their employees ‘to get used to’ the kinds of questions in the actual questionnaire that follows. The electronic version of the questionnaire can be used by any employee as a self-audit tool: employers were very firm in the conviction that the tool should be used as a way to inform an individual about his or her CPD needs. Discussion with line managers should be carried out with a hard copy version of the responses.

There are eight main sections of the online questionnaire. Fig 1 shows the screen of section 4 of the online questionnaire that asks questions related to ‘Probability and uncertainty’.

![Fig 1: Screen of section 4 of the online questionnaire](image)

All the sections are designed in a similar way. At the end of section 8, a pdf file is created by clicking on the Submit button.

(b) A curriculum in statistical awareness which is agreed with STEM employers. This curriculum was developed in a Moodle environment and is freely available. This curriculum is available from the main web site [www.rssscse.org.uk](http://www.rssscse.org.uk) and was developed from the curriculum we proposed and discussed with STEM employers.

**An Agreed Statistical Awareness Curriculum for STEM Employees**

We present the three curricula that were agreed after discussions with a range of STEM employers. The specifications cover what their employees should be able to:

- fully understand or do;
- identify and critically evaluate;
- know about.

1) STEM graduate employees should be able to fully understand or do;

For a given problem, use a problem solving approach to make evidence based decisions, that is they should be able to:

- identify relevant questions that need to be answered;
- identify the target population; recognise the population structure and properties; choose an appropriate sampling approach that could be used.
- decide what needs to be measured/recorded; identify the corresponding measurement scale(s); know how to collect or arrange collection of the required data.
identify appropriate summary measures that could be used; identify appropriate graphical presentations that could be used; process the data obtained in the manner identified.

assess the initial questions raised in the light of the results obtained; recognise whether more questions need to be addressed; decide on actions as a result of the findings.

have an awareness of data quality, how data are generated and where it comes from;

use probability as a measure of uncertainty; calculate probabilities for compound events; understand and calculate conditional probabilities (for example using a bivariate table);

understand how common causes (inherent or natural variation) and special causes (external source of variation) can have an impact on processes in STEM industries; understand variability and propose appropriate summary measures and graphical representations to aid understanding of its impact in different problem situations;

understand the importance of and be able to effectively use graphical presentation of data;

know how mean range and standard deviation can be used to describe distributions and know how to distinguish between discrete and continuous distributions;

understand the process by which inference is used to make decisions; make appropriate inferences in different problem situations;

know the central limit theorem and understand its importance to inference;

know how to use basic statistical tests and interval estimates and understand the situations in which they are appropriate;

understand how bias can arise in sampling and measuring in STEM industries; undertake appropriate actions to reduce bias when it arises;

understand what missing values are, how they can arise and what action to take when they do;

understand how correlation can be used to measure association between two variables;

use simple linear regression;

understand how some variables can change through time and that running means can be used to estimate trends;

know how control charts can be used to monitor processes and how measures of process capability can help inform decision making in STEM industries;

know how to interpret trends and runs in control charts.

2) STEM graduate employees should be able to identify and critically evaluate

For a given presentation/report/study/publication, STEM employees should be able to:

identify and critically evaluate the nature of sampling methods used;

identify and critically evaluate the experimental design employed;

assess the quality of the questions where a questionnaire is employed and critically evaluate the use of the questionnaire in the context;

understand written descriptions associated with numerical and/or graphical presentations and critically assess their quality and relevance;

identify important points that can be made from the information provided and critically assess points made in the presentation for accuracy and relevance;

offer constructive criticism of the conclusions drawn by the author/reporter.

3) STEM graduate employees should;

know about applications of probability and risk and be aware of the distinction between relative and absolute risk;

know that samples that are to be used to make wider inferences should be drawn using well designed experiments or sampling frames;

know what types of information and data are collected by government and other national and international agencies and be aware of the use to which such data should be and is currently put;

be aware of how statistics is used in industry and commerce;

be aware of areas in which statisticians are currently employed and know about the types of problems they are addressing;

be aware of the use of statistical indicators in measuring performance and know about the strengths and weaknesses of such indices;

know that very large data sets are increasingly used by industry;

commerce and government and be aware that they pose special problems of analysis and know how they are used;

know about the use of statistics in different applied areas for example in recording, investigating and reporting crime and its use in medicine in developing new medicines, recording and reporting the quality of patients’ experiences;
be aware of the basic technical terms that might be encountered in everyday life such as ‘significant’, ‘confidence interval’, ‘correlation’ and ‘standard deviation’.

Sample Teaching Resource

In view of the project requirement to provide a sample resource in just one STEM subject area, in designing the resource we adopted the following guiding principles:

- it should deal with a topic that employers would perceive as forming part of the curriculum dealing with statistical topics that STEM graduates should be able to identify and critically evaluate;
- it should be a topic that is applicable (albeit with differing context) across STEM disciplines;
- it should consist of a PowerPoint presentation; notes in support of the PowerPoint; and an additional exercise with supporting data;
- it should allow for both low and intermediate levels of mathematical skill.

This PowerPoint resource is downloadable from the RSSCSE web site at www.rsscse-edu.org.uk

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References


maths e.g. version 2 and Teacher interface

Martin Greenhow, Brunel University

maths e.g. is a free-to-use collection of almost 2000 mathematics questions with random parameters and feedback spanning topics from GCSE to undergraduate level 2 made available to mathcentre by Martin Greenhow and Abdulrahman Kamavi from Brunel University. After an initial successful trial, version 2 of maths e.g. is now available at http://www.mathcentre.ac.uk:8081/mathseg/

This page is for student use so you can simply point your students here, preferably with some advice on which question topics to attempt. Students can also use the search facility. Staff might find this a source of inspiration when setting examples sheets and/or assessments.

There is also a teacher's interface at: http://www.mathcentre.ac.uk:8081/mathsegteacher/

This resource is for teachers and lecturers, not for students. Teachers need to sign up and login to the system, after which they may use it to compose their own tests by selecting (specifically or randomly) questions from the entire database of questions. We hope that this is as easy as shopping on Amazon, but we have included a set of instructions linked from the title page. Please make frequent use of this - it will give your students access to about 2000 questions that have (mostly) been tested over several years. Our experience has been that students learn a great deal and we have hard evidence to back that up!

Further developments will take place over the next few months, so please email your feedback using the link on the title page.