The Transition into University: What Engineering Students Know

THE TRANSITION INTO UNIVERSITY: WHAT ENGINEERING STUDENTS KNOW

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ABSTRACT

This work arose from the perception that it would be extremely useful in delivering and improving first-year undergraduate engineering modules if the staff could be given a profile of the knowledge and understanding of the incoming student cohort. This knowledge and understanding is usually not well captured or described by prior qualifications, because it would ideally embrace both technical understanding and also practical skills and a general understanding of the societal context in which engineering is being taught. We therefore developed a set of web-based diagnostic and support tools designed to identify more clearly the attributes of students entering engineering programmes in the UK in 2010 and to support their transition into university.

The project team devised 50 questions for incoming students, developed a web-based tool for their delivery during the first two weeks of the academic year and an initial data query tool for retrieval of the resultant data. This questionnaire has been run with more than 300 students in four universities and some initial conclusions have been drawn. There are differences in detail but these four first year student cohorts are quite similar in their incoming knowledge and skills.

KEYWORDS

Transition; prior knowledge; induction into engineering; first year experience;

BACKGROUND

The project arose from the perception that it would be extremely useful in delivering and improving first-year undergraduate engineering modules if the lecturing staff could be given a clear profile of the knowledge and understanding of the incoming student cohort. This knowledge and understanding is not well captured or described by prior qualifications (such as

A-levels in the UK), because it would ideally embrace both technical understanding and also practical skills and a general understanding of the societal context in which engineering is being taught.

The aim of this project was to scope and test both content and mode of use of a set of web-based diagnostic and support tools designed to identify more clearly the attributes of students entering engineering programmes in 2010 (and beyond) and to support their transition into university.

IMPLEMENTATION

The implementation of the project involved four inter-connected and mutually dependent aspects: These were the development of the questionnaire, the development of the on-line test delivery environment, the delivery of the tests to the selected student cohorts and the subsequent analysis of the large amount of data thus collected. These four aspects will be considered in turn:

The questionnaire:

The content of the questionnaire covers, albeit with only a few questions each;

- The technical knowledge which an incoming student should have gained from prior study (principally physics, chemistry and mathematics);
- Practical skills (such as use of workshop hand tools);
- Familiarity with major examples of engineering in society (such as nuclear energy), and;
- Knowledge of adjacent areas of developing importance (such as biology).

A target questionnaire completion time of less than one hour dictated that the number of questions should be limited to 50 or 60 and the content therefore represents a compromise between the breadth implied by the above list and the depth desired by the future teachers of these students. The topics to be covered were eventually agreed to be:

- Chemistry
- Energy – kinetic and potential
- The Workshop
- Nuclear Power
- How they work – mechanical parts
- General knowledge – environmental, evolution and biology
- Electronics and optics
- Office IT
- General physics – forces and motion
- General engineering – loads and gravity
- Materials properties
- Maths – trigonometry, binary and equations

About 70 questions were written by members of the team, of which 50 were deployed in the first questionnaire. Considerable time was spent refining the wording of the selected questions: to use a vocabulary and style appropriate to the intended cohort; to devise unambiguous multiple choice questions that each addressed a single concept or idea; to design answer choices that would unearth common misconceptions; and to ensure questions were culturally and linguistically neutral. This was probably the most difficult task of the project.

A “not sure” option was included in as many questions as possible, and it was emphasized to the students that they were not being “marked”. Three specimen questions are reproduced as Appendix 2, and the complete set can be obtained from the author on request.

The delivery environment:

No piece of commercial software was found to offer the required flexibility in delivery (any student, anywhere) and data collection and analysis (free access by all partners to all results in a spreadsheet). A web-based questionnaire delivery system and data retrieval system was therefore developed, which offers almost any type of question (including graphics if necessary) and enables the output of every answer in raw spreadsheet form for analysis. The data input by the student, prior to answering the questions, comprises:

- Host institution [from a drop-down list of partners]
- Programme of study [from a drop-down menu of programmes provided by each partner]
- Highest prior qualification [A-levels, apprenticeship, Baccalaureat, Foundation Year, NVQ, SQA Advanced Highers, SQA Highers, Other]
- Nationality (effectively fee status) [UK, EU, Other]
- Email address [for response and feedback – need not be university address; not a requirement if feedback is only to be given immediately]

Clearly these are tailored to the UK environment, but could easily be modified to reflect local conditions in other countries. The rubric at the beginning of the questionnaire (reproduced as Appendix 1 below) emphasises the rationale behind the exercise and is intended to remove apprehension about the test from the students’ minds.

The questionnaire can be seen and used at www.stem-transition.ac.uk . Three specimen questions are in Appendix 2.

Delivery to the students:

Each partner university chose how to deliver the questionnaire. All elected to do it in week 2 of the first semester, when almost all students would have completed their registration and have email and web access within the university. Most delivery was in the context of a first-year study skills or core skills module. Response rates were better when the exercise was carried out in a timetabled class session (eg 112 completed questionnaires from a possible 154 students at University A) and lower when the students were told about the exercise and asked to do it later (e.g 93 completed questionnaires from a possible 270 at University B). One complete programme cohort at University C missed the opportunity because of a local system crash, but the response rate from the other University C cohort was good.

It did not prove possible to implement the automatic email to each student who completed the questionnaire, and thus the students received no feedback on their performance this year. The feedback should identify gaps in knowledge, understanding and experience and should point students towards learning resources to help them improve. It is an urgent priority to ensure that this is implemented next year.

For the same reason, and additionally because it is difficult to locate support resources at exactly the appropriate level for each question, support was not offered individually to students.

However there are a number of semi-generic sites which offer explanations for almost every question. These include:

www.mathcentre.ac.uk
www.howstuffworks.com
www.raeng.org.uk/education/diploma/maths/default.htm
http://sls.uwe.ac.uk/ls/orgchem/

The authors are currently implementing a system of feedback to every student who completes future questionnaires.

Data analysis:

All the data, from a total of 312 students, is available in spreadsheets. Partners from the individual universities have downloaded their own cohort data and are using it in different ways. Centrally we have so far analysed the data at the following levels:

1. Correct answers to each question at university level (i.e. one set per university) and in aggregate (sum of all four universities);
2. Not-sure answers to each question at university and aggregate levels;
3. Correct answers per question-group at university and aggregate levels;
4. Prior qualification, and;
5. Nationality;

We have not yet had the time resource to analyse the data in terms of:

6. Programme of study (i.e. Engineering discipline). The number of returns for each discipline are also too small to give significant information at this stage.

DISCUSSION AND CONCLUSIONS

Barriers

The key barriers to success and on-time delivery were found to be:

- The difficulty of writing good questions – tuning the questions took a great deal of meeting time;
- Restriction of the questionnaire length in order to enable students to complete it within one hour. In practice we over-estimated the time required and could add several more questions next time. However the restriction of time still means that each topic can only be explored through a small number of questions – essentially a sampling approach to the students' knowledge, rather than a comprehensive survey;
- The reliable delivery to a large fraction of the student cohort. This is particularly difficult for those cohorts without a single class scheduled for a computer laboratory;
- The difficulty of delivering tailored support to every student, for every question. With the benefit of hindsight this was never likely to be achievable within this project: Pearson have spent millions of dollars developing good feedback for assessment questions (e.g. in Mastering Engineering) and still only cover a fraction of the ground we are surveying.
- Some students gave fake email addresses, indicating that (despite our efforts to persuade them otherwise) they were concerned about the results being used against them. The behaviour of a significant minority of students who – despite all our advice to the contrary – treated the questionnaire as an assessment of them, merits further exploration (see below under Recommendations for others).

Conclusions and evidence of success

The key indicator of success is that all partners are enthusiastic about deploying the questionnaire in future years (after some necessary fine tuning of the questions).

Although it is the key task of each partner to interpret and use the data from their own students to improve engineering education within their own institution, there are some overall conclusions which can be drawn at this stage. These include:

1. There is a wide range of highs and lows in understanding across all topics;
2. There is a large degree of similarity between the student cohorts from the four universities, with only the University C students demonstrating a significantly different pattern of knowledge in some areas.
3. Only five of the 50 questions were answered correctly by more than 90% of all students. After debate it was agreed that there is value in retaining these questions for two reasons: they help give the students confidence, and they should be useful as a check that key topics remain well understood over the next few years (or not, if that is the finding!);
4. Many students have clearly learned something about topics which are not directly taught to them. However there is generally a lower understanding, across all cohorts, of topics which might be regarded as scientific or engineering "general knowledge" (e.g. evolution, nuclear power, photosynthesis);
5. On average only 6% of responses were "not sure", and these were largely clustered around 8 questions with not-sure responses of 15-40%. This should help us identify key misconceptions. There was a weak correlation between the average mark for a question and the number of not-sures – in other words there was a slight tendency for poorly-answered questions to attract a larger number of not-sures
6. Only 8 questions were answered correctly by less than a third of the students. The topics of these questions ranged across almost all topic areas, including chemistry, physics (mechanics), materials, general knowledge and mathematics. These are the most important general lacunae which should be brought to the attention of staff teaching first-year students.
7. In terms of initial qualifications, students with A-levels or a Baccalaureate (i.e those with slightly more academic qualifications) performed about six percentage points (59% vs 53%) above those with other qualifications, including those who undertook a foundation year before entering their first year. They were also slightly less inclined to answer "not sure" (6% vs 8%)
8. In terms of national background, UK students (actually those with a residential qualification sufficient for them to pay "home" fees) performed slightly better than those from the EU and ten percentage points (59% vs 49%) better than those from other countries ("Overseas", likely to contain many students from China, India and Malaysia).

The full data spreadsheets from which the above interim conclusions are drawn are available from the author at goodhew@liv.ac.uk.

Some of the conclusions we can draw appear to be generic, at least in the UK. For example all cohorts tested show considerable weaknesses in their understanding of chemistry, nuclear power, electronics, optics and the properties of materials. They are particularly ignorant about environmental and biological issues (average score 10%). They all did well on the questions about energy, workshop tools and MS Office. However since each of these areas is only tested with a few (three to six) questions we can have little confidence in the reliability of these subjectspecific conclusions. This situation will be improved greatly if we succeed in running the questionnaire with more students and more institutions in 2011 and 2012. It should be possible to collect >600 student responses in 2011 and >1000 in 2012, greatly increasing the statistical significance of our conclusions and making it worthwhile to examine the data at the discipline level (mechanical, electrical, etc). Of course if other institutions (especially CDIO partners) choose to join the experiment then our statistical base will improve rapidly, and we could consider drawing international comparisons.

Recommendations for others

Anyone contemplating deploying this questionnaire or developing a similar tool would be well advised to read the whole of this report and to speak to one or more of its authors.

A key issue is how the questionnaire is delivered to students. As was explained above, it proved difficult to persuade students that this is not a test of their status or progress but a snapshot of the cohort to help staff to match their teaching to the whole student cohort. Our recommendations are that this effect is likely to be minimised when the exercise is carried out with a "captive" class (e.g. all together in a computer lab) immediately following a clear explanation of the purpose of the questionnaire. It would be an interesting research project to explore student attitudes and the effectiveness of various differently-nuanced explanations – some of which could perhaps emphasize more strongly the altruistic nature of the whole exercise.

Concluding remarks

This has been a highly successful project within the confines of very limited funding. The whole team (4 institutions plus Cogent) together with a likely three additional universities (CDIO partners Lancaster, Aston and Strathclyde) are very keen to improve the questionnaire and use it in September/ October 2011. This work is ongoing. Other institutions wishing to deliver the questionnaire to their own students should contact the corresponding author. Their programmes can be added with minimal effort.

Appendix 1

Rubric presented at the top of the questionnaire:

"The questionnaire we are asking you to undertake is for the benefit of yourself and future generations of students. We are trying to establish what you and your fellow-students as a whole know and understand about engineering and some of the science and maths which underpins it. If we can find this out, we can modify the modules you will be attending in order to fill in gaps, and exploit strengths, which your particular group of students have.

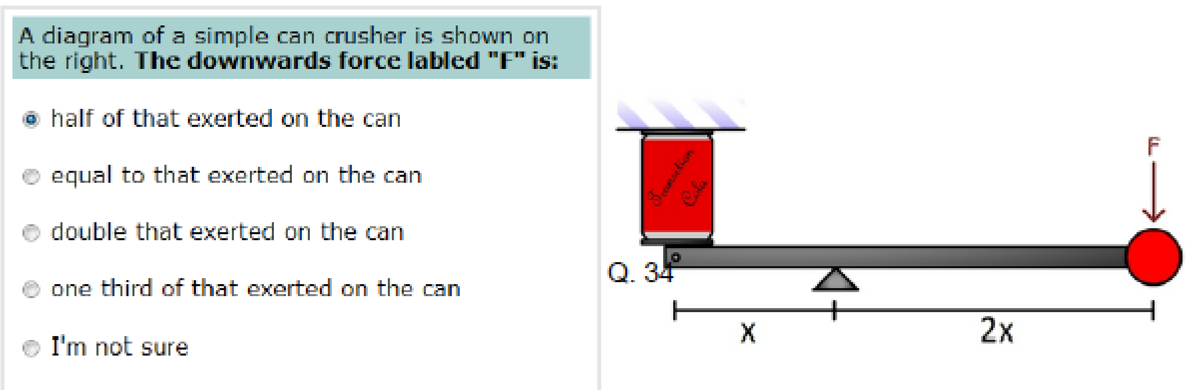
This is NOT a test, it carries no marks and your results will not be used by anyone to assess you. Staff at your university will not have access to individual results, only to the combined results of your whole year group. However to help you understand your current state of knowledge and experience you will receive, after completing the questionnaire, an analysis of where you have gaps in your knowledge, together with some suggestions as to how you might like to fill these gaps. This is simply to help you be better prepared for your engineering studies.

Please answer the questions as honestly and quickly as you can. We do not want you to spend too long doing this, and if you seek help or look up the answers then your results will be of no use to us in improving your modules, and also very little use to you! If you are curious to know more about any topic, then look it up after you have finished the questionnaire.

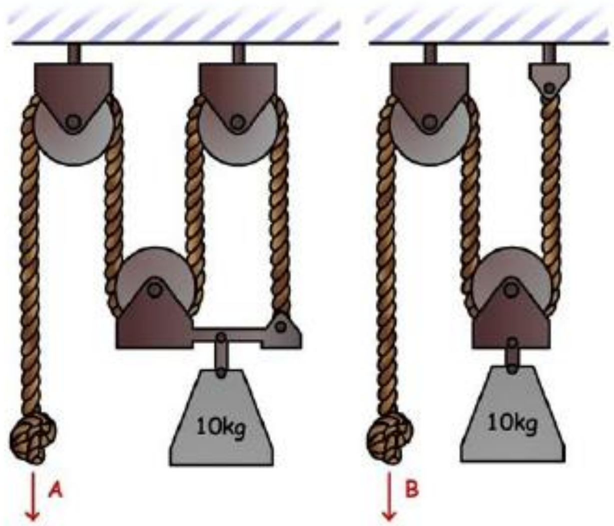
Thank you for your cooperation."

Appendix 2

Three specimen questions (with answers checked):

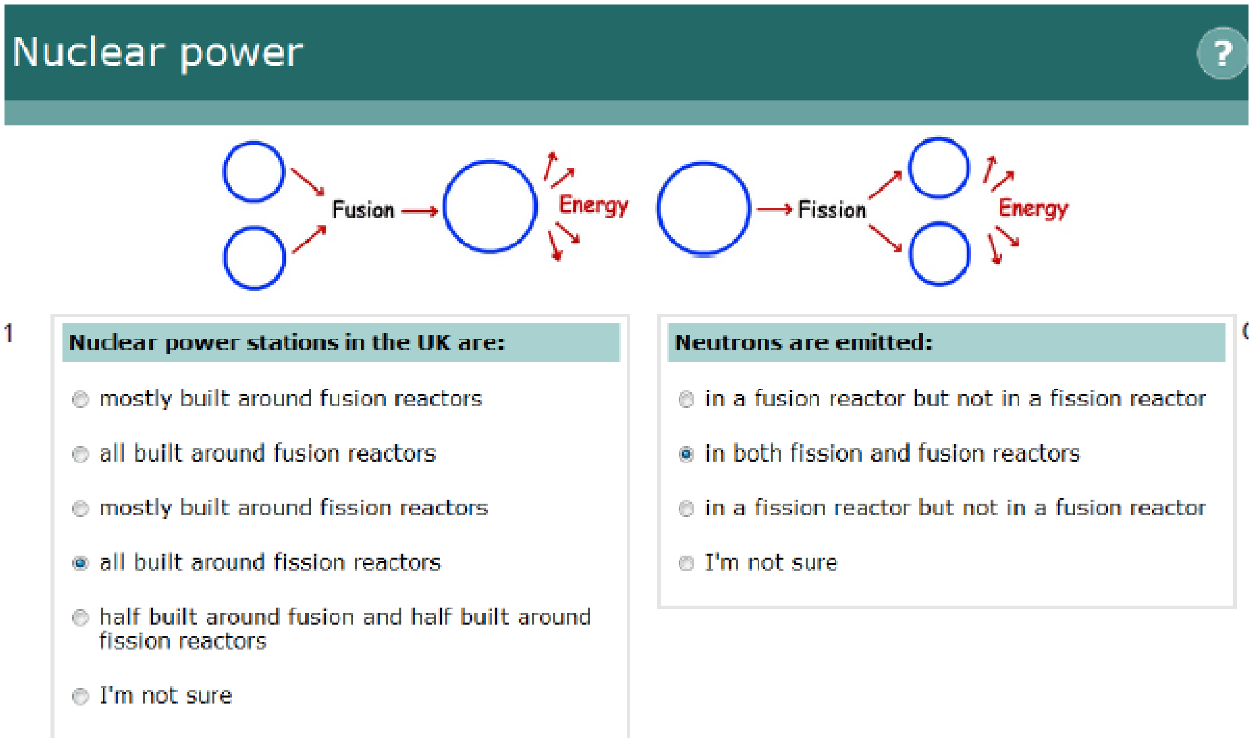


How They Work – Mechanical Parts



Above are two similar pulley systems.
Pulling rope A would be:

- easier than rope B and would lift the weight further
- easier than rope B but would not lift the weight as far
- more difficult than rope B and would not lift the weight as far
- more difficult than rope B but would lift the weight further
- I'm not sure



BIOGRAPHICAL INFORMATION

Peter Goodhew is Emeritus Professor in the School of Engineering, University of Liverpool, UK. He is one of the Directors of CDIO and the joint Leader of the UK & Ireland region. He is interested in many aspects of engineering education and has recently published a short book on the subject: “Teaching Engineering”, downloadable from http://www.materials.ac.uk/resources/Teaching-Engineering.pdf

Dr Matt Murphy, Dr Charles McCartan, Dr James Ren, Professor Peter Myler and Dr Caroline Sudworth are partners in the STEM Transition project.

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