Raising learner awareness of progress towards UK-SPEC learning outcomes

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Abstract

This paper introduces UK-SpecIAL, developed to help engineering students better understand how their modules relate to each other and to the engineering professions towards which they are working, and to raise their awareness of their progress towards UK-SPEC learning outcomes. Our example is for electronic, electrical and computer engineering, but could be extended for other engineering subjects. Log data indicates that learners use the information provided about their general progress across modules and questionnaire responses suggest students consider UK-SpecIAL to be a useful support for their independent learning.

Introduction

UK-SpecIAL is an adaptive environment to promote learner independence amongst engineering students. We first describe the requirements for accredited engineering degrees; then explain how independent open learner models (IOLM) can be used to promote reflection, planning, formative assessment and learner independence. We present the UK-SpecIAL IOLM, designed to facilitate metacognitive skills throughout an engineering degree, and give results of deployment in first year modules.

UK-SPEC for accreditation

Individuals applying to become chartered engineers need to meet the educational and professional development requirements of the UK-SPEC Standard for Professional Engineering Competence (Engineering Council, 2005). The educational requirements for this can be satisfied by gaining a degree which meets the learning outcomes defined by the UK-SPEC documentation (Engineering Council, 2004). The learning outcomes (LO) are categorised under five broad headings:

(i) underpinning science and mathematics
(ii) engineering analysis
(iii) design
(iv) economic, social and environmental context
(v) engineering practice.

Each of these contains specific learning outcomes[1], e.g:

engineering analysis includes:

- ‘ability to apply and integrate knowledge and understanding of other engineering disciplines to support study of their own engineering discipline’
- ‘understanding of engineering principles and the ability to apply them to analyse key engineering processes’ (Engineering Council, 2004).

engineering practice includes:

- ‘awareness of nature of intellectual property and contractual issues’
- ‘ability to work with technical uncertainty’ (Engineering Council, 2004).

Each LO is relevant to several modules and each module contributes to several LOs. The Institution of Engineering and Technology (IET)’s interpretation of UK-SPEC LOs for electrical, electronic and computer engineering degrees (IET, 2006), was used as the basis for this work.

As an illustration of the range of LOs addressed by a single module, Table 1 shows the LOs to which the first year *EE1A: Digital Logic and Microprocessor Systems* module contributes. (The text is taken from the IET interpretation of UK-SPEC[2].)

Table 2 shows how several first year modules contribute to a single LO through ‘Knowledge and understanding of scientific principles and methodology necessary to underpin their education in their engineering discipline, to enable appreciation of its scientific and engineering context, and to support their understanding of historical, current, and future developments and technologies’ (Engineering Council, 2004).

Table 1. UK-SPEC LOs to which module EE1A (Digital Logic and Microprocessor Systems) contributes

Module EE1A (Digital Logic and Microprocessor Systems)	
LO B1 Underpinning scientific principles	DC and AC circuits
LO B2 Underpinning maths	Number systems and codes; Boolean algebra
LO B4 Engineering principles	Circuit theory; digital electronics; electronic components; digital circuits and logic families; combinatorial and sequential logic circuits; number systems
LO B8 Investigate and define a problem	Use a structured design approach
LO B11 Use creativity to establish innovative solutions	Demonstrate familiarity with tools and techniques; use a structured design approach
LO B19 Knowledge of particular materials, equipment, processes or products	Knowledge of particular materials, equipment, processes or products; knowledge and understanding of equipment, materials and processes employed in the design, production and testing of digital systems
LO B20 Workshop and laboratory skills	Work safely in a workshop or lab, using a range of tools related to the assembly of electronic circuits and systems
LO B22 Understanding use of technical literature and other information sources	Understanding use of technical literature and other information sources

Table 2. Contribution of first year modules to LO B1

LO B1	EE1A	EE1B	EE1C2	EE1F1	EE1H1	1IEE
Basic electric and magnetic principles		X	X		X	
DC electric circuits	X	X			X	
AC electric circuits	X	X			X	
Forces, energy and work		X				X
Newton's laws		X				
Circular motion		X	X			
Basic properties of materials		X				
Basic quantum physics		X				
Thermal analysis		X				
Vibrations and waves				X		

Key: EE1A - Digital Logic and Microprocessor Systems; EE1B - Circuits, Devices and Fields; EE1C2 - Introduction to Electrical Engineering; EE1F1 - Introduction to Information Engineering; EE1H1 - Introduction to Interactive and Multimedia Systems; 1IEE - Introduction to Energy Engineering

UK-SPEC for students

It is widely accepted that students do not necessarily understand the relationships between modules at the point they are studying them and engineering education is not immune to this (Avitabile et al., 2005). UK-SPEC, although designed for educators with reference to engineering degree accreditation, also provides a framework within which to consider highlighting *to the students themselves* the relevance of aspects of their degree to engineering professions. UK-SpecIAL was designed to address the issue of students not fully understanding the purpose of modules and to raise awareness of how their learning relates to professional engineering. UK-SPEC (Engineering Council, 2004) and the IET (2006) interpretation were used as the basis for the design of UK-SpecIAL.

Adaptive learning environments and learner modelling

Most adaptive learning environments include a model of the target domain (knowledge/concepts/skills) – the *domain model* (DM)[3] – and a model of the individual's understanding of the domain – the *learner model* (LM)[4]. Typical examples of the main components of an adaptive learning environment are illustrated in Figure 1. The LM is dynamically inferred during the interaction, based on the user's responses to questions; attempts at problem-solving or other tasks; requests for help or hints; time on task or other features of the interaction that could help a system better understand the user. The LM could be inferred using a variety of techniques. Commonly the LM may contain learner knowledge as a subset of expert knowledge (left of Figure 1), where the LM would be expected to develop (or grow) to approximate the DM over time; or it may also include other information such as inferred misconceptions (right of Figure 1). The DM and LM are then used to infer suitable guidance for the individual, according to the current state of their knowledge (e.g. automatic selection or generation of relevant information at an appropriate level; exercises tailored to their current knowledge or specific difficulties; individualised feedback). Thus the LM is usually used by the computer environment to enable automatic personalisation.

Open learner models

While LMs are primarily used to enable adaptive interactions, there has been increasing interest in opening the LM to the user in an understandable form to encourage formative assessment, planning and other metacognitive skills (Bull and Kay, 2008), as illustrated in Figure 2. These are commonly known as open learner models (OLM).

OLMs can be presented in a variety of formats. The top of Figure 3 gives four examples: (i) a skill meter for each topic or concept (the most common form of simple OLM, e.g. Corbett and Bhatnager, 1997; Mitrovic and Martin, 2007; Papanikolaou et al., 2003; Weber and Brusilovsky, 2001); (ii) structured representations of a learner's understanding showing, for example, conceptual relationships (e.g. Dimitrova, 2003; Mabbott and Bull, 2006; Perez-Marin et al., 2007) and less common representations such as (iii) statements of specific beliefs and (iv) graphical portrayals of beliefs. Figure 3 also shows specific OLM interface examples: a lecture structure and concept map (Mabbott and Bull, 2006), each allowing the display of relationships between concepts and the user's level of understanding of concepts (by the colour of labelled nodes), and a simple graph representation similar to skill meters, but with knowledge of a topic on the right hand side of an axis and the existence of misconceptions or general difficulties/lack of knowledge on the left (Bull et al., 2006). Structured presentations are

Figure 1. Adaptive learning environments

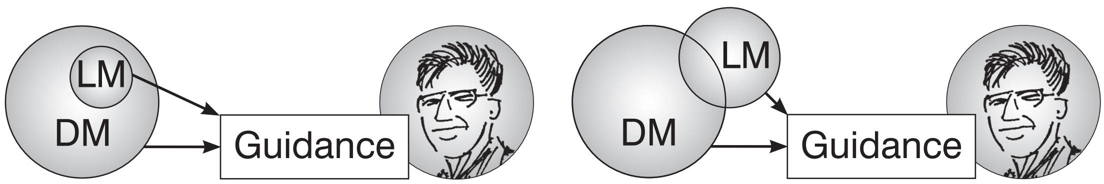


Figure 2. Open learner models

Figure 3. Example externalisations of the learner model

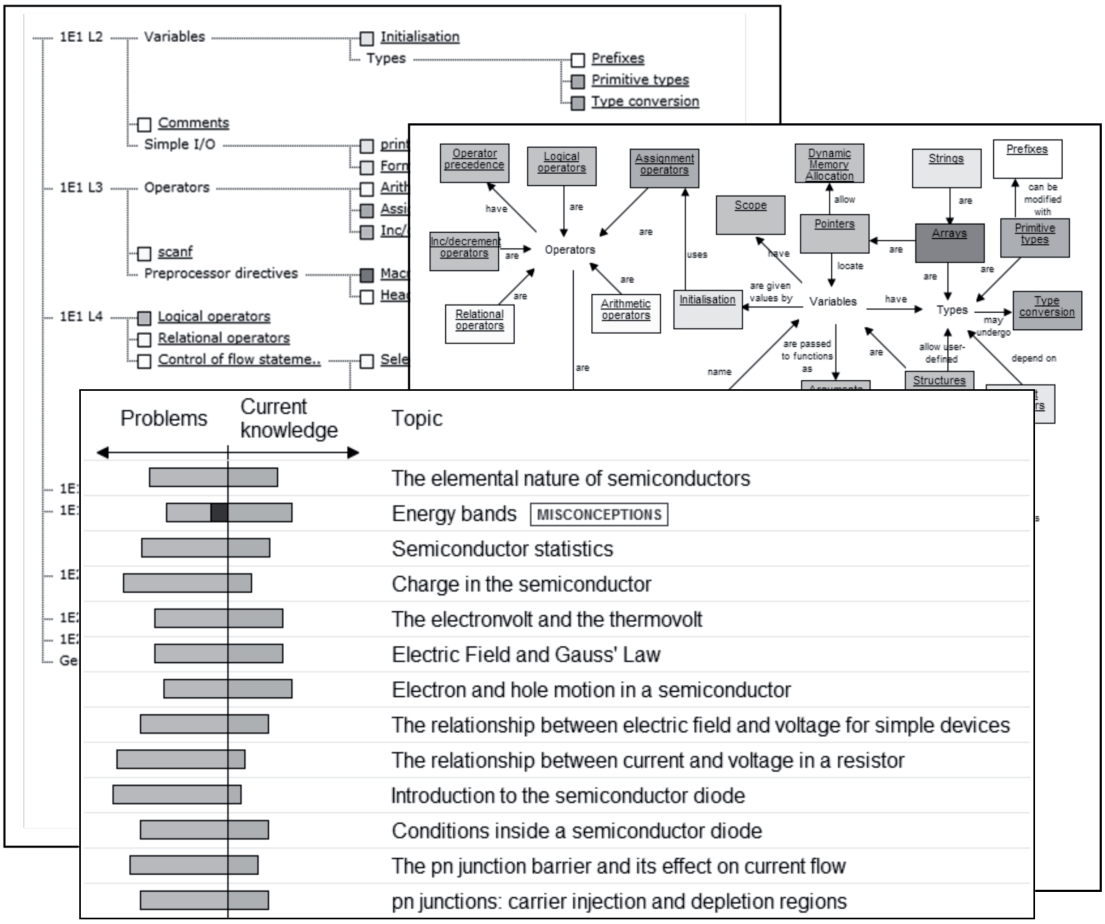
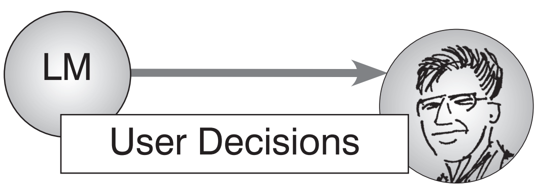


Figure 4. Independent open learner models



useful when the underlying LM is complex and the domain can be reasonably broken down into structural relationships. In cases where a single environment is to be used across a set of modules (as here) a simple LM allows easier deployment and a simple OLM maintains consistency and predictability for students across modules.

Independent open learner models

Learner control and responsibility are important issues in adaptive learning environments and OLMs (Kay, 1997). The *independent open learner model* (IOLM – Figure 4) goes one stage further in the aim of promoting metacognition and learner independence. Rather than leaving greater control with the system, according to the contents of DM and LM, the environment contains no DM (or DM is used solely in inferring student knowledge, not for system adaptation). The responsibility for decisions in their learning rests with the learner (Bull et al., 2008). The aim is that, on seeing the contents of their LM, they are prompted to reflect on their knowledge and learning and to *themselves* consider how best to proceed. This fits well with the Higher Education Academy's (2004) aim of encouraging learner reflection and self-assessment (and at the same time addresses some of the criticisms of adaptive environments – reducing such learner responsibility – by offering flexibility of use, see e.g. Beetham, 2007).

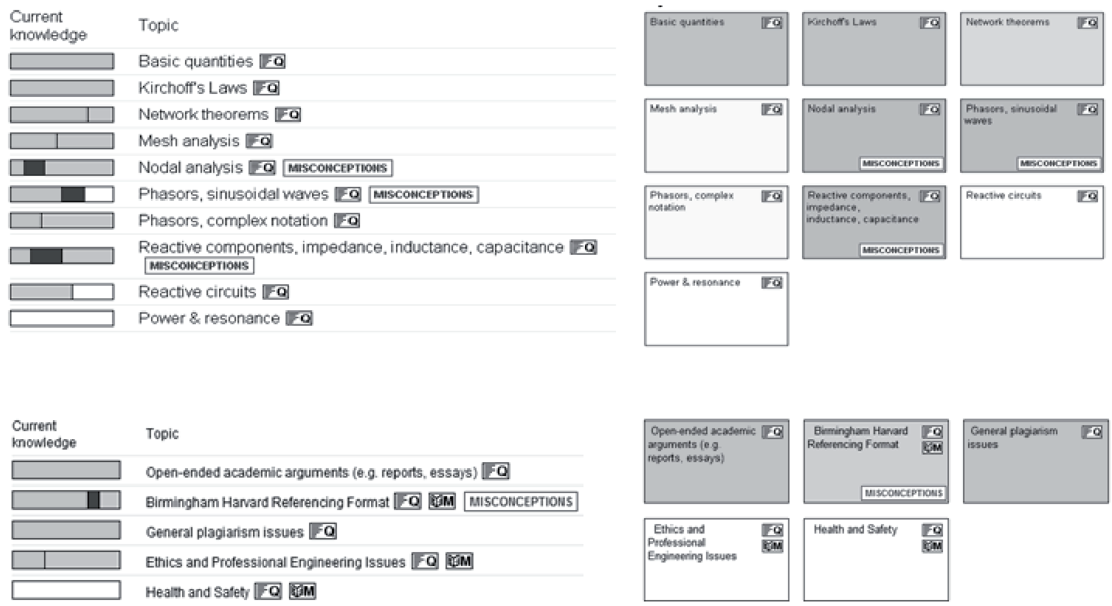
The UK-SpecIAL independent open learner model

UK-SpecIAL stands for UK-SPEC Independent Adaptive Learning. In this section we first present OLMlets, on which UK-SpecIAL draws, and then introduce UK-SpecIAL.

OLMlets

The OLMlets IOLM offers formative assessment opportunities for students in their various modules without increasing the workload of lecturers beyond initial setup requirements,

Figure 5. The OLMlets skill meters and boxes IOLM views (Bull et al., 2006)



in line with other uses of computer-assisted assessment in engineering (see Barker, 2004) but using an adaptive approach maintaining focus on current understanding (rather than test performance). Multiple-choice questions and response options are input by the lecturer(s), including options indicating common misconceptions (Bull et al., 2006).[5] For each module, the learner views their LM at intervals of their choosing, in any (or all) of five simple formats. Two of these, the 'skill meters' and 'boxes' views are illustrated in Figure 5 for two modules. In the first the module is split into ten topics; the second has five topics.

The skill meters show the extent of current understanding of a topic (green – indicated by medium shading in Figure 5). Misconceptions are prevalent across the range of science and engineering disciplines (Kalman, 2008); the skill meters therefore indicate the extent of misconceptions in the topic in red (shaded dark). More general lack of knowledge or difficulties not linked to specific misconceptions are shown in grey (light shading). White (unshaded) indicates insufficient data to model level of knowledge of a topic. Where misconceptions are inferred, students can obtain a brief text description of their misconception(s) by clicking on the "MISCONCEPTIONS" link (e.g. *you may believe that resistance is reactive; you may believe that voltages are summed at a node* (Bull et al., 2008)). The 'boxes' views on the right of Figure 5 show the same information by colour. Bright green indicates strong understanding of a topic; lighter shades of green, less strong understanding; red shows topics with misconceptions; and grey, general difficulties (each indicated by different levels of shading in Figure 5). The 'Q' icons lead to questions and 'M' to learning materials (e.g. lecture notes, slides, web links). OLMlets LMs are inferred based on the user's last five attempts at questions on each topic, dynamically updating with greater weighting on the most recent of these latest five attempts. Thus the LMs always represent *current* knowledge states. Previous studies have indicated that OLMlets support a variety of approaches to learning (Bull et al., 2008).

UK-SpecIAL

As stated previously, each module contributes to a range of UK-SPEC LOs and each LO is addressed by several modules. Figure 6 shows a box in UK-SpecIAL for each module that contributes to LOs B20 and B21 and indicates the overall level of understanding, calculated as an average of the individual's knowledge level of topics comprising an OLMlets module. Each module appears under the LO to which it contributes. Clicking a module title shows the details contributing to that LO for that specific module (each module may contribute to a LO in a different way). Figure 6 gives the example 'work safely in a workshop or lab, using a range of tools related to the assembly of electronic circuits and systems'. This text is from the IET interpretation of UK-SPEC (IET, 2006). UK-SpecIAL is currently implemented for most first year modules.

Figure 7 summarises the above in graphical form, using two modules and two LOs as examples. Module 1 has three topics, each of which calculates the LM based on the previous five responses to questions in the topic. Module 2 has five topics. An average or overall model for each module is calculated according to the current knowledge level in each topic comprising the OLMlets course. This overall model is displayed to the learner through UK-SpecIAL. In Figure 7, Module 1 contributes to four LOs; Module 2 contributes to two. When considering the range of modules that students will be studying in any one year, and that there are forty LOs in UK-SPEC (for BEng and MEng), it can be appreciated that mapping becomes quite complex.

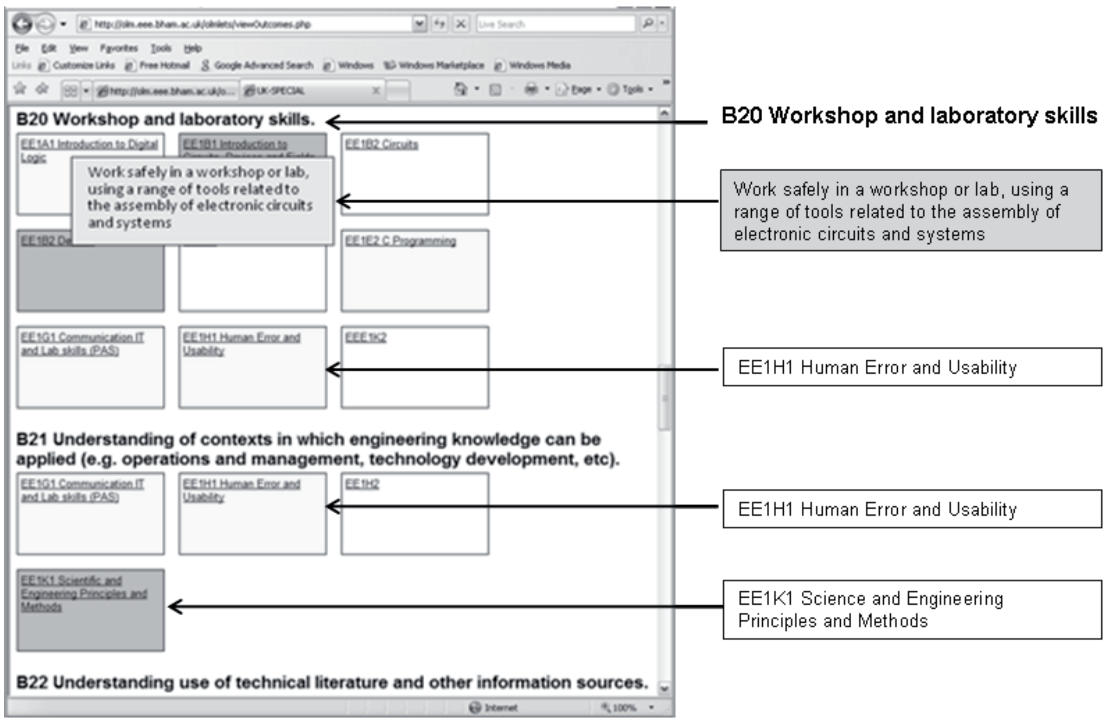


Figure 6.
The UK-SpecIAL independent open learner model (across modules)

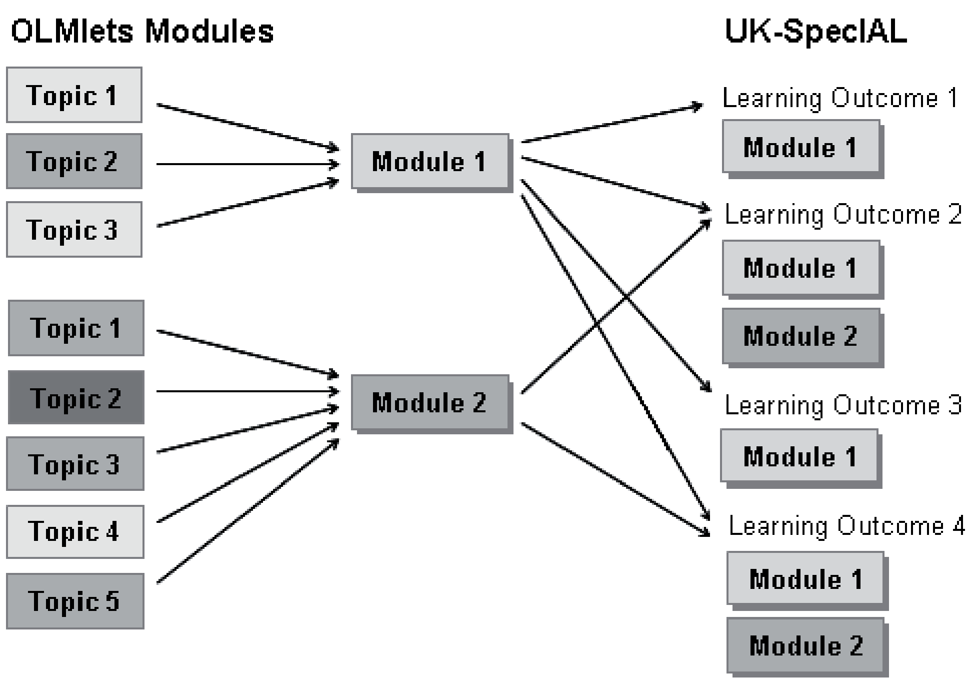


Figure 7.
OLMlets and UK-SpecIAL

UK-SpecIAL is a complementary approach to EASIMAP, which uses UK-SPEC to match progress towards LOs to student achievements in a grid, based on lecturer assessments (Maddocks, 2007). While EASIMAP uses lecturer input about performance, OLMlets automatically updates a simple model of a learner's knowledge during their online formative assessment in a variety of modules which is then used by UK-SpecIAL to present progress in relation to UK-SPEC LOs – information designed for students to monitor their learning across modules.

Evaluation

Our questions concern whether students will use an IOLM aimed at raising awareness of relationships between components of their modules, how these relate to UK-SPEC and professional engineering and their perceptions of the utility of UK-SpecIAL.[6]

Participants, materials and methods

Participants were 77 students completing their first year in Electronic, Electrical and Computer Engineering at the University of Birmingham during the 2008/09 academic year. OLMlets was available in 10 first year modules: eight in term 1 and two in term 2. The aims of UK-SpecIAL were introduced as part of a lecture on professional engineering skills and the first UK-SpecIAL accesses (not included in our data) were made at the end of a laboratory session about one third of the way through the autumn term in the same module (taken by 69 of the students). Others came across UK-SpecIAL through the link in OLMlets or through other students. All 77 users are retained in the data as it was analysed anonymously.

The 69 students receiving the lecture and laboratory introduction completed coursework in November 2008 relating to professional engineering, contributing 7% of the module mark. While use of UK-SpecIAL was not assessed, the issues addressed by UK-SpecIAL were relevant to the coursework. All UK-SpecIAL (and OLMlets) use after the initial laboratory session was in the students' own time.

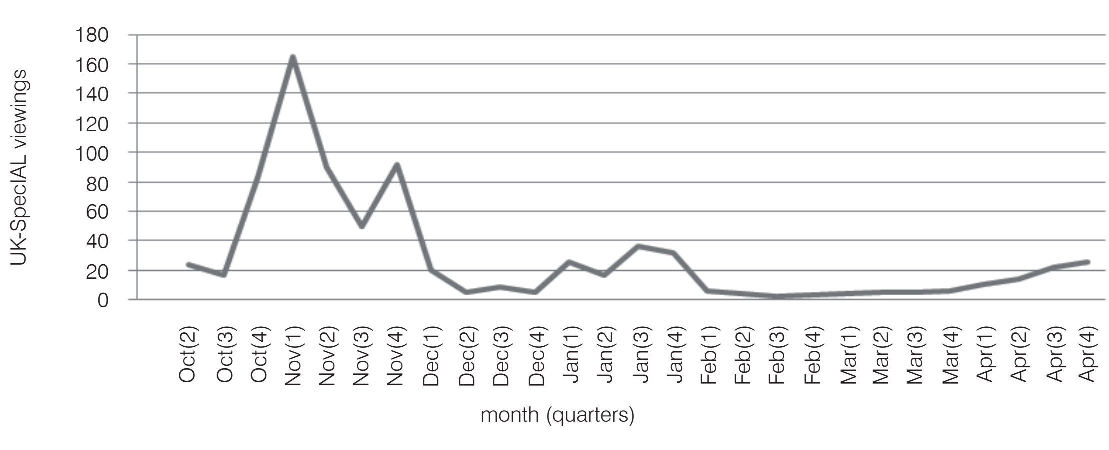
System logs were examined. 22 volunteers in the module in which UK-SpecIAL was introduced completed questionnaires at the end of the autumn term. Responses to statements were on a five-point scale (5: strongly agree; 4: agree; 3: neutral; 2: disagree; 1: strongly disagree) and open-ended comments were sought. The second year cohort also completed a brief questionnaire using the same fixed-response options.

Results

80854 questions were attempted in OLMlets across the various modules (mean 1050, median 896, range 47-317). 778 inspections of UK-SpecIAL were made (mean 10.1, median 7, range 1-113).

Figure 8 shows the spread of UK-SpecIAL accesses over time. UK-SpecIAL was introduced (to 69 of the 77 students) about half way through October 2008 and viewings continued during this month. In November accesses peaked, followed by a dip in December. Further references to UK-SpecIAL were made in January 2009, but dropped in February and March. April saw an increase.

Figure 8. UK-SpecIAL accesses over time



Over three quarters of students were accessing UK-SpecIAL from more than one module, with nearly half accessing it from three or more (maximum 8 – left of Figure 9). One module was the origin of 42% of UK-SpecIAL viewings and three originated a further 35% (right of Figure 9). The remaining 23% of viewings were made quite equally from the other six first year modules in OLMlets. These differences are not explained by the number of students registered on a module. Most accesses were made from the module in which UK-SpecIAL was introduced, with a high proportion of first year students taking the module. However, the three modules that each contributed 10-15% of viewings had high, medium and low student numbers, despite most of the other modules having high enrolments. The higher UK-SpecIAL access modules were first term modules.

Figure 10 (left) shows no strong correlation between the number of accesses a student made to UK-SpecIAL and the number of modules in which they were using OLMlets (correlation coefficient 0.26). Figure 10 (right) shows no correlation between the extent of OLMlets use measured by the number of questions attempted in OLMlets across modules and the number of accesses to UK-SpecIAL (correlation coefficient -0.02).

Table 3 shows that students considered that UK-SpecIAL helped them to identify relationships across their modules with reference to UK-SPEC LOs, relationships between their modules and UK-SPEC and links between UK-SPEC and professional engineering. Students also claimed to trust the information displayed in UK-SpecIAL.[7] Although UK-SPEC is intended for those designing and offering degree courses, students also considered it helpful to be aware of this information. Few knew of UK-SPEC before commencing their degree and current second years (who had not used UK-SpecIAL) had low knowledge.

Figure 9. UK-SpecIAL accesses and use of OLMlets

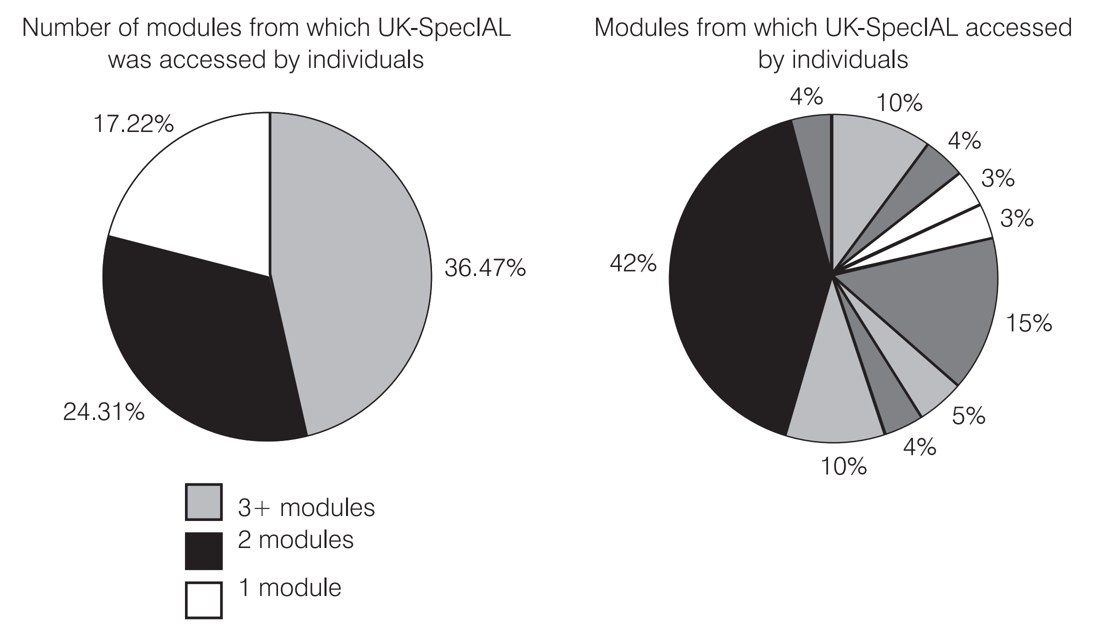


Figure 10. UK-SpecIAL accesses and use of OLMlets: comparisons

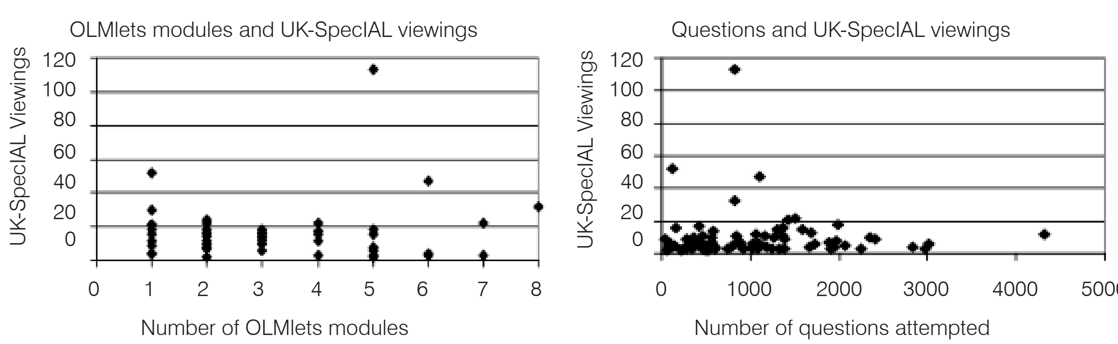


Table 3. Questionnaire responses

UK-SpecIAL questionnaire item	Mean	Med	Range
Helped identify relationships – LOs across modules	4.3	4	3-5
Helped identify relationships – modules/UK-SPEC	4.3	4	2-5
Helped identify relationships – UK-SPEC/professional engineering	4.2	4	2-5
Trusted UK-SpecIAL	4.4	5	3-5
Useful to know about UK-SPEC	4.5	5	3-5
Knew about UK-SPEC before starting degree	1.7	1	1-5
Second years' knowledge of UK-SPEC	2.1	1.5	1-5

The following are typical excerpts from open-ended comments:

> *It is very useful to know how my modules relate to UK-SPEC so that I know exactly if I am on the right track to become a professional engineer [...] It is important to know about UK-SPEC because it can act as a gauge which shows the threshold standards required for a professional engineer.*

> *OLMlets and UK-SpecIAL have helped my understanding of UK-SPEC because when I answer the OLMlets questions I can then check UK-SpecIAL to see if my knowledge is at the correct level to fulfil the UK-SPEC learning outcomes and I can see how my modules relate to these outcomes.*

> *The point I find particularly important is how UK-SpecIAL relates to each module and then allows a student to see how the different modules fit together to provide a broad knowledge spectrum. This helps to prevent students seeing each module as a completely separate entity and allows them to gain a better overall view.*

> *The headings tell the user how the modules will help them with their engineering profession, rather than just what maths the module is teaching (for example).*

> *[The] tendency of students not knowing why they are studying their modules will be greatly reduced.*

> *[OLMlets and UK-SpecIAL] are good at getting an idea of the aims of the course as they lay things out clearly on what we need to be able to do, but only as an initial starting point.*

> *I think the ideas of UK-SPEC are good however I think even without knowing UK-SPEC you will apply the majority of it through knowledge and common sense.*

Discussion

Students generally inspect their OLMlets LMs after 1-2 questions (Bull et al., 2008). Here we are interested in their accesses to UK-SpecIAL. The UK-SpecIAL information changes slowly in comparison to OLMlets, as each UK-SpecIAL entry shows an overview of the average knowledge level of all the topics in a module. Therefore frequent UK-SpecIAL access would not help with progress monitoring (indeed, students are not expected to be able to answer all – or even many – questions in the earlier stages of a module). Therefore our investigation was concerned with whether students made multiple UK-SpecIAL accesses over the period of deployment, rather than seeking high levels of interaction.

Across the first year modules, the mean number of questions attempted was a little over 1000, with the median approaching 900 (range 47-4317). Mean UK-SpecIAL access was 10.1, median 7 (range 1-113). Therefore, after the initial laboratory introduction with 69 of the 77 participants (excluded from the data), students returned to UK-SpecIAL. This is probably partly due to the 7% assessment in the module relating to professional engineering skills. However, as shown in Figure 8, inspections of UK-SpecIAL continued after the November coursework deadline (albeit at a lower level). The December dip may have been due to the break between the two terms, as there was increased usage in January. This increase may have been related to assessments in other modules where tests or coursework deadlines for the previous term were in January (and students perceived UK-SpecIAL to be relevant) or it may have been that students generally had more time available at the start of the second term, before their workload increased. In the latter case, the February/March decrease could be attributed to the same cause – later in the term there will have been more deadlines. This possibility would be compatible with the increase during April (the break after the end of the second term). However, levels of use should be expected to be lower in the second term as there were only two term 2 modules in OLMlets (and therefore only two modules that could illustrate a student's progress towards UK-SPEC LOs during that period in UK-SpecIAL). Further work would help clarify the reasons for usage patterns. It would also be of interest to investigate whether any students continue to refer to UK-SpecIAL during the final revision and examination periods in May/June. UK-SpecIAL is not intended for this stage as it does not distinguish specific knowledge, topics or skills, as would likely be the stronger focus for students at exam time.

Over three quarters of students were accessing UK-SpecIAL from more than one OLMlets module; nearly half from three or more. While all 10 OLMlets modules were the origin of some UK-SpecIAL viewings, over three quarters came from four modules. The highest access (42%) came from the module in which UK-SpecIAL was introduced (the module with the clearest relevance to professional engineering in general). There was no correlation between the number of questions students attempted (across modules) and accesses to UK-SpecIAL and no strong relationship between the number of modules in which students were using OLMlets and their level of UK-SpecIAL use. Further work could investigate why certain modules were the origin of more UK-SpecIAL viewings than others, for example, to what extent this depends on the module content, the timing of the module, the nature of the assessment in the module, etc. (The number of students registered on a module did not account for these differences.)

All 77 students registering for first year OLMlets modules were included in the data (i.e. not just the 69 who were introduced to UK-SpecIAL). Therefore the results probably underestimate use amongst those informed of UK-SpecIAL (the remainder had no explanation of its aims, or how to use it). Furthermore, it was previously found that more students attempt OLMlets questions in one of the modules than are actually taking that module (Bull et al., 2008). If these additional students are second years aiming to review their understanding of basic first year material then these interactions will appear amongst first year students' data. If this is the case, the means and medians of OLMlets use will probably be higher than shown in our results, as these users' other OLMlets interactions will appear in the second year data (which is not included here). Similarly, as UK-SpecIAL is currently implemented for first year modules only, the UK-SpecIAL access data will have been underestimated. (If second year students are included amongst our first year data, the UK-SpecIAL viewing levels will have been calculated using data from students for whom UK-SpecIAL is not relevant.) Conversely, the impression that all first years made some access to OLMlets and UK-SpecIAL will be inaccurate. Nevertheless, even if not all first years were accessing the environments, there are sufficient users to suggest it is worthwhile to continue deployment.

There was a high level of agreement amongst the 22 volunteers who completed questionnaires, with statements relating to the utility of UK-SpecIAL for identifying relationships between modules, between modules and UK-SPEC, and between UK-SPEC and professional engineering. Students also claimed to trust UK-SpecIAL and considered it useful to know about UK-SPEC. Given that second year students had little knowledge of UK-SPEC and current first year students (before commencing their engineering studies) had even lower awareness of UK-SPEC, UK-SpecIAL appears to have been instrumental in developing this awareness. The excerpts from typical open-ended comments indicate that students are able to clearly articulate such relationships, further evidencing this understanding. Most comments were positive, relating to these links or to the utility of UK-SpecIAL as a support for independent learning (as in the example where the student recognises the aim of OLMlets and UK-SpecIAL as a 'starting point' for their independent learning). The main negative comment referred to the fact that it is not necessary to know the details of UK-SPEC in order to become a professional engineer as these will also be applied by taking a 'common sense' approach and from the ideas already embedded in the engineering degree curriculum. Indeed, we would not expect UK-SpecIAL to be useful to all students – those who have a good understanding or ability to interpret the issues as they arise, and who have a high level of confidence in this ability, would not need the UK-SPEC LOs and, by default, would not need their progress towards these to be made explicit through UK-SpecIAL.

While we have here considered the modules from which students accessed UK-SpecIAL, it does not actually matter how many or which specific modules are used, as long as consultation of UK-SpecIAL leads to an overall understanding of progress towards the UK-SPEC LOs. However, the fact that many *were* accessing UK-SpecIAL from multiple OLMlets modules suggests that this is indeed the case.

Summary

This paper has introduced UK-SpecIAL, an environment designed to raise learners' awareness of their progress towards meeting UK-SPEC learning outcomes. Uptake of UK-SpecIAL suggests that students find it useful, and their questionnaire responses indicate their perceptions of the benefits. We therefore suggest that this type of approach can be usefully deployed in engineering degrees to encourage learner independence and an understanding of the purpose of engineering studies.

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Notes

1 Note that these LOs differ from those commonly used in specific modules which, for example, may be presented as: ‘on successful completion of this module you will be able to: design/select/solve...’ See Biggs and Tang (2007).

2 The IET numbering has since been changed. We here retain the original numbers that reflect the UK-SpecIAL interface as used at the time of deployment.

3 Note that this is a *model* of the domain; it is not a web page with information, or a set of correct answers: the system can reason about the domain because it understands its content. This may be, for example, a representation of facts, rules, conceptual or hierarchical relationships.

4 Again, this is a *model* of understanding; it is not the learner’s answers to questions, etc.

5 While multiple-choice questions are sometimes criticised for assessing lower order skills, they can also be designed to address higher skills; e.g. understanding of relationships, applicable also in e-assessment contexts (Crisp, 2007).

6 As the aim is to raise awareness of issues across modules and how these relate to engineering professions, in students’ own time, we do not measure learning gains: it is not possible (or appropriate) to control the independent learning and metacognitive activities that OLMlets and UK-SpecIAL aim to facilitate in a real use setting.

7 Definition of trust: ‘the individual user’s belief in, and acceptance of the system’s inferences; their feelings of attachment to their model; and their confidence to act appropriately according to the model inferences’ (Ahmad and Bull, 2008).

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