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Incorporating UK-SPEC Learning Outcomes into an Open Learner Model to Promote Learner Independence

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Abstract

This project report introduces the UK-SpecIAL environment, developed to help engineering students better understand how their modules relate to each other; to the engineering professions towards which they are working; and to raise their awareness of their progress towards the UK-SPEC Learning Outcomes. Our example is for electronic, electrical and computer engineering, but could be extended for other engineering subjects. UK-SpecIAL was deployed in a selection of first year modules in the 2008-2009 academic year. Log data indicates learners use the information provided about their general progress across modules, and questionnaire responses suggest that they consider UK-SpecIAL a useful support for independent learning.

1. Introduction

This report describes UK-SpecIAL, an adaptive environment to support engineering students and promote learner independence. The report will be of interest in particular to those teaching electrical, electronic and computer engineering, and of general interest to those involved in teaching on other engineering degrees.

We first describe the requirements for accredited engineering degrees, the motivation for the project; we explain how independent open learner models can be used to promote reflection, planning, formative assessment and learner independence, and how we have previously employed such an approach, OLMlets.

We then present the UK-SpecIAL independent open learner model designed specifically to facilitate metacognitive skills such as the above throughout an engineering degree, drawing on the learner models of OLMlets. Finally, the results of deployment of UK-SpecIAL in first year modules throughout the 2008-2009 academic year, are presented and discussed.

1.1 UK-SPEC for Accreditation

The UK-SPEC Standards for Professional Engineering Competence (Engineering Council, 2004) must be met in order for degrees to be accredited. UK-SPEC identifies five areas: underpinning science and mathematics; engineering analysis; design; economic, social and environmental context; engineering practice.

Each of the above areas is divided into specific learning outcomes[1], for example, engineering analysis includes:

- "ability to apply and integrate knowledge and understanding of other engineering disciplines to support study of their own engineering discipline";

[1] Note that these learning outcomes are not in the same the format as is commonly used to describe learning outcomes for specific modules which, for example, are often presented as: "on successful completion of this module you will be able to: design/select/solve..." (see Biggs & Tang (2007), for further discussion).

- "understanding of engineering principles and the ability to apply them to analyse key engineering processes".

engineering practice includes:

- "awareness of nature of intellectual property and contractual issues";
- "ability to work with technical uncertainty".

Each UK-SPEC learning outcome is relevant to several modules, and each module contributes to several learning outcomes. The Institution of Engineering and Technology's (IET) interpretation of the UK-SPEC learning outcomes for electrical, electronic and computer engineering degrees (IET, 2006), was used as the basis for the project.

1.2 UK-SPEC for Students

It is widely accepted that students do not always understand how the various components of their modules are related at the point they are studying them; a situation that also applies in engineering education (Avitabile et al., 2005). UK-SPEC, although designed for educators with reference to the accreditation of engineering degrees, also provides a framework within which to consider highlighting the relevance of aspects of their degree with reference to the engineering professions, *to the students themselves*. The UK-SpecIAL environment was designed to address the issue of students not having full awareness of the purpose of their modules, and to raise learner awareness of how their learning relates to professional engineering. To this end, UK-SPEC (Engineering Council, 2004) and the IET (2006) interpretation were used as the basis for the design of UK-SpecIAL. In the following section we introduce the concepts of learner modelling and independent open learner models, and then describe our UK-SpecIAL environment.

2 Adaptive Learning Environments and Open Learner Models

A learner model allows a computer or web-based educational environment to adapt the interaction to the individual learner's needs, by inferring a model of their current understanding (*learner model*) based on their actions in the environment. The learner model may contain learner knowledge as a subset of expert knowledge; or it may include other information such as inferred misconceptions. The adaptive environment may then infer suitable guidance strategies for the individual, according to the current state of their knowledge. Thus the learner model is usually used solely by the computer or web-based environment in order to enable automatic personalisation of the interaction.

Opening this learner model to the user in a form that they can understand (an *open learner model*), can be a useful way to encourage formative assessment, planning and other metacognitive skills (Bull & Kay, 2008). Open learner models can be presented to the user in a variety of formats, but simple representations of learner understanding are particularly useful when aiming to deploy an environment across modules (as in this project), as this maintains consistency and predictability for students.

An *independent open learner model* goes one stage further in the aim of promoting metacognition and learner independence. Rather than leaving more of the control of the interaction with the adaptive learning environment according to the contents of learner model, the entire responsibility for decisions in their learning rests with the learner (Bull et al., 2008). The aim is that, on seeing the contents of their model, the learner is prompted to reflect on their knowledge and learning and to *themselves* consider how to best proceed in order to improve their understanding. This fits well with the Higher Education Academy's (2004) aim of encouraging learner reflection and self-assessment.

3 The UK-SpecIAL Independent Open Learner Model

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

3.1 OLMlets

OLMlets aims to provide formative assessment opportunities for students in their various modules without increasing the workload of lecturers beyond the initial setup requirements, in line with other uses of computer assisted assessment in engineering (see Barker, 2004); but using an adaptive approach that maintains focus on the learner's current understanding (rather than test performance). It is written in the PHP scripting language, with data stored with the MySQL relational database engine. The application is hosted via an Apache web server running on a Sun Solaris system. The OLMlets environment has been available in the School of Electronic, Electrical and Computer Engineering at the University of Birmingham for four years. Multiple choice questions and response options are input by the module lecturer(s), including options indicating common misconceptions (see Bull et al., 2006).[2] The most common form of simple open learner model is the skill meter (e.g. Corbett & Bhatnager, 1997; Mitrovic & Martin, 2007; Papanikolaou et al, 2003; Weber & Brusilovsky, 2001). OLMlets also uses this display format, but includes four other presentations to allow user choice. The 'skill meters' and 'boxes' learner model views are illustrated in Figure 1.

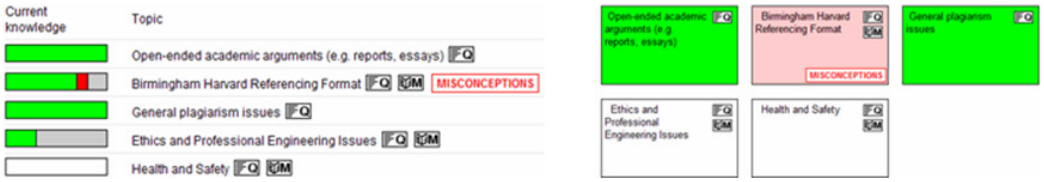

Figure 1. The OLMlets skill meters and boxes independent open learner model views (Bull et al., 2006)

The skill meters on the left show the extent of current understanding of a topic (in green). Student misconceptions are prevalent across the range of science and engineering disciplines (Kalman, 2008), and the skill meters therefore also include an indication of the extent of misconceptions in the topic in red (and more general lack of knowledge or difficulties not linked to specific misconceptions in grey). In cases where misconceptions are inferred for a topic, students can obtain a brief text description of their misconception(s) by clicking on the "MISCONCEPTIONS" link. For example, misconceptions held at some point during the year by several first year users include the following (see Bull et al. (2008), for further detail):

- a weighted average is calculated in the same way as an ordinary average
- denominators are summed when adding fractions
- the first bit allocated in Huffman coding is the most significant bit
- the fundamental frequency of a square wave is 1/T
- inverting and non-inverting amplifiers have the same feedback circuits
- flow creates potential difference

[2] While multiple choice questions are sometimes criticised for assessing lower order skills, they can also be designed to address higher skills. For example, a student's understanding of relationships, applicable also in e-assessment contexts (Crisp, 2007).

- voltages are summed at a node
- the momentum of an electron in a full valence band does not change under the influence of an electric field

The boxes views on the right of Figure 1 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. The 'Q' icons lead to questions on the topic; the 'm' icons to learning materials, e.g. lecture notes, slides, web links. The OLMlets learner models 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 learner models always represent *current* knowledge states.

3.2 UK-SpecIAL

UK-SpecIAL is an extension to the OLMlets web application. As stated previously, each OLMlets module contributes to a range of UK-SPEC learning outcomes; and each learning outcome is addressed by several modules. Figure 2 shows a box in UK-SpecIAL for each module that contributes to learning outcomes B20 and B21: "workshop and laboratory skills", and "understanding of contexts in which engineering knowledge can be applied (e.g. operations and management, technology development, etc.)", respectively; and indicates the overall level of understanding, calculated as an average of the individual's knowledge level of the topics comprising an OLMlets module. Each module appears under each of the learning outcomes to which it contributes. Clicking on a module title shows the details contributing to that learning outcome for that specific module (each module may contribute to a learning outcome in a different way). Figure 2 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 taken from the IET interpretation of UK-SPEC (IET, 2006). UK-SpecIAL is currently implemented for most first year modules.

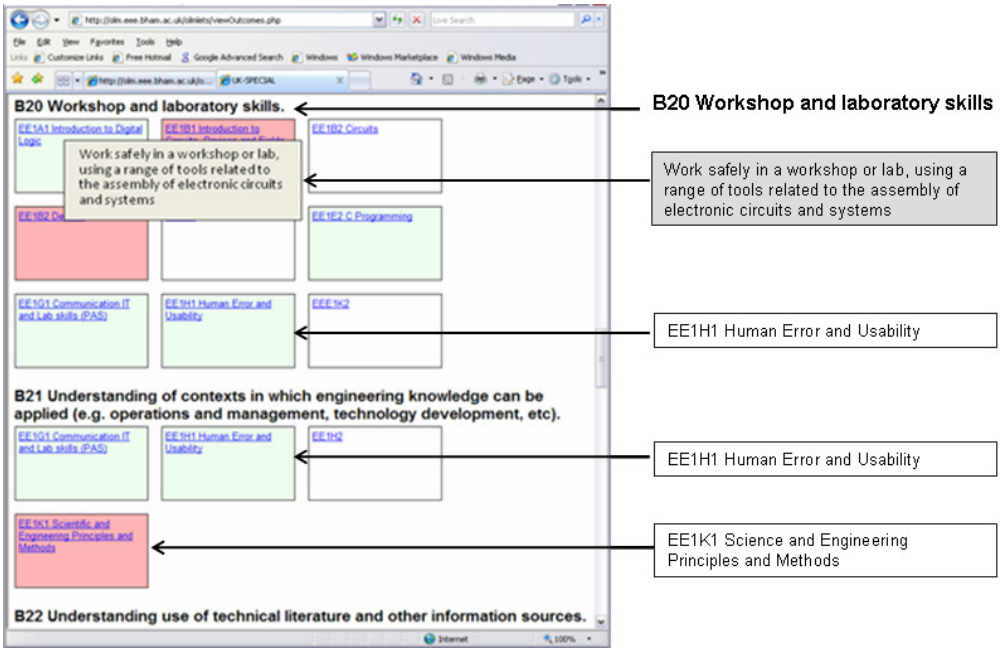

Figure 2. The UK-SpecIAL independent open learner model (across modules)

UK-SpecIAL has built upon the high usage levels of OLMlets (see Bull et al., 2008). It is a complementary approach to EASIMAP, which uses UK-SPEC to match

progress towards learning outcomes to student achievements in a grid format, based on lecturer assessments of the student's learning (Maddocks, 2007). While EASIMAP uses lecturer input about student performance, OLMlets automatically creates and updates a simple model of a learner's knowledge during their online formative assessment in a variety of modules, which is used by the UK-SpecIAL environment to present progress in relation to UK-SPEC learning outcomes - information designed for students to use to monitor their learning and advancement towards learning outcomes across the modules in their degree. OLMlets and UK-SpecIAL can be integrated closely with specific modules by the module lecturer(s), or can be used optionally according to students' own study preferences, where use is not a required component of a module. In most current use, an external link to OLMlets is provided amongst the content of the sections for specific modules in the Virtual Learning Environment used at the University of Birmingham. (UK-SpecIAL is then accessed through the OLMlets module, though it can also be accessed directly.)

4. Evaluation

Our questions concern whether students will use an independent open learner model aimed at raising their awareness of relationships between their various modules, and how these relate to UK-SPEC and professional engineering. In addition we investigate student perceptions of the utility of UK-SpecIAL for these purposes.

4.1 Participants, Materials and Methods

Participants were 77 students completing the first year in the School of Electronic, Electrical and Computer Engineering, University of Birmingham, during the 2008-2009 academic year. OLMlets was available in 10 first year modules; eight in term 1 and two in term 2. Students became familiar with OLMlets through independent use in several modules. 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, which was taken by 69 of the students. Other students came across UK-SpecIAL on their own through the link in OLMlets, or from hearing about it from other students. We have retained all 77 users in the data, as data was analysed anonymously.

The 69 students who received the lecture and laboratory introduction were required to complete a short piece of coursework in November 2008 related to professional engineering, contributing 7% of the final module mark. While use of UK-SpecIAL was not assessed, the issues addressed by UK-SpecIAL were directly relevant to the coursework. All UK-SpecIAL (and OLMlets) use after the initial laboratory session was in the students' own time, and at locations of their choice.

System logs were examined to determine students' use of UK-SpecIAL. 22 volunteers in the module in which UK-SpecIAL was introduced, completed questionnaires at the end of the module (end of the autumn term). Responses to questionnaire statements were required 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 scale for fixed-response options.

4.2 Results

The mean UK-SpecIAL access was 10.1, median 7, range 1-113. Figure 3 shows the spread of accesses to UK-SpecIAL over time. UK-SpecIAL was introduced (to 69 of the 77 students) around half way through October 2008, and viewings continued

during this month. In November accesses to UK-SpecIAL 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 a slight increase.

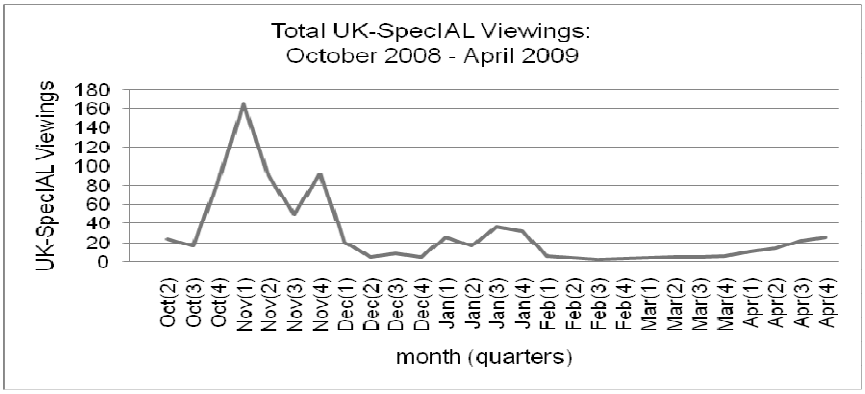

Figure 3. UK-SpecIAL accesses over time

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 modules (left of Figure 4). One module was the origin of 42% of UK-SpecIAL viewings; and three, a further 35% of viewings (right of Figure 4). The remaining 23% of UK-SpecIAL viewings were made quite equally from the other six first year modules available in OLMlets. These differences are not explained by the number of students registered on a module. Most UK-SpecIAL 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 UK-SpecIAL viewings had high, medium and low student numbers, despite most of the other modules having high enrolments. The higher UK-SpecIAL access modules were all first term modules.

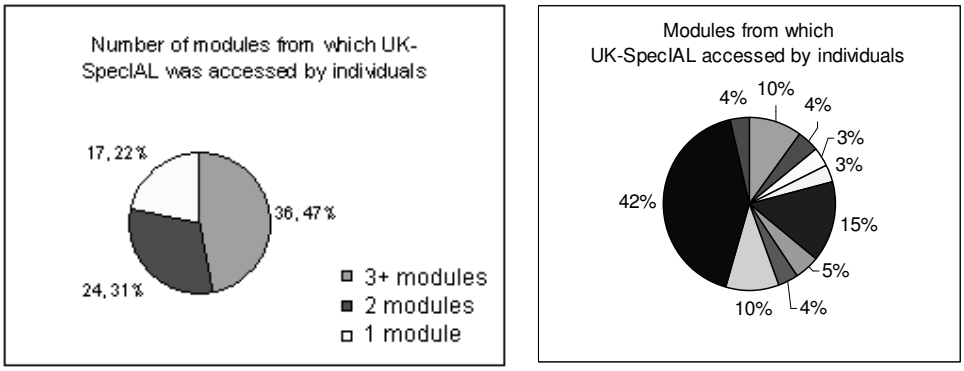

Figure 4. UK-SpecIAL accesses and use of OLMlets

Figure 5 (left) shows that there was 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 6 (right) shows no correlation between the extent of OLMlets use measured by the number of questions attempted in OLMlets across all modules, and the number of accesses to UK-SpecIAL (correlation coefficient -0.02).

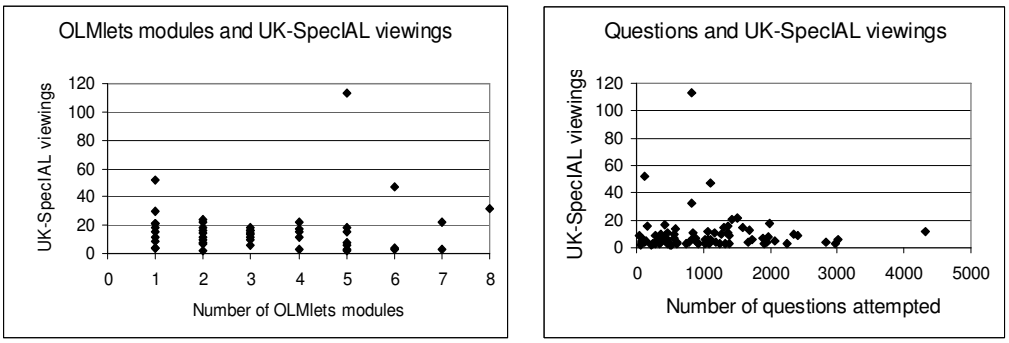

Figure 5. UK-SpecIAL accesses and use of OLMlets: comparisons

Table 1. Questionnaire responses

UK-SpecIAL Questionnaire Item	Mean	Med	Range
Helped identify relationships - learning outcomes 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
Level of trust in 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 year students' knowledge of UK-SPEC	2.1	1.5	1-5

From the questionnaire responses, Table 1 shows that students considered UK-SpecIAL to have helped them identify relationships across their modules with reference to UK-SPEC learning outcomes; relationships between their modules and UK-SPEC; and links between UK-SPEC and professional engineering skills. Students also claimed to trust the information about their progress towards the learning outcomes displayed in UK-SpecIAL. 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 the current second years (who had not used UK-SpecIAL) also had low knowledge.

The following are typical excerpts from students' 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.

4.3 Discussion

OLMlets was already in use in Electronic, Electrical and Computer Engineering, accepted by students, and considered useful by them as a learning support alongside their lecture courses (see Bull et al., 2008). The UK-SpecIAL project built upon this situation, to extend the benefits offered by independent open learner models available in individual modules in such a way as to offer students an overview of their developing knowledge and skills *across* their modules, and how this relates to their future engineering professions.

The UK-SpecIAL information changes very slowly in comparison to the OLMlets learner models, as each UK-SpecIAL entry shows an overview of the average level of knowledge of all the topics in an OLMlets module. Therefore frequent access to UK-SpecIAL would not bring any value in terms of monitoring progress (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 accesses to UK-SpecIAL over the period of deployment (at different stages of learning), rather than seeking high levels of interaction.

After the initial laboratory introduction (excluded from the data) with 69 of the 77 participants, students returned to UK-SpecIAL. In part this is likely to be because of the 7% assessment in one of the modules that related specifically to professional engineering skills. However, inspections of UK-SpecIAL continued after the November deadline for the coursework (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. Levels of usage were low in February and March, but there were only two term 2 modules available in OLMlets, and therefore only two modules that could illustrate a student's progress towards UK-SPEC learning outcomes during that period in UK-SpecIAL. UK-SpecIAL accesses started to increase again in April, suggesting that students were reviewing their progress between the modules and their end-of-year examination preparation. UK-SpecIAL is not intended for use after this stage, as it does not distinguish specific knowledge, topics or skills within a module, 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 origins of some UK-SpecIAL viewings, over three quarters of accesses came from four modules. The highest levels of access (42%) came from the module in which UK-SpecIAL was introduced: the module with the most obvious relevance to professional engineering in general. There was no correlation between the number of questions students attempted (across modules) and their 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 does this depend on the content of the module, 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 the aims of UK-SpecIAL, or how to use it). Furthermore, it has been found previously that sometimes more students attempt OLMlets questions in one of the modules, than there are students actually taking that module (Bull et al., 2008). If these additional students are second years aiming to review their understanding of some of the basic first year material, these interactions will appear amongst the first year students' data. If this is the case, the UK-SpecIAL access data will have been underestimated, as UK-SpecIAL is currently implemented for first year modules only. Conversely, the impression that all first years made some access to

UK-SpecIAL will be inaccurate. Nevertheless, even if not all current first year students were accessing the environment, there are sufficient users of UK-SpecIAL to suggest it is worthwhile to continue deployment, and for further development. In particular we would like to extend UK-SpecIAL to all years in order that students may continue to track their progress towards the UK-SPEC learning outcomes throughout their degree, as OLMlets is also available in some of the higher-level modules.

Amongst the 22 volunteers who completed questionnaires, there was a high level of agreement with questionnaire 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 had even lower awareness of UK-SPEC before commencing their engineering studies, 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 suggesting this understanding. The large majority of comments were positive, relating to these links or to the utility of UK-SpecIAL as a support for independent learning (as in the example given 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 an engineering degree. Indeed, we would not expect UK-SpecIAL to be useful for 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 learning outcomes and their progress towards these to be made explicit through UK-SpecIAL.

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

5 Reflections

The UK-SpecIAL approach was probably successful at least in part because of the existing deployment of OLMlets in the School. It was very easy for students to access UK-SpecIAL directly from their current activities. OLMlets is subject-independent, and so could easily be taken up in other engineering degrees. The specific adjustments necessary for UK-SpecIAL to match to different modules and/or engineering fields could be achieved with a little more programming work on the UK-SpecIAL environment. With such development it will also be possible for it to take in information in the same form as generated by OLMlets, for deployment based on student information from other sources.

A second, and possibly the primary factor contributing to the success of the project was the combination of Investigators who, between them, had a strong understanding of the requirements of engineering degrees and a detailed knowledge of UK-SPEC applied to engineering degrees; and experience in research, design and practical deployment issues in the field of adaptive learning environments. Without this complementary knowledge, it would have been very difficult to achieve a successful deployment.

The final factor that likely influenced initial uptake of UK-SpecIAL was the identification of a specific module in which to introduce it. The aims of UK-SpecIAL

were explained, and an opportunity to access the environment at the end of one of the scheduled laboratory sessions, were incorporated into the module. This appeared sufficient to prompt continued use by students, even from their other modules.

6 Conclusions

This project has built on successful deployment of an independent open learner model throughout various modules, over four years. As indicated above, UK-SpecIAL is ultimately intended as a modular extension (for use together with the existing approach, or another approach that can store information about a student's overall level of knowledge of each module in a similar simple numerical form). Uptake of UK-SpecIAL suggests that students find this a useful environment, and their questionnaire responses indicate their own perceptions of the benefits. We therefore suggest that an approach such as ours can be usefully deployed to encourage learner independence in engineering degrees, and recommend further investigation into the reasons for students' usage patterns, to determine whether additional encouragement to use the environment at certain times of the year might be appropriate; and whether additional support for interpreting the UK-SpecIAL information would be helpful for some.

Acknowledgements

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