

# Highlighting Learning Across a Degree with an Independent Open Learner Model

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**Abstract.** This paper introduces UK-SpecIAL, a simple independent open learner model to raise learner awareness of their progress towards learning outcomes across components of their degree. UK-SpecIAL was deployed in first year courses in electronic, electrical and computer engineering. Questionnaire responses and usage logs suggest the independent open learner model approach may be able to help students understand how their various courses relate to each other, and to the overall aims and requirements of their degree and future professions.

## 1. Introduction

Open learner models are learner models that may be viewed by the user in an understandable form. Access to a system's representations of user knowledge can facilitate metacognitive processes (e.g. formative assessment, reflection, planning) [1] and prompt greater learner control and responsibility for their learning [2]. Open learner models have been designed for a range of domains, from subjects such as programming [3] and databases [4]; to technical terminology [5] and music theory [6].

Independent open learner models (IOLM) are independent of a larger system, and at the centre of interactions [7]. The aim is to encourage independent learning as a result of accessing the learner model, without the additional tutoring of a typical intelligent tutoring system. IOLMs fit well with current educational aims of promoting learner independence, and metacognitive skills such as self-assessment and reflection (as encouraged by the U.K. Higher Education Academy [8]), as users actively make decisions about their learning according to the contents of their open learner model.

Our previous work with OLMlets identified the ability of a simple IOLM to support learning in a range of courses [7]. However, it is quite common for students to not fully understand how the parts of their degree fit together, until the end of a set of courses—or even later [9]. Therefore, in this paper we focus on an additional component (UK-SpecIAL) for use with OLMlets (or similar environment), to promote learner awareness of their knowledge and developing skills *across* the courses comprising their degree; i.e. how their knowledge contributes to their development overall.

The following section introduces national standards for engineering degree programmes. We then describe how learner modelling in OLMlets is used by UK-SpecIAL, with the aim of raising learner awareness of their knowledge across courses and how this relates to the acquisition of professional engineering skills. Finally, we present an evaluation of UK-SpecIAL as a support to first year university students.

## 2. Meeting Standards for Professional Engineering Competence: UK-SpecIAL

The UK SPEC Standards for Professional Engineering Competence [10] must be demonstrated in engineering degree programmes for degrees to be accredited. UK SPEC covers five areas: (i) underpinning science and maths; (ii) engineering analysis; (iii) design; (iv) economic, social and environmental context; (v) engineering practice. The Institution of Engineering and Technology (IET) has interpreted the UK SPEC learning outcomes for electrical, electronic and computer engineering degrees [11].

Within individual courses, intended learning outcomes are generally listed as statements of the form "on successful completion of this module you will be able to design.../select.../solve..." (see [12]). However, these intended learning outcomes do not directly match UK SPEC learning outcomes: more than one course contributes to each UK SPEC learning outcome; and most courses contribute to more than one UK SPEC learning outcome. Examples of UK SPEC learning outcomes include "knowledge and understanding of scientific principles"; "understanding use of technical literature and other information sources"; "knowledge of particular materials, equipment, processes, or products"; "use creativity to establish innovative solutions" [10].

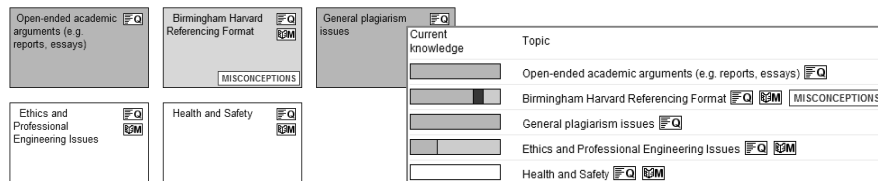
The UK-SpecIAL (UK SPEC Independent Adaptive Learning) environment aims to show how students' work for individual courses is contributing to their learning in the areas defined by UK SPEC - how it meets national standards for engineering competence (see [13] for details). We first describe OLMlets, which performs the learner modelling and opens the model to users with reference to specific courses, and then present UK-SpecIAL, which draws on the OLMlets models.

OLMlets is in its fourth year of deployment in a variety of courses in Electronic, Electrical and Computer Engineering, University of Birmingham, and has been taken up by two-thirds of students [7]. Because OLMlets is designed for a range of courses which are likely to have different structures and different kinds of conceptual relationships, the learner modelling is simple. The model is constructed based on answers to multiple choice questions input by the instructor [14]. The underlying model is stored in numerical form, with a number between 0 and 1 for each topic or concept modelled; and a number in the same range (0-1) for the likelihood of the user holding a specific misconception in a topic (related to a set of misconception descriptions created by the instructor). Modelling occurs over the five most recent attempts in a topic, with the weighting in the model increasing over these five attempts (by 0.3 each time) according to the recency of the attempt. There can be as many topics or concepts as the instructor chooses, and these can be as fine- or course-grained as the instructor wishes. UK-SpecIAL is accessible from each of the OLMlets courses. UK-SpecIAL draws on the underlying OLMlets learner models, giving an average of the individual topic models for each course, as follows:

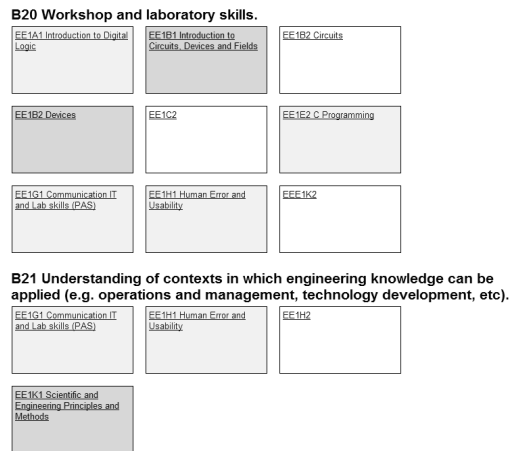
$$S_i = \frac{\sum_{n=1}^5 w_{n,i} a_{n,i}}{\sum_{n=1}^5 w_{n,i}} \quad \begin{array}{l} \text{where } w_{n,i} = 1 + 0.3n \text{ is the weighting for the } n^{\text{th}} \text{ attempt} \\ \text{in topic } i, \text{ with } n = 5 \text{ representing the most recent and} \\ a_{n,i} \text{ is the score (1 or 0) for the } n^{\text{th}} \text{ attempt in topic } i. \end{array}$$

The overall course value is  $S = \sum_{i=1}^m S_i / m$  where  $m$  is the number of topics in the course.

OLMlets allows learners to view their learner model in five formats. Figure 1 shows two of these as an illustration. The 'skill meters' give current knowledge levels (green: medium shading in Figure 1) for each topic; any misconceptions held (red: dark shading); and generally problematic areas, i.e. not related to specific misconceptions (grey: light shading). White indicates insufficient data to model. The 'boxes' use shades of green to indicate strength of knowledge in each topic. (The 'Q' icons lead to questions on the topic; the 'M' icons to learning materials, e.g. course notes, slides, web links; the misconceptions links lead to brief statements of likely misconceptions.)



**Figure 1.** Boxes and skill meter OLMlets views (Communication, IT and Lab Skills course)



**Figure 2.** The UK-SpecIAL open learner model for all courses

The UK-SpecIAL interface is similar to the OLMlets boxes view, as shown in Figure 2. Each learning outcome (B20, B21 in Figure 2) is given as a heading, and a box is shown for each course that contributes to that learning outcome. Thus each course will appear the same number of times as the number of UK SPEC learning outcomes to which it contributes. Clicking on a course title (inside a box) displays text stating how the course contributes to a learning outcome (e.g. *Work safely in a workshop or laboratory environment while using: a range of tools related to the assembly of electronic circuits and systems; a range of equipment to perform measurements and procedures of relevance to analogue electronic engineering. Demonstrate the development of keyboard skills and an ability to: use web browsers intelligently; acquire experience in the use of suitable software packages.*) Therefore students can see which courses contribute to which UK SPEC learning outcomes, and how individual courses contribute to a particular learning outcome. Users appear to trust the UK-SpecIAL information [13].

### 3. Use of an Independent Open Learner Model Across a Degree

This section considers whether students find a simple IOLM helpful to understand the overall expectations of their degree, and whether they are meeting the requirements.

#### 3.1 Participants, Materials and Methods

Participants were 22 volunteers in their first year of a 3 year BEng or 4 year MEng degree. (Degrees ranged from traditional engineering degrees such as Electronic and Electrical Engineering, or Computer Systems Engineering; to more human-focussed degrees such as Computer Interactive Systems.) All were taking a compulsory introductory course in general laboratory, report writing and engineering skills, and UK-SpecIAL was introduced in the context of this course to help students understand UK SPEC learning outcomes with reference to their degrees. Interactions were automatically logged. At the time of the coursework deadline (5 weeks later), students also handed in a questionnaire. Responses were required on a five point scale: 5 - strongly agree, 4 - agree, 3 - neutral, 2 - disagree, 1 - strongly disagree. Open-ended comments were also sought. Part of the coursework included a written analysis of issues related to requirements of professional engineers (and so relevant to UK SPEC), contributing 7% of the course mark, and the contents of the OLMlets learner models (Figure 1) comprised 7% of the mark. Our sample comprises around 1/3 of the cohort. For comparison, current second year students were asked by questionnaire about their awareness of UK SPEC.

#### 3.2 Results

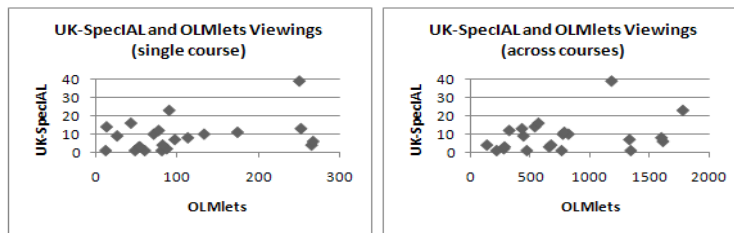
Table 1 shows the extent of use of OLMlets and UK-SpecIAL, taken from the logs, and the questionnaire responses. Most students attempted over 100 questions in the general skills course. Students were also using OLMlets in other courses. (For comparison: in the two other courses that were compulsory for all or most first years, that used OLMlets, students were also answering over 100 questions on average - in both cases the medians were over 300. One of these courses summatively assessed the OLMlets learner models; use in the other course was optional.) Students were generally accessing their OLMlets learner model frequently, after attempting one or two questions. UK-SpecIAL viewings averaged 9.7 (median 7.5 viewings). Most students achieved an 'excellent' level of knowledge by the end of the general skills course: mean 0.93, median 1.0, on the scale 0-1. (For comparison: in the other two courses taken by most first years, knowledge level means were both 0.7, medians 0.9.)

On the 5-point scale, Table 1 shows questionnaire responses relating to whether the IOLMs helped users identify their knowledge within topics in a specific course (OLMlets), and across courses (UK-SpecIAL). In general, students found both IOLMs helpful. Table 1 also shows perceptions of the utility of UK-SpecIAL according to its aims of helping learners appreciate how their various courses contribute to meeting learning outcomes for an accredited engineering degree. While, as indicated by the range figures, there were some who did not understand the purpose of UK-SpecIAL, the majority did consider it helpful for understanding how learning outcomes are relevant across courses, how courses relate to UK SPEC, and how UK SPEC is relevant to professional engineers. Nearly all students agreed that it was important or useful to know about UK SPEC to contextualise their learning, but few had knowledge of UK SPEC before being

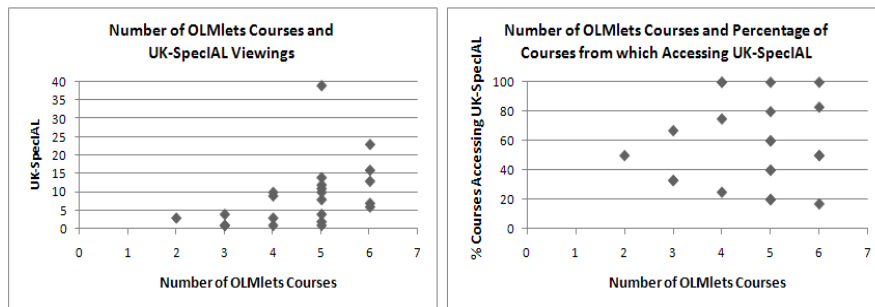
introduced to it through UK-SpecIAL. Current second years' understanding of UK SPEC is lower than for first year students. (These students had not used UK-SpecIAL.)

**Table 1.** OLMlets and UK-SpecIAL: log data and questionnaire data

| <i>Log Data</i>  | <i>Mean</i> | <i>Med.</i> | <i>Range</i> |
|--|-------------|-------------|--------------|
| Questions attempted in general skills course                 | 146.3       | 116         | 45-537       |
| Knowledge level (0-1) in general skills course               | 0.93        | 1.0         | 0.6-1.0      |
| OLMlets learner model viewings in general skills course      | 106.7       | 81.5        | 12-267       |
| UK-SpecIAL learner model viewings                            | 9.7         | 7.5         | 1-39         |
| <i>Questionnaire Item</i>                                    | <i>Mean</i> | <i>Med.</i> | <i>Range</i> |
| Helped identify knowledge in a course (OLMlets)              | 4.6         | 5           | 4-5          |
| Helped identify knowledge across courses (UK-SpecIAL)        | 4.0         | 4           | 1-5          |
| Relationships: learning outcomes across courses (UK-SpecIAL) | 4.3         | 4           | 3-5          |
| How courses relate to UK SPEC (UK-SpecIAL)                   | 4.3         | 4.5         | 2-5          |
| How UK SPEC relates to professional eng. (UK-SpecIAL)        | 4.2         | 4           | 2-5          |
| Important/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          |



**Figure 3.** UK-SpecIAL viewings compared to OLMlets viewings in general skills course (left) and all OLMlets courses in which individuals were registered (right)



**Figure 4.** UK-SpecIAL viewings and number of OLMlets courses in which individuals were registered (left); number of OLMlets courses and number of courses UK-SpecIAL used (right)

Figure 3 suggests no strong correlation between the number of accesses to UK-SpecIAL and the number of OLMlets accesses in the course in which OLMlets was introduced (correlation coefficient 0.34), and in all first year courses in which students were using OLMlets at the time (correlation coefficient 0.33). Figure 4 shows UK-

SpecIAL viewings were not necessarily more frequent by those using OLMlets in more of their first year courses (correlation coefficient 0.44), and most were accessing it from multiple courses, with some accessing it from all or most courses in which they were using OLMlets (correlation coefficient 0.04). Only two courses assessed the learner models; therefore most students were also using OLMlets optionally to support their learning.

The following illustrate typical open-ended comments:

- 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.
- I believe that as an aspiring engineer it is very important to know about UK SPEC as it gives me a further knowledge of what is required of me as an engineer and also what is required of other engineers in different fields.
- 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).

There were also a few comments indicating that, while useful, it is not necessary to know about UK SPEC as long as the principles are included in the degree, e.g.:

- 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.

### 3.3 Discussion

On average students attempted over 100 questions in OLMlets during the general skills course. Users viewed their individual learner models frequently (after every one or two questions). It could be argued, of course, that the frequent learner model inspection was due to there being no other form of feedback available, and that this was used in a strategic approach to the OLMlets assessment in our specific course of interest (by the end of the course, most users had obtained an excellent level of knowledge in all topics in their learner model). However, our previous work suggests that a large proportion of students also adopt this approach in courses where use of OLMlets is optional [14], and usage levels are not necessarily highest in courses that assess the learner models [13]. We therefore suggest that this particular assessed setting did not greatly alter typical usage patterns. In this paper we are interested in the way in which students were (or were not) accessing UK-SpecIAL alongside their use of OLMlets. It was found that most students were accessing UK-SpecIAL from several courses (i.e. not only the course with which it was particularly associated), and that several accesses were made throughout the 5 week period of the study. This suggests that students generally used UK-SpecIAL as intended: as a comparative overall view of their progress towards general learning outcomes. (144 further UK-SpecIAL accesses were made between the point of data collection for our course of interest, and the start of the second term's courses i.e. when there was no specific assessment related to UK-SpecIAL.) There was no clear relationship between number of viewings of UK-SpecIAL and extent of viewing the OLMlets learner models, or the number of OLMlets courses that students were using. It appears then, as with use of OLMlets [14], individual differences in preferences are to be found in use of an IOLM to help learners keep track of their progress across courses, and investigate relationships between courses.

Students generally considered OLMlets and UK-SpecIAL useful to help them identify their knowledge in specific courses and across courses. The figures were a little

higher for OLMlets than UK-SpecIAL, but this may be because most of the first term's courses had not yet ended at the time of the OLMlets assessment and completion of questionnaires, and the second term's courses had not yet begun, students were not in a position to fully understand links between them. Further investigation of user perceptions of the utility of UK-SpecIAL will be made at the end of the year.

For the most part students felt UK-SpecIAL helped them understand relationships between learning outcomes across courses, how these related to UK SPEC and how UK SPEC relates to professional engineering. This is particularly evident in the open-ended comments, where students clearly articulated their own interpretations: seeing relationships rather than separate modules; and how this relates to engineering professions more broadly. Students generally also thought it important to know about UK SPEC, though not all shared this view, as indicated by the comment that it is sufficient if the principles are embedded in courses. This is a valid response—UK-SpecIAL aims to help students recognise how their courses are relevant to professional engineering by relating courses to components of UK SPEC. If a student is able to gain this understanding by other means, there is less need for them to explore these relationships in UK-SpecIAL.

Few students were aware of UK SPEC before commencing their degree and, given the mostly positive reactions from the first years to gaining a better understanding of the learning outcomes across their degrees and how these contributed to their future careers, it is necessary to find out whether they may have gained this knowledge through some other means. For this purpose we investigated whether the current second years were aware of UK SPEC and found that, while some students had some knowledge, the level of understanding of UK SPEC was very much lower. We therefore conclude that it is probably the introduction to UK SpecIAL that fostered this understanding.

The fact that the OLMlets learner models contributed 7%, and a discussion of professional engineering relevant to UK SPEC 7%, to the course mark, is likely to have influenced some students to use OLMlets and UK-SpecIAL. Nevertheless, as stated in the Introduction, OLMlets has been taken up by about two thirds of students across all courses in which it is available, even though use of OLMlets is not assessed in most courses. Therefore we speculate that, given the positive questionnaire responses to UK-SpecIAL, students would investigate this kind of IOLM sufficiently in other contexts to discover the benefits for themselves, if they are encouraged to do so.

It is possible that those who gave permission for their data to be used for research (one third of those registered on the course), were the more enthusiastic or successful learners. Ethical considerations preclude us from investigating this further. However, we can still see that many learners may gain a greater insight into the structure and broader requirements of their degree through this kind of approach. It may not suit all, but it is worthwhile if there are sufficient students finding it beneficial which, based on the results, we believe there are. It seems that even a simple overview IOLM can have a strong effect on students' understanding of their degree. Future work will consider UK-SpecIAL in the context of all courses a student is taking (e.g. how do they use UK-SpecIAL in different courses - does this depend on how they use OLMlets in different courses?) We will also consider whether more structured or alternative representations might be possible in UK-SpecIAL without reducing understandability or usability. The approach may also be transferrable to other disciplines.

#### 4 Summary

We have presented UK-SpecIAL, a simple IOLM to help users recognise their progress and how they are meeting UK SPEC learning outcomes across courses in their degree. UK-SpecIAL draws on the OLMlets learner models, and was deployed to support learning in electronic, electrical and computer engineering courses. Questionnaire responses and usage logs suggest that even simple IOLMs can help students appreciate their understanding of course content; and comprehend the way in which their courses relate to one another and the requirements and expectations of their future professions.

#### Acknowledgements

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