Design and Evaluation of Adaptive Feedback to Foster ICT Information Processing Skills in Young Adults

Beate Grawemeyer
Knowledge Lab
Birkbeck, Univ. of London
beate@dcs.bbk.ac.uk

Konstantinos Karoudis
Knowledge Lab
Birkbeck, Univ. of London
k.karoudis@dcs.bbk.ac.uk

George Magoulas
Knowledge Lab
Birkbeck, Univ. of London
gmagoulas@dcs.bbk.ac.uk

Marta Pinto
Faculty of Psychology and Education Science
Univ. of Porto
martapcarvalho@fpce.up.pt

Alexandra Poulovassilis
Knowledge Lab
Birkbeck, Univ. of London
ap@dcs.bbk.ac.uk

ABSTRACT

This paper explores the provision of adaptive hints based on attainment levels in the context of supporting the development of young adults' ICT information processing skills. We describe the design of the LIBE VLE, particularly its personalisation and adaptation features, and a User Study undertaken with young adults at a vocational education centre. Using data collected through the LIBE VLE, we analyse the relationships between learners' accessing of hints, motivation, and performance. Results point to a positive effect of accessing of hints on students' perception of the LIBE VLE and their likelihood of using it again for further learning; and also a positive effect of students' interest in the course subject on their engagement and performance in course activities. These findings have important implications for supporting young adults in developing key competences necessary for integration into the workforce and for fostering self-regulated lifelong learning.

Keywords

ICT information processing skills; adaptation; feedback

1. INTRODUCTION

Information and communication technologies (ICT) are key to the creation of new social and economic opportunities and improved access to services, education and training. The plethora of free learning materials on the internet has the potential to greatly enhance knowledge, but this is only possible if there is a personal motivation to learn and if an individual possesses the skills necessary for accessing and exploiting such materials. Mastering STEM skills in particular plays an increasingly important role in employment and social inclusion. In this context, low educational achievers[1] even those with basic computer skills, encounter significant difficulties in tackling complex tasks requiring efficient information processing in technology-rich environments. Most such students are not expected to continue into higher education and they may face difficulties in a technology-rich society when it comes to integration into the workforce.

Reducing the proportion of students who struggle to master basic literacy and numeracy skills by age 15 is receiving high priority in the education agenda internationally. For example, in the European context, improving literacy and numeracy standards for both children and adults remains an important goal of the European Commission's Education and Training work programme, initially launched in 2002. These types of learners demonstrate low formal educational achievement levels and low motivation for learning, especially STEM-related skills.

This paper describes work towards addressing the needs of this diverse audience, undertaken in the context of the LIBE project - "Supporting Lifelong Learning with Inquiry Based Education" (see http://libeproject.it/[2]). The project has developed a Virtual Learning Environment (VLE) tailored towards offering personalised open-access e-learning courses to low-achieving 16-24 year olds who may be at risk of exclusion from further education and employment. LIBE courses target four transversal competences — Literacy, Numeracy, IT literacy, and Problem solving in technology-rich environments, drawing on the competency specifications of the OECD's PISA and PIAAC studies [16, 15] and the IEA's ICILS [6]. Design of LIBE courses starts from the interests and motivations of students on the basis of their daily experiences. Students can study in anonymity, where and when they choose, each at their own pace. The LIBE learning ex-

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[1]The OECD's definition of "low achievers" is those who score below level 2 on the combined mathematics, reading and science literacy scale of the PISA test.

[2]The LIBE project was funded by the Lifelong Learning Programme of the European Commission, ref. no. 543058-LLP-1-2013-1-IT-KA3-KA3MP. The LIBE project team was a multidisciplinary one: in addition to the authors' institutions, it involved the Dept. of Education at Roma Tre University (who were the LIBE Project Coordinator), the Centre for Lifelong Learning at Lillehammer University College, and the Dept. of Research Methodology, Measurement and Data Analysis (OMD) of the University of Twente.

perience is individualised and non-competitive, encouraging a sense of achievement and self-confidence with the aim of fostering engagement with longer-term learning.

The LIBE VLE is an Intelligent Tutoring System (ITS) [7] that supports inquiry-based learning. LIBE employs personalisation technologies to adapt the learning experience to the student's evolving profile of knowledge and skills, along three axes: content, support, and assessment. By offering personalisation LIBE aims at enhancing students' engagement and motivation to learn. LIBE addresses "assessment for learning" and "assessment of learning" simultaneously by using continuous unobtrusive measuring of performance while learners are engaged in course activities [24] and by offering tailored feedback to learners during formative assessment activities.

A review of the state-of-the-art on feedback provision and formative assessment conducted in the early stages of the LIBE project [10] concluded with the recommendation that, in order to maintain LIBE learners' attention, motivation and self-confidence, their performance should be continuously monitored, and course content and feedback should be adapted to learners' attainment levels. This paper explores this recommendation, focussing in particular on the provision of hints that are adaptive to individuals' attainment levels. A further dimension of adaptation explored by the project, but which is not our focus in this paper, was to include computerized adaptive testing (CAT) functionality, in which the difficulty of test questions is adapted to the student's current attainment level, estimated from their performance on previous tasks [12].

The LIBE project is novel in addressing specifically the development of key ICT information processing skills for those who need them most, namely young adults with low educational achievement. This paper explores for the first time the provision of adaptive hints in this context. We investigate in particular the relationships between learners' performance and accessing of such hints; learners' motivation and accessing of hints; and learners' motivation and performance.

In Section 2 we briefly describe related work in intelligent tutoring systems, feedback provision, and the role of motivation in students' learning. In Section 3 we give on overview of the LIBE project and the design of the LIBE VLE, specifically its personalisation and adaptation features, to the level of detail necessary for the rest of the paper. In Section 4 we describe a User Study undertaken to evaluate the provision of hints that are adaptive to learners' attainment levels. Section 5 analyses the results of this study, Section 6 discusses the implications of these results, and Section 7 draws conclusions and identifies several directions of further work.

2. RELATED WORK

Intelligent Tutoring Systems (ITS) aim to guide students through learning activities by maintaining information about their levels of knowledge and skills, and using this to provide feedback relating to their progress on the task set and on possible next steps [7]. There has been much research in ITS in relation to feedback, with the development of approaches for gradual provision of support and adaptation of feedback according to learners' individual characteristics [2]. Most approaches use the learner's knowledge level and rely on a learner model to provide personalised feedback. This typically requires an adaptation model or personalisation engine that incorporates a form of 'tutoring' knowledge representation encoding feedback generation and presentation methods, and that uses this knowledge together with learners' individual characteristics to generate and communicate the feedback.

Previous studies point to higher learning gains when "elaborated" feedback is provided compared to only simple forms of feedback provision such as whether an answer is correct or not [4, 23]. Provision of immediate feedback on question attempts and the opportunity to use that feedback in subsequent attempts at the same question has also been found to have a positive effect on learning, particularly for lower-achieving learners [5, 21, 13]. LIBE draws on these previous studies by providing within the LIBE courses elaborated feedback in the form of hints containing cues towards a correct solution to a problem, and by allowing this feedback to be subsequently used in multiple attempts at the same question.

Previous work has found that students may be motivated to learn by their self-efficacy beliefs, goals, personal interests, task-value beliefs, and contextual factors such as provision of tailored support; moreover, the learning task itself should be appropriately challenging for the student (not under- or over-challenging) [17]. Students' cognition, emotional and motivational beliefs are activated when they start performing a learning task, and their ability to control and regulate these can have a high impact on their learning performance [19, 18]. Students' perception of their self-efficacy influences their academic motivation and achievements [20]. Students with high self-efficacy belief work harder, persist longer and achieve higher performance. Students seek feedback when they are motivated by their belief in how well they would perform the learning task, as well as their task-value belief, and students' motivation is important in their accessing and processing of feedback [22]. LIBE draws on these previous studies by aiming to encourage a sense of achievement and self-confidence, offering tailored feedback and adapting course content and feedback to learners' attainment levels.

3. THE LIBE PROJECT

The LIBE project aimed to offer personalised e-learning courses to young adults (16-24 years old) who may be at risk from exclusion from further education, training and employment. LIBE courses are built around inquiry learning activities and target four transversal competences: Literacy, Numeracy, IT literacy, and Problem solving in technology-rich environments. The LIBE VLE is configured with an extensible set of learning objectives relating to each of these four competences. Each activity within a course is associated with one of the four competences and, optionally, with a specific learning objective.

Drawing on the PISA, PIAAC and ICILS frameworks, the project recognised the importance of adopting a cognitive rather than just a procedural approach towards the development of digital literacies and of addressing a broad range of competencies. An online test targeting the full range of LIBE learning outcomes was developed, using released test items from the OECD PISA and PIAAC surveys. This test was subsequently partitioned according to the learning objectives targeted by each test item and embedded into each LIBE course in the form of a short pre- and post-test. As well as allowing measurement of the learning gains made through completing a course, the pre-tests in particular serve an important role in the initialisation of the LIBE Learner Profile, upon which the provision of adaptive hints depends, as described in subsequent sections of the paper.

Before a student begins a course, the pre-test gathers information about their attainment in the competencies targeted by that course. This information is used by the system to initialise the adaptation process. As the student then engages in each course activity, these attainment levels are automatically updated according to the student's performance. Students' estimated attainment levels can be used to offer a personalised experience — for example, different levels of explanation of specialist terminology, different levels of hints to students who may be struggling with completing an activity, and tests at differing levels of difficulty.

Ten focus groups were conducted at the start of the project, in Italy, Norway and Portugal, with targeted participants representative of the LIBE audience (teachers and trainers of low-achieving young adults from schools and vocational training centres, and about 50 students). These discussions focussed on key competences, learning needs and priorities of low educational achievers, successful e-learning experiences by such students, their relationships with ICT, and their diverse learning settings (school, vocational education, continuing education, non-formal learning).

Six courses were developed during the LIBE project, designed after analysis of the focus group discussions. Each course presents a topic that was identified as being of broad appeal to these young people, e.g. writing a CV, searching for information on the internet, managing personal finances, sports, consumer awareness. Each course focusses on one or two of the four competences. The six courses developed are freely accessible at www.libecourses.com.

Towards the end of the project, the courses were piloted with over 600 young adults in Italy, Norway and Portugal, to evaluate their quality and appeal. Learners expressed generally positive attitudes towards their learning experience across all courses and towards the overall user friendliness of the LIBE VLE. For details of the outcomes of these trials we refer readers to [11]. Due to lack of time before the end of the project, there was no specific focus on personalisation in these trials, hence the subsequent User Study that we report on in this paper.

3.1 LIBE VLE Architecture

Following the focus group meetings, a list of Initial User and Technical Requirements for the LIBE VLE were collaboratively identified and prioritised by the whole LIBE project team [8]. Due to project resource constraints, the software development remit for developing the LIBE VLE was to reuse as much as possible existing open-source e-learning software. An analysis was therefore undertaken of 14 open-source Learning Management Systems (see [8] for details), focussing on functionalities most relevant to the needs of LIBE, and Moodle was selected as most closely matching the LIBE requirements. A first prototype of the LIBE VLE was developed, incorporating the necessary extensions to Moodle to address the initial User and Technical requirements. The six LIBE courses were implemented using this first prototype, which served to evaluate its functionalities and to determine the Final User and Technical Requirements. These Final Requirements included more precisely

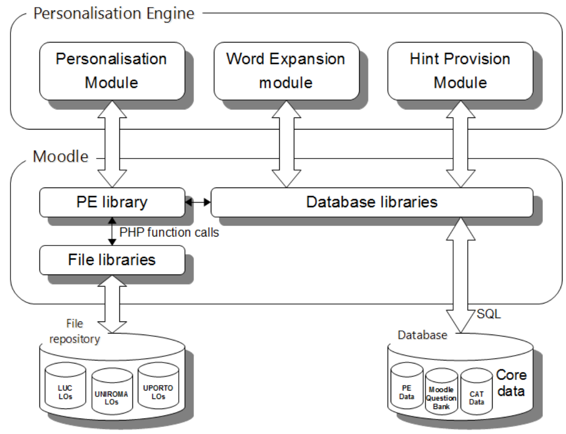

Figure 1: Personalisation Plug-in Architecture.

articulated requirements relating to: (i) course personalisation; and (ii) computerized adaptive testing (CAT).

To address the CAT requirements, eight open-source CAT tools were reviewed [9], and the tool selected as most closely matching the LIBE requirements was the Adaptive Quiz Moodle plug-in[3]. To address the course personalisation requirements, some 30 new LIBE database tables were designed to hold time-stamped data about the ways in which students are interacting with the LIBE courses, the tests and feedback offered to students, and the LIBE Learner Profile that holds information about students' characteristics, attainment scores and attainment levels (students' actual test results are stored in Moodle's core database tables). The LIBE Learner Profile is dynamically maintained by the system for each student as they are working through LIBE courses. It contains a history of the student's estimated attainment scores and levels with respect to the four transversal competences and with respect to specific learning objectives.

A second prototype of the LIBE VLE was developed, incorporating the integrated CAT tool and a new Personalisation Engine (see below). The design and evaluation described in this paper relates to this second prototype of the LIBE VLE, which consists of a Moodle installation, together with a new Personalisation plug-in developed by the LIBE project, and 18 other externally developed free plug-ins (for details of these we refer readers to the LIBE e-Booklet at http://libeproject.it/?p=888).

Figure 1 illustrates the architecture of the Personalisation plug-in, where PE denotes "Personalisation Engine". The Personalisation plug-in comprises the PE library and the PE Data. A Web Service API supports communication between the Personalisation Engine and the PE library. The PE library is implemented as a Moodle activity library: it retrieves user-related data from the Moodle database through the Database libraries and provides this information to the Personalisation Engine for further processing. The PE Data consists of the LIBE database tables storing the information needed for the PE to perform its adaptation and user support tasks. CAT Data corresponds to the Adaptive Quiz Data of the Adaptive Quiz plug-in mentioned earlier. The Moodle Question Bank contains questions imported into

[3]https://moodle.org/plugins/view/mod_adaptivequiz

Moodle to support the generation of adaptive quizzes. The File repository contains SCORM files corresponding to the LIBE courses.

The Personalisation Engine consists of the three modules:

- Personalisation Module: estimates the student's current attainment scores based on the activities completed so far, their difficulty levels, and the student's test results.
- Word Expansion Module: provides explanations of predefined words according to the student's estimated attainment level in Literacy.
- Hint Provision Module: provides hints according to the student's estimated attainment level in the competence and/or the learning objective targeted by the current activity.

The Word Expansion and Hint Provision modules retrieve the student's estimated attainment scores and details of recent student-system interactions from the PE data in order to select the appropriate explanation/hint, accessing the PE Data through the Database libraries. These modules are both called from within LIBE course pages using XMLHttp requests and are stored as PHP files on the LIBE server.

The Personalisation Engine architecture is extensible with additional modules to provide additional personalisation functionality. For example, in the early stages of the LIBE project a Sequence Adaptation module was also envisaged, but ultimately it was not possible for the project team to fully scope precise requirements for such a module within the time and resource constraints of the project.

The general design of LIBE's provision of adaptive feedback follows the layered approach of [3], comprising three main layers: the analysis layer, the aggregation layer, and the feedback presentation layer. The analysis layer is implemented within the Personalisation Module. The aggregation and feedback presentation layers are implemented within each of the other two modules, relating in each case to the adaptation functionality provided by that module. Advantages of adopting such a layered approach include dividing the complex problem of provision of intelligent support into smaller, more manageable, sub-problems; modular development that facilitates testing, formative evaluation and iterative refinement of the intelligent support; and easier extensibility with new feedback strategies and capabilities.

The analysis layer consists of several computational analysis modules (CAMs), each focussing on one aspect of the student-system interactions. Each CAM selects from the File repository and the PE data just the information that is required for its purposes. It generates additional student-related data that is stored in the PE data and will be consumed by the aggregation layer. In the case of LIBE, the CAMs include a module that computes the user's current estimated attainment score (a number) for each of the four competences targeted by LIBE, and a module that computes the user's current estimated attainment score for each of the learning objectives associated with activities that the user has completed so far.

The aggregation layer combines the information produced by the CAMs, and possibly also additional information from the PE data, in order to determine what type of feedback should be provided for the student at this time. This information will be consumed by the feedback presentation layer, which is responsible for selecting the actual feedback message to be presented to the student. In the case of LIBE, the aggregation layer is rule-based, since LIBE's personalisation and adaptation requirements were elicited from the pedagogical experts in the project team in the form of IF-THEN-ELSE rules. A rule-based implementation approach has the added benefit that the personalisation/adaptation logic is straightforward to understand by non-technical experts, and to change if necessary following further evaluation activities.

For the user study described in this paper, the following simple logic was implemented: Two hints were designed for each of three attainment levels (Low, Medium, High) in Literacy for three of the seven activities that students undertook from a course relating to Literacy (see Section 4). If a student currently at level x for Literacy requests a hint, they are shown hint 1 relating to attainment level x; the student is then expected to attempt the question — if they request a hint again without attempting the question, they are shown again hint 1. If the student's first attempt is wrong, they can request another hint, in which case hint 2 relating to attainment level x is shown. Any subsequent requests for a hint for that question result in hint 2 being shown again.

The feedback layer combines information produced by the aggregation layer (e.g. type of feedback to be provided) and information from the PE data (e.g. information relating to the student's recent history of interactions) in order to select and provide the appropriate feedback message. In the case of LIBE, the aggregation layer applies logic that estimates the current attainment level of each student for each competence and each learning objective (these levels may be one of Low, Medium, High) from their current attainment scores. The PE data stores a history of the evolving attainment levels for each student. The feedback layer combines information about the student's current attainment levels with knowledge of how many times the student has attempted the question so far in order to select and present (if the student requests it) either hint 1 or hint 2 of the appropriate level.

An introduction to the LIBE VLE is provided in the LIBE e-Booklet at http://libeproject.it/?p=888 with more details in the extensive set of resources on the LIBE website at http://libeproject.it/

4. USER STUDY

For this user study we were interested in how well the pre-test predicted students' subsequent performance, and how access to adaptive hints relates to a student's learning performance and learning experience. We were also interested to explore how a student's motivation influences their performance. Specifically, we formulated the following questions:

- Does the initialisation of the students' profiles with the results of the pre-test enable the prediction of students' subsequent learning performance?
- Is there a correlation between level of attainment and number of times hints are accessed?
- Do students have higher learning performance when they access the hints?
- Do students who are highly motivated in the course subject and content request more hints than students who are less motivated?

Table 1: Pre-test Activities

Activity	Type of Activity
0.1	cloze question test (10 questions)
0.2	multiple choice (2 questions)
0.3	multiple choice, matching (4 questions)
0.4	drag and drop labels (1 question)
0.5	multiple choice (2 questions)
0.6	cloze test (2 questions)

- Do students who access more hints show higher motivation to use the LIBE VLE again?
- Do students who show high motivation in the course subject and content perform better than students who are less motivated?

In order to answer these questions, we conducted a study with students at a Vocational Training Centre in the region of Porto (Portugal). The selection of participants was based on all being young adults (16-24) enrolled in Vocational Education and Training courses. 23 students took part, 20 female and three male, and all agreed to participate in the study on a voluntary basis. Of the 19 students who entered their age information, their minimum age was 16, maximum 19 and median 17. The user session took place in a classroom equipped with computers connected to the internet, with the presence of one teacher and one facilitator (researcher).

The study related to the first part of the "Saving the World from my Neighbourhood" LIBE course designed by the University of Porto. This course targets one competence – Literacy. The pre-test comprised six test activities, listed in Table 1, all relating to Literacy. The results of the pre-test were used to initialise the students' attainment scores and levels within their learner profiles. Feedback messages within the main course that students then undertook were tailored to their level of attainment in Literacy, dynamically updated as students progressed through the course. The computation of attainment scores for Literacy was based on a simple averaging of the student's performance over all the test activities undertaken thus far (including both in the pre-test and in the main course). In the absence of any test calibration data from earlier LIBE project trials, an attainment score of 0-33% was categorised as indicating a Low attainment level, of 34-66% as a Medium attainment level and of 67-100% as a High attainment level (we stress that these attainment levels do not necessarily correspond to low, medium or high achievement in calibrated tests).

The user study focussed on the first seven activities of the "Saving the World from my Neighbourhood" course. Table 2 lists these seven activities, showing in each case the learning objective. Hints were available for Activities 1.1, 3.1 and 3.2. A hint is shown only if the student explicitly requests one by clicking on a clearly visible "Hint" button. For this study, two hints were designed for each attainment level (Low, Medium, High) for Activities 1.1, 3.1 and 3.2. For example, suppose a student currently at Medium attainment level is working on Activity 3.1 and requests a hint before attempting that question. The student would be shown the hint "Estás a reutilizar objetos quando os transformas em itens novamente úteis" ("Reusing objects means transforming them into items that are useful again"). The student would then be expected to attempt the question (if they pressed the Hint button again, they would receive the same hint). If the student's first attempt is wrong, they can request another hint; in this case, the hint "Ao transformar um objeto antigo em um novo e desejável, estás a reutilizar o objeto" ("When you transform an old object into a new and useful item, you are reusing the object") would appear.

Table 2: Main course activities

Activity	Learning Objective
1.1	Understand the global meaning
2.1	Make semantic inferences
2.2	Locate explicit information
3.1	Make lexical inferences
3.2	Make semantic inferences
3.3	Make lexical inferences
3.4	Make lexical inferences

After taking the pre-test, students were asked to watch an introductory video describing the "Green Neighbourhood Youth Association", and then to read a piece of text relating to resource efficiency. Activity 1.1 comprised two multiple choice questions about the overall meaning of the video and the text, in which students had to complete two sentences by selecting one out of four possible options for each sentence.

In Activity 2.1, students were asked to read another piece of text, describing the different ways in which the "Green Neighbourhood Youth Association" reduce waste. Students were asked to show their understanding of the term "reduce waste" by completing a short piece of text with the missing words (selected in each case from a pull-down list). Activity 2.2 comprised a multiple choice question relating to the waste reduction text students had read earlier.

In Activity 3.1, students were asked to read a short text about waste reuse and to look at two pictures showing examples of items that can be refurbished and reused. They then had to select three (out of six) words most closely corresponding to the word "reuse". Activity 3.2 presented a short phrase relating to waste reuse and tested students' understanding of this phrase by asking them to select which one out of four possible explanations most closely corresponds to it. In Activity 3.3 students had to drag and drop labels onto images to show which objects can be reused and which are non-reusable. Finally, in activity 3.4 they had to select from a list of nine items all those that could be reused.

The facilitator began the session by first saying a few words about the LIBE project and the activities that students would be asked to do. Students were then given the link to the LIBE website and asked to log in (using provided anonymised accounts) and fill in some background information about themselves. When everyone had completed this, students were given 1 hour and 15 minutes to complete the pre-test and main course. Successive activities became available as soon as a student had completed the previous one. The activities were shown in a main index with an empty tick box next to them to allow students to track their progress. As soon as an activity was completed the box next to it was ticked and the next one became available. Completed activities were locked and could not be revisited by the students (apart from activities 1.1, 3.1 and 3.2 that could be repeated once). After finishing the main course, participants were asked to complete a short questionnaire (presented to them through the LIBE VLE) that included questions re-

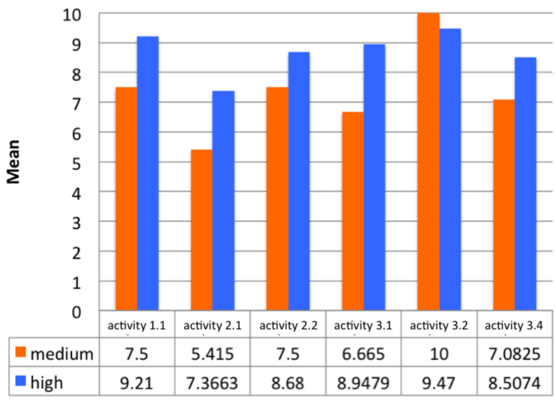

Figure 2: Students mean performance per main course activity.

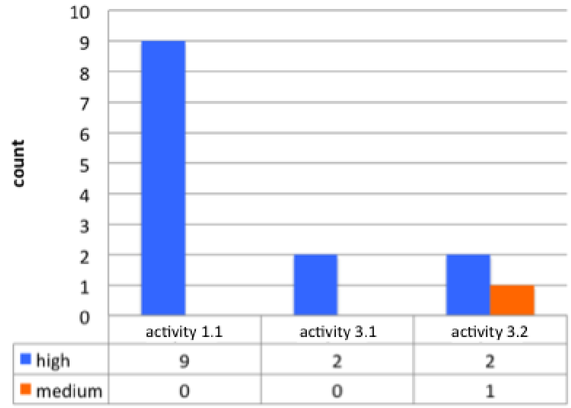

Figure 3: Hints requested per attainment group.

lating to their motivation and learning experience and how difficult they found the course.

5. RESULTS

We explore each of the six research questions listed at the start of Section 4. Technical problems caused incomplete collection of the data on activities 0.4 and 3.3, and so this data is not included in the following analysis.

5.1 Relationship between pre-test performance and main course performance

In each of the pre-test activities students were able to score up to 10 points, giving a maximum total score of 50 for the pre-test as a whole after discarding the faulty data for pre-test activity 0.4. The average student score on the pre-test was 40.90/50 (min=30.00; max=48.33; SD=5.79). As described earlier, the pre-test performance was used to classify students into low, medium or high attainment level in Literacy. Only two groups emerged from this classification: 4 students were classified as showing medium attainment and 19 were classified as showing high attainment in Literacy (the fact that participation in the trial was voluntary may have had a self-selecting bias towards higher performing students).

Figure 2 shows the mean performance of students in these two groups on each of the main course activities. Similarly to the pre-test, students were able to score up to 10 points in each main course activity, giving a maximum total score of 60 on the main course as a whole after discarding the faulty data for main course activity 3.3. The average student score on the main course was 50.79/60 (min=33.33; max=58.33; SD=6.37).

As the size of the two groups was unequal, we used a Mann-Whitney test to investigate if there is a difference in performance between the groups, summing the individual scores from the main course activities into an overall main course performance score. The main course performance of the high attainment group (Mdn=51.57) was significant higher than that of the medium attainment group (Mdn=45.83), $U=12.5$, $z=-2.08$, $p<.05$, $r=-0.43$.

This result shows that the classification of students into medium and high attainment levels in Literacy after completion of the pre-test can be used to predict their subsequent learning performance.

5.2 Relationship between level of attainment and accessing of hints

As described earlier, adaptive hints were provided on activities 1.1, 3.1 and 3.3. Five students accessed these hints: four with high attainment level and one with medium attainment level. One reason that few students accessed hints might have been because of the high proportion of students with high attainment levels, who were preforming well without requiring hints.

Figure 3 shows the total number of times hints were requested in the different activities by students with different attainment levels. No statistical difference was found between the two attainment level groups and the number of times hints were accessed ($U=37.5$, $z=-.056$, $p>.05$, $r=-0.01$).

We also investigated if students' self-rating of how difficult the main course activities were — this was one of the questions of the post-course questionnaire — was correlated to how many hints were accessed or to their main course performance. For this question students could select an answer of: I found all the questions easy, I found most questions easy (but some were challenging), I found most of the questions challenging (but some were easy), I found all of the questions challenging. No significant correlation between students' answers and the number of hints accessed was found ($r=-.22$, $p>.05$). There was also no significant correlation between students' answers and their main course performance ($r=-.32$, $p>.05$). This might imply that students who had medium attainment levels might have overestimated their ability and might therefore have thought that extra help via the hints was not needed.

5.3 Relationship between accessing hints and performance on activities

Figure 4 shows the average performance on the main course overall plotted against the number of times hints were accessed across in total all the main course activities. No significant correlation was found between the number of times hints were accessed and the students' performance ($r=.10$, $p>.05$). Also, the number of times a hint was accessed on an individual activity was not significantly correlated with the performance on that activity (activity 1.1: $r=-.13$, $p>.05$; activity 3.1: $r=-.03$, $p>.05$; activity 3.2: $r=.09$, $p>.05$).

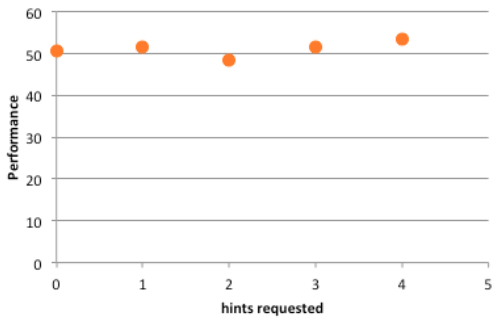

Figure 4: Students' average main course performance and number of times hints were accessed.

5.4 Relationship between accessing hints and motivation on course subject and content

In order to investigate the relationship between a student's accessing of hints and their motivation, we investigated the correlation between the number of times students requested hints and their answers to a subset of questions from the post-course questionnaire that related to the student's motivation towards the course subject and content. This subset of questions are listed below:

a) I like what I have learned in this course.
b) It is important for me to learn what was taught in this course.
c) I think I will be able to use the skills I learned in this course.
d) I think that what I am learning in this course is useful for me to know.
e) I think that what we are learning in this course is interesting.
f) Understanding this subject is important to me.
g) I think the content of this course is useful.

Students could select one of four possible answers in each case: Strongly disagree, Disagree, Agree, Strongly agree.

No significant correlation was found between the total number of times students requested hints over the whole of the main course and their average score over questionnaire questions a)-g) ($r=.06$, $p>.05$). This was also the case when we looked at the number of hints requested in the individual activities 1.1 and 3.2 (activity 1.1: $r=.10$, $p>.05$; activity 3.2: $r=-.38$, $p>.05$). However, for activity 3.1, there was a significant correlation between the number of times students accessed hints and their average score over questions a)-g) ($r=.42$, $p<.05$). This indicates that when students were highly motivated in the course subject and content they were more likely to request hints in this activity.

5.5 Relationship between accessing hints and learning experience

We were interested to explore if the number of times students accessed hints correlated with their learning experience. One question from the post-course questionnaire related to a student's learning experience, asking if they would like to use the LIBE system frequently. Again, students could select an answer of Strongly disagree, Disagree, Agree, Strongly agree.

A significant correlation was found between the total number of times hints were accessed in the main course activities and the answer to this question ($r=.43$, $p<.05$). This was also the case individually for main course activity 1.1 ($r=.44$, $p<.05$), but not for activity 3.1 ($r=.32$, $p>.05$) or activity 3.2 ($r=.24$, $p>.05$).

This indicates that when students accessed hints more often (especially on main course activity 1.1) they subsequently felt more positively about the learning environment and would like to use it more often in the future.

5.6 Relationship between motivation on course subject and content and performance

In order to investigate if there is a link between a student's motivation and their performance on the main course activities, we explored the correlation between students' answers to the subset of questions from the post-course questionnaire relating to students' motivation towards the course subject and content (questions a)-g) listed earlier) with the student's performance on the main course activities.

When the student's scores on all main course activities were combined, then there was no significant correlation between their motivation and their overall main course performance ($r=-.06$, $p>.05$). This was also the case in five out of the six main course activities individually (activity 2.1: $r=-.35$, $p>.05$; activity 2.2: $r=-.12$, $p>.05$; activity 3.1: $r=-.12$, $p>.05$; activity 3.2: r=.,07 $p>.05$; activity 3.4: $r=.01$, $p>.05$).

However, on main course activity 1.1 there was a significant correlation between a student's motivation and their performance on that activity ($r=.49$, $p<.05$). This indicates that for main course activity 1.1 a student's motivation is important: the higher the student's motivation the higher their performance on that activity.

6. DISCUSSION

Our results show that students classified with high attainment levels in Literacy after completion of the pre-test outperformed students classified with medium attainment levels. This means that students' estimated attainment levels can be used to predict subsequent learning performance and therefore can provide robust information about which level the hints need to be adapted to.

There was no statistical difference in the number of times hints were accessed between the different groups. This may imply that when hints are adapted to the attainment level of the student, students find such hints supportive even if their attainment level is high.

Our results did not show a relationship between the number of times hints were accessed and students' learning performance. The reason for this might be that students already had relatively high attainment levels when they started the course activities, as only medium and high levels of attainment were found from the pre-test activities. Our results might have been different for students with lower attainment levels at the beginning of the main course. Also, some students with medium attainment level might have overestimated their ability and might have thought they did not need any help via the hints ([22] notes similar overestimation by students of their information literacy ability in other learning contexts).

On main course activity 3.1 we found that students with higher motivation accessed the hints more often than students with low motivation. In activity 3.1 students were asked to identify words that most closely correspond to a particular different word, namely "reuse", which involved making lexical inferences. Making such lexical inferences is one of the most difficult main course activities, in comparison to, say, multiple choice questions about overall meaning (activity 1.1) and making semantic inferences about a short phrase (activity 3.2).

This result implies that students who are more highly motivated are more likely to be engaged in performing a learning activity, especially when the task is difficult, trying to overcome difficulties by seeking help via the hints. This confirms earlier research into how students' motivation and self-regulated learning strategies are related to their engagement in learning tasks (e.g. [18, 19, 20]).

We also found that students who accessed the hints more often felt more positively about the VLE and would like to use it more often in the future. This was particularly true for activity 1.1, where the students were asked about the overall meaning of the course subject. This result highlights the potential of providing hints that are tailored to the attainment level of the student, as this adaptation may have helped to create a better learning experience for students who accessed the hints more often. Improving a student's learning experience is an important factor in learning as it is more likely that the student will use the VLE again for further learning.

Additionally, for main course activity 1.1 students' performance on that activity was related to their motivation. This indicates that when students are motivated and interested in a particular course subject they will perform better on activities that are centred on this subject. Again, this confirms earlier research, e.g. [17], that shows that a student's motivation is an important factor in learning.

7. CONCLUSIONS

The LIBE project - "Supporting Lifelong Learning with Inquiry Based Education" - was concerned with the development of ICT information processing skills in low-achieving young adults. This paper has explored for the first time the provision of adaptive hints based on attainment levels in this context.

LIBE courses target four transversal competences, and the LIBE VLE is configured with an extensible set of learning objectives relating to each of them. Each course activity is associated a competence and, optionally, a specific learning objective. The LIBE Learner Profile holds information about students' estimated attainment scores and levels in these competences and learning objectives. As a student engages with a course, their attainment scores and levels are automatically updated according to their performance. The estimated attainment levels can be used to offer students different levels of explanation of specialist terminology, different levels of hints, and tests at differing levels of difficulty.

We have described the design of the LIBE VLE, and a User Study conducted with young adults at a vocational education centre using the pre-test and first seven activities of a course focussing on Literacy. Using students' responses to the pre-test, data from their interactions with the main course activities, and their responses to the post-course questionnaire, we have analysed the relationships between their accessing of hints, motivation, and performance. The results point to the effectiveness of the initialisation of the LIBE Learner Profile, which classifies students into different attainment levels on the basis of their performance on the course pre-test. These estimated attainment levels can be used to predict subsequent learning performance and therefore can provide a robust basis for the adaptation of hints provision.

The results also highlight that students' motivation is important for learning. Students who are highly motivated in the course subject perform better on activities centred on that subject. Also, when students are confronted with a more difficult activity, motivation is an important factor in how deeply they engage with the activity. When students are highly motivated they are more likely to access the hints available for a difficult task, which may in turn help them to complete the task. Students who accessed the available hints more often also felt more positively about the LIBE VLE itself and would be more likely to use it again the future.

Our general recommendation is that the course subject needs to be motivating for students as they will perform better on activities centered around subjects that they are highly motivated in. They will also be more likely to access the hints available, which in turn may help them with the more difficult tasks. This kind of engagement with the learning environment also creates a more positive learning experience, which has important implications for lifelong learning since students are more likely to use the VLE again to access further learning resources.

Providing feedback which is adapted to students' attainment levels is particularly important in the LIBE context. Traditional adaptive learning support takes into account a student's performance to provide feedback. However, low-achieving students might have difficulties to follow traditional feedback as certain specialist terminology might be unfamiliar to them. Therefore, adapting the feedback based the student's attainment level can help students to follow the support provided more effectively.

The user study reported here was small-scale and the results are preliminary findings. Further research on the provision of adaptive feedback requires additional trials with student groups of broader backgrounds and achievement ranges; trials targeting the other transversal competences too, beyond Literacy; calibration of the LIBE pre-tests and main course activities; and refinement of the rules used to categorise students into low, medium and high attainment. Similar trials and calibrations are required for the provision of vocabulary explanations that are adaptive to the students' Literacy levels, and for the computerized adaptive testing. For these new studies, participants will be selected based on their performance in the targeted competence(s), with the aim of having an equal proportion of low, medium and high achieving students. This will help to investigate in more detail the association between students' attainment level and their accessing of hints. In order to investigate the effectiveness of the adaptive hints, participants will be divided into three groups (each with roughly equal numbers of low, medium and high achieving students): a group for which no hints are provided as they undertake the course, a group for which only generic hints are provided, and a group for which hints that are adapted to students' attainment level are provided. Pre- and post-tests will be used to investigate learning gains in all cases. The final questionnaire will be extended to include questions about the usefulness of the hints, which will provide information about the students' perception of the hints provided (if they were participating in one of the groups that had hints available). We will also follow this with focus groups, where participants will be engaged in a more detailed discussion about their experience with the LIBE VLE and the hints provision.

Finally, feedback from the focus groups held after the large-scale piloting phase at the end of the LIBE project included two key recommendations relating to further development of the LIBE VLE itself: one focus group in Norway suggested that including a "timeline" showing a learner's progression within the current course would help learners see "how far along they are"; one focus group in Portugal suggested that including a "scoring system" showing the learner how many correct and incorrect questions they had answered so far on the course would be a way of motivating them to do better. These recommendations point to the need for research into the design of Open Learner Models [1] in the LIBE context of developing ICT information processing skills for low-achieving young adults.

Beyond learners' engagement with the six LIBE courses, the LIBE project aspired to foster longer-term use of the internet as a rich source of information and learning opportunities, aiming towards self-regulated lifelong learning. The growing focus on low educational achievers (see e.g. [14]) and on strategies for tackling issues relating to the 'NEET' generation (Not in Education, Employment or Training), makes the LIBE research findings of broad interest to educators, stakeholders and the public at large.

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8. REFERENCES

[1] S. Bull and J. Kay. Student models that invite the learner in: The SMILI:() open learner modelling framework. *International Journal of Artificial Intelligence in Education*, 17(2):89–120, 2007.

[2] K. Chrysafiadi and M. Virvou. Student modeling approaches: A literature review for the last decade. *Expert Systems with Applications*, 40(11):4715–4729, 2013.

[3] S. Gutierrez-Santos, M. Mavrikis, and G. Magoulas. Layered development and evaluation for intelligent support in exploratory environments: the case of microworlds. In *ITS2010*, pages 105–114, 2010.

[4] J. Hattie and H. Timperley. The power of feedback. *Review of educational research*, 77(1):81–112, 2007.

[5] I. Ibabe and J. Jauregizar. Online self-assessment with feedback and metacognitive knowledge. *Higher Education*, 59(2):243–258, 2010.

[6] ICILS. IEA International Computer and Information Literacy Study. 2013. https://nces.ed.gov/surveys/icils/about.asp.

[7] K. R. Koedinger et al. New potentials for data-driven intelligent tutoring system development and optimization. *AI Magazine*, 34(3):27–41, 2013.

[8] LIBE. Deliverable 4.1: Inventory of Open-Source Technological Solutions for E-Learning. http://libeproject.it/?page_id=47, 2014.

[9] LIBE. Deliverable 4.2: Inventory of Computerized Adaptive Testing Tools for E-Learning. http://libeproject.it/?page_id=47, 2014.

[10] LIBE. Deliverable 4.4: Report on effective feedback and formative assessment in e-learning. http://libeproject.it/?page_id=47, 2014.

[11] LIBE. Deliverable 6.3: Evaluation of LIBE e-learning delivery and student learning. http://libeproject.it/?page_id=47, 2015.

[12] J. M. Linacre et al. Computer-adaptive testing: A methodology whose time has come. *Chae, S., Kang, U., Jeon, E., Linacre, J.M. (eds.): Development of Computerised Middle School Achievement Tests, MESA Research Memorandum*, (69), 2000.

[13] S. Narciss. The impact of informative tutoring feedback and self-efficacy on motivation and achievement in concept learning. *Experimental Psychology*, 51(3):214–228, 2004.

[14] OECD. Low-performing students, why they fall behind and how to help them succeed. 2016. http://www.oecd.org/edu/low-performing-students-9789264250246-en.htm.

[15] OECD. OECD Skills Outlook 2013: First Results from the Survey of Adult Skills. http://dx.doi.org/10.1787/9789264204256-en.

[16] OECD. PISA 2012 Assessment and Analytical Framework: Mathematics, Reading, Science, Problem Solving and Financial Literacy. http://dx.doi.org/10.1787/9789264190511-en.

[17] P. R. Pintrich. A motivational science perspective on the role of student motivation in learning and teaching contexts. *Journal of Educational Psychology*, 95(4):667–686, 2003.

[18] P. R. Pintrich and D. H. Schunk. *Motivation in education: theory, research, and applications*. Upper Saddle River, NJ: Merrill Prentice-Hall, 2002.

[19] P. R. Pintrich, C. Wolters, and G. Baxter. Assessing metacognition and self-regulated learning. In G. Schraw and J. Impara, editors, *Issues in the measurement of metacognition*. Lincoln, NE: Buros Institute of Mental Measurements, 2000.

[20] D. Schunk and F. Pajares. The development of academic self-efficacy. In I. A. Wigfield and J. Eccles, editors, *Development of achievement motivation*. San Diego, CA: Academic Press, 2002.

[21] V. J. Shute. Focus on formative feedback. *Review of educational research*, 78(1):153–189, 2008.

[22] C. Timmers, J. Braber-Van Den Broek, and S. Van Den Berg. Motivational beliefs, student effort, and feedback behaviour in computer-based formative assessment. *Computers & education*, 60(1):25–31, 2013.

[23] C. Timmers and B. Veldkamp. Attention paid to feedback provided by a computer-based assessment for learning on information literacy. *Computers & Education*, 56(3):923–930, 2011.

[24] M. Webb, D. Gibson, and A. Forkosh-Baruch. Challenges for information technology supporting educational assessment. *Journal of Computer Assisted Learning*, 29(5):451–462, 2013.