DIAGNOSTIC TOOL AND ONLINE RESOURCE PROVIDING MATHEMATICS SUPPORT FOR NON-SPECIALISTS

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Abstract

We report on the development of a diagnostic tool to provide support for non-mathematics students. This tool has been designed to aid the transition onto university courses where mathematics is required during the course, but is not a pre-requisite. Our experiences in running espressoMaths (the university-wide mathematics support drop by station), in addition to discussions with academics from different faculties, highlighted the need for mathematics support at the University of the West of England (UWE, Bristol) across a broad range of abilities and applications. Students get very stressed and frustrated by their mathematical limitations affecting their studies. Our aim, in developing the diagnostic tool, is to better prepare such students for their studies so that they feel more supported in their transition to University and start at UWE with a stronger mathematical base.

Keywords: Diagnostic tool, e-assessment, e-learning.

1 INTRODUCTION

Making the transition from secondary school to university is challenging for many first year students, both personally and academically [1]. Finding effective ways of supporting students through this transition has long been a focus of research [2,3]. Lack of confidence has been identified [4] as one of the reasons some students find this transition difficult. High attrition rates have financial implications for first-year students who drop out mid-year and for the universities [5] and contribute negatively to league table positions [6].

Despite Mathematics A-level (the UK public examination normally taken at age 18) being the most popular subject taken [7], this qualification is not a requirement to study many quantitative courses in higher education [8,9]. For a variety of reasons, many students are entering higher education without the requisite mathematical competences needed to study such courses [10]. Osmon [11,12] conducted an investigation of the mathematical preparedness of students entering undergraduate courses requiring some mathematical knowledge beyond GCSE Mathematics (the UK public examination normally taken at age 16). As a remedy, many courses contain some mathematical "top-up" content [12].

In this paper we report on the development of a diagnostic tool and online resource to provide support for non-mathematics students. The aim of our work is to increase the mathematical ability and awareness of students prior to their starting at the University of the West of England (UWE) in subjects that require competency in mathematics at foundation and first year. The implementation of the diagnostic tool and online resource includes the use of UWE's in-house e-assessment system, Dewis [13], as well as the expertise of the Learning Innovation Unit [14]. Dewis has been used as the primary diagnostic tool and this provides additional feedback support in the form of signposting to learning materials based on areas that require attention.

We carried out an investigation into the mathematical requirements of students from the courses across all the faculties at UWE. The user logs from espressoMaths [15] (the university-wide mathematics support drop by station), pinpointed the UWE courses and specific areas of mathematics in which students currently require extra support. As a result of this investigation, two courses were identified to be in the pilot study, namely BSc Architecture and BSc Health Sciences. For each course a list of key mathematical topics has been identified and course-specific learning resources (instructional videos triggering additional information and Dewis questions as the video plays) have been created to supply a coherent learning mechanism for the different topics. It is anticipated that applicants, having access to this resource, will be confident about having applied to UWE, feel more supported in their transition to University and start at UWE with a stronger mathematical base.

2 METHODOLOGY

2.1 Preliminary steps

The first step in the project was to investigate the mathematical requirements of students from the programmes across all the faculties at UWE. This was done by data-mining the espressoMaths logs [15] and through discussions with UWE programme leaders of quantitative courses where a post-16 mathematics qualification was not a pre-requisite. This exercise allowed us to pinpoint the areas of mathematics in which students are perceived as requiring extra support and also where it would be beneficial for students to be more aware of the involvement of mathematics in their programmes. Aggregated espressoMaths data is illustrated in Fig. 1. It can be seen that Science students were the biggest users of the service followed by Health and Social Care. The topics that students required help with were also scrutinised and help with numeracy was the largest query category followed by algebra. The large number of numeracy queries was mainly from Nursing students who are required to pass regular numeracy tests as part of their training.

Subject	No. of visits
Science	280
Health & Social Care	169
Business	57
Built Environment	47
Not Specified	34
Accountancy	28
Economics	22
Other	22
Computing	16
Marketing	15
Humanities	10

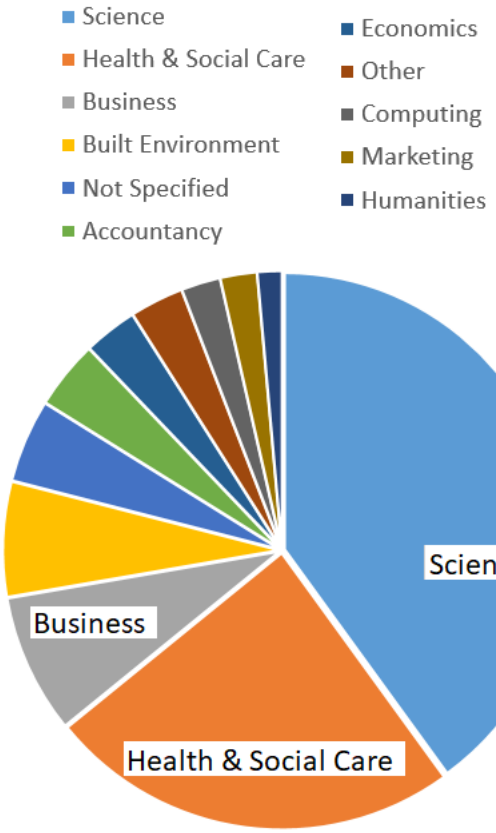

Figure 1: EspressoMaths attendance data, listed by subject area.

We identified two pilot groups of students, namely, those students taking the foundation route of the BSc Architecture award and Health Science Apprenticeships. For each of these two groups we identified a list of mathematical topics which were important for future success in the subject. For Health Science Apprenticeships, four mathematical topics were identified and these four topics were split further into sub-topics as illustrated in Table 1. The next step was to identify what support materials already existed in these identified mathematical topics. The project aims to re-use UWE support materials as much as possible, augmenting the content with external support materials (e.g. those available from the mathcentre site [16]) where required.

2.2 The Dewis e-assessment system

Dewis is a fully algorithmic open-source web-based e-Assessment system which was designed and developed at UWE. It was originally designed for the assessment of mathematics [13] and is now used in a wide range of subjects, such as Business Statistics [17], Nursing [18], Engineering [19] and Computer Science [20].

Table 1. Mathematical topics and sub-topics identified for Health Science Apprenticeships.

Topic 1: **Algebra** • Simplify Algebraic Expressions • Change the Subject of an Equation • Substitute Numbers into Equations • Solve Simple Equations	Topic 3: **Numbers** • Negative numbers • Fractions, Decimals and Percentages • Ratios, Proportion and Rates of Change • Standard Form • Converting Between Different Units
Topic 2: **Graphs** • Plot and Interpret Straight Line Graphs • Graphs involving distance, speed and acceleration	Topic 4: **Handling Data** • Rounding Numbers • Mean, Median, and Mode

Dewis uses an algorithmic approach, which enables the solution, marking and feedback algorithms to respond dynamically to a student's input and as such can perform intelligent marking [21]. In addition, the Dewis system is data-lossless; that is, all data relating to every assessment attempt is recorded on the server. This enables the academic to efficiently track how a student or cohort of students has performed on a particular e-Assessment [22]. Having been used at UWE and elsewhere for formative and summative e-assessments for over 10 years, a large number of feedback-rich Dewis questions exist covering a wide range of topics. Research [23] has shown that students learn from high quality e-assessment feedback. Students have found Dewis very useful to their learning in both mathematics-based subjects [24] as well as for non-mathematics specialist subjects, such as nursing [18].

2.3 Structure of the learning materials

We have constructed a web-based learning resource that has intelligent branching and provides decision trees to navigate the students through the resource. Dewis is used as the primary diagnostic tool, which then signposts the user to further online learning materials, as required. In particular, for each sub-topic, we created a corresponding Dewis e-assessment; most of the questions came from Dewis' extensive existing question bank but some questions were created specifically for this resource. The students' performance in this e-assessment will determine what additional material the students are directed to work through. An example of the structure of this additional material is shown in Fig. 2. We use Xerte as the vehicle for displaying this material [25]. We identified key skills required to complete each sub-topic successfully. For example, under the sub-topic of 'Algebra: Simplify Algebraic Expressions', we identified two key skills, namely simplifying linear and non-linear expressions. For each individual key-skill (in each sub-topic), we created a corresponding Xerte Learning Resource (XLR). Each XLR is a web browser tool containing partitioned regions that can interact with the user and each other. Each of the regions in an XLR can contain a learning resource such as, for example, instructional videos, e-assessments (Dewis or otherwise), text and images. Typically, on accessing the XLR students are directed to first watch a video (playing in the top left-hand box of the page). Key points can be communicated in the text area (in the bottom left-hand box of the page) and break points can be inserted into the video in order to add emphasis. Finally, having watched the video, students may practice the mathematical subject that they have just learned about, by testing themselves using the assessment (which appears in the right-hand side box of the page).

3 OVERVIEW OF RESOURCE

In this paper we shall give an overview of the resource as it has been set up for the Health Science Apprenticeships. Each course/programme has its own Programme Learning Resource (PLR) and the front page of the PLR for those students studying for Health Science Apprenticeships is shown in Fig. 3. Prior to entering the PLR front page, students have the option to access either anonymously or pseudonymously. If the latter is selected then the system records the student's performance, without knowing who the student is, and thus offers the option for the student to keep track of where they have

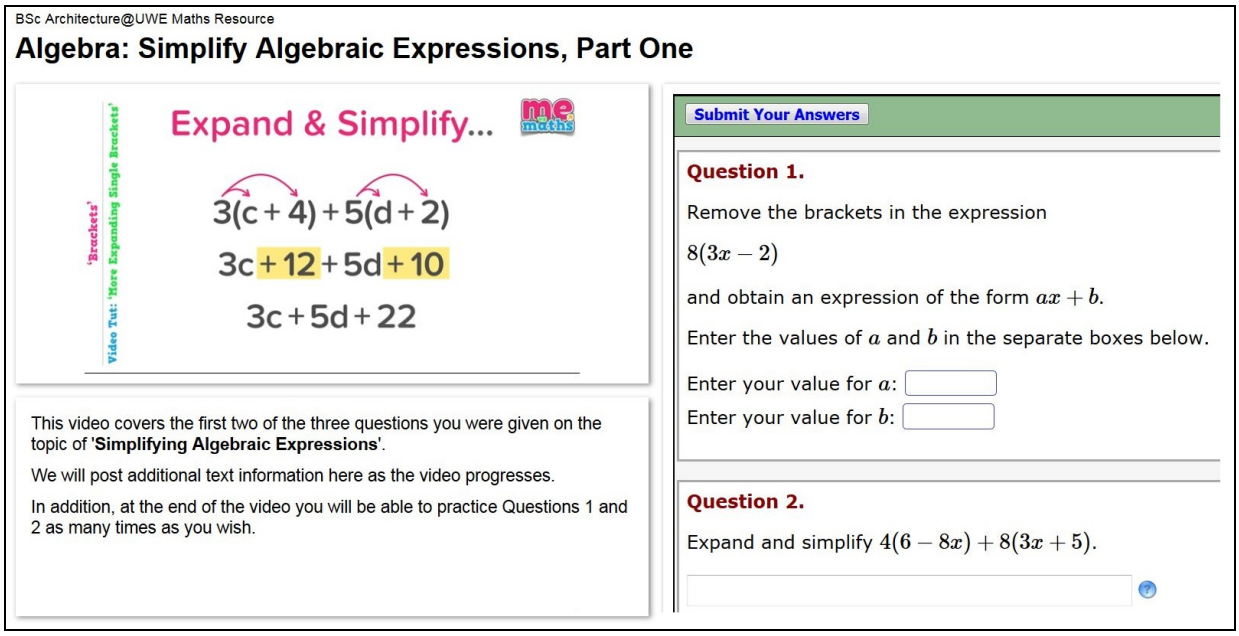

Figure 2: An example of a Xerte Learning Resource (XLR).

got to within the resource. This means that they can return to the resource at a later date and pick up where they left it. Also it enables them to publish their attainment record if they should so wish. Note that in Fig. 3 we have chosen to enter the PLR anonymously and so we have been allocated a username of *guest*. In this case, our progress will be stored only for the duration of the session; once the browser has been shut down all data for the session will be discarded.

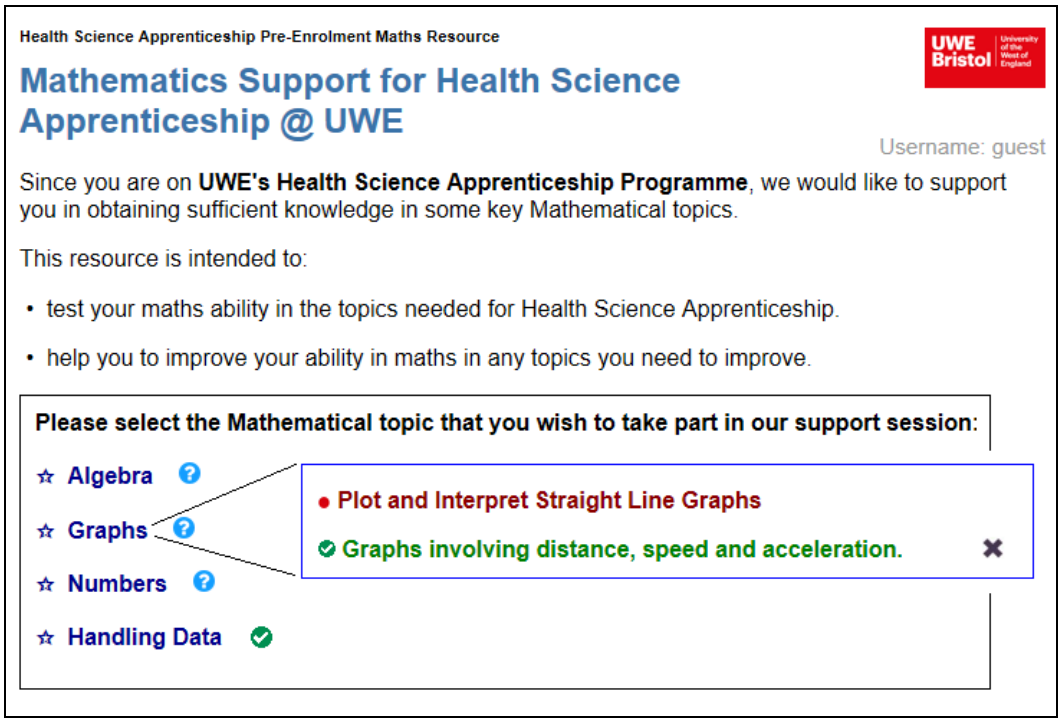

Figure 3: PLR front page showing topics.

For Health Science, four mathematical topics were identified (as listed in Table 1) and these form the front page of the PLR. Each of the topics is a link and on clicking on one of these topics, the sub-topics appear, as shown in the inset box in Fig. 3. When a student accesses for the first time, the links to these sub-topics are coloured red. This indicates that the activities associated with that particular sub-topic have not yet been successfully completed. On successful completion, this text becomes green, as shown for 'Graphs involving distance, speed and acceleration' in Fig. 3. The blue question mark icons indicate that the overall topic has yet to be completed and clicking on it will give brief

additional information about what is involved in each topic. If a topic has been successfully completed (that is all of its sub-topics are successfully completed) a green tick icon replaces the aforementioned blue question mark. This is shown in Fig. 3 for the topic of 'Handling Data'.

On clicking on a sub-topic, students are directed to start the corresponding e-assessment in order for the PLR to gauge their understanding of that particular subject. This, in turn will enable the system to guide them to further resources on that particular sub-topic depending on their performance. An example of such an e-assessment is shown in Fig. 4. In this case, two questions have been presented involving plotting and interpreting straight line graphs. Note that we have deliberately answered the first question incorrectly and the red box is due to a pre-submission verification check; the question asked for an answer to two decimal places, whilst an answer to three decimal places has been entered. Due to the algorithmic nature of Dewis, each time a student enters the test students are presented with different realisations of the questions.

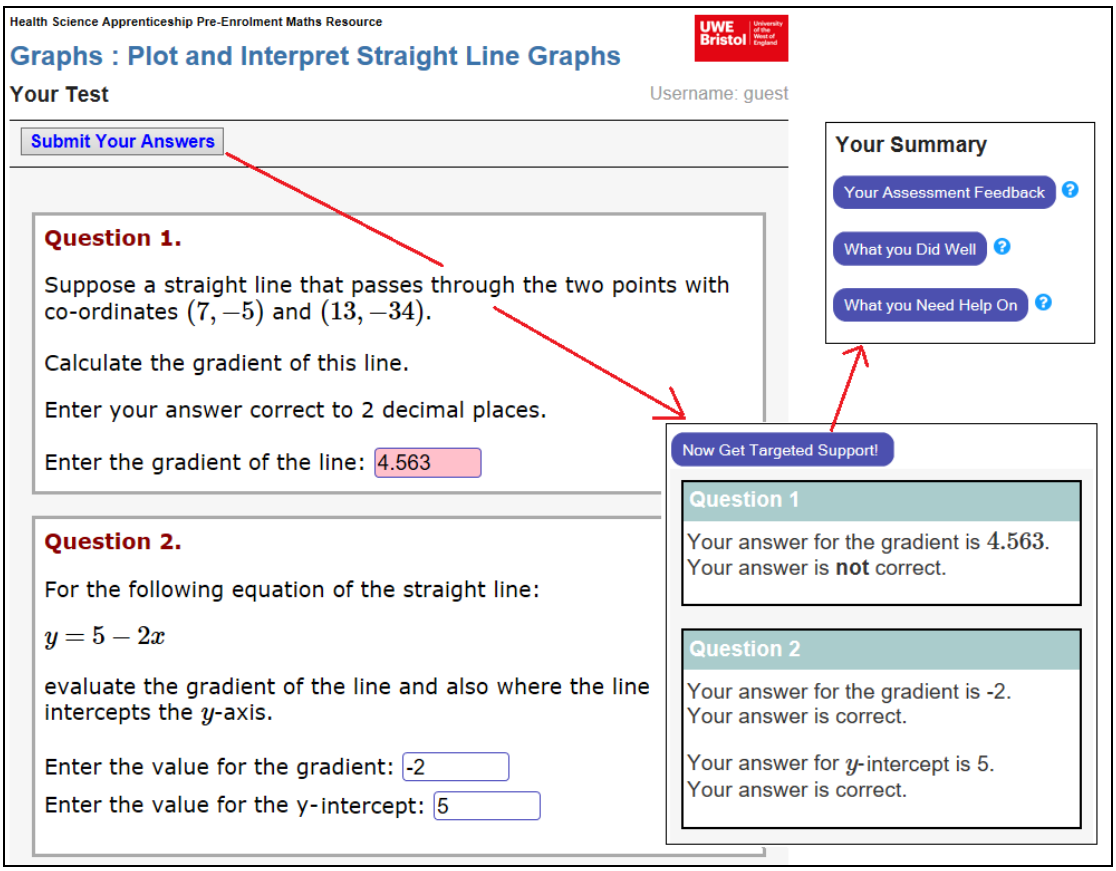

Figure 4: Sample Dewis e-assessment (left). The report received on submission (bottom right). The options available once targeted support is clicked (top right)

On submitting their answers, Dewis automatically marks the submission and students are presented with a report detailing how they did on the test, as shown in the bottom right of Fig. 4. Note that no marks are presented here, just statements as to whether they answered the question(s) correctly or incorrectly. The non-disclosure of marks is a deliberate feature of the PLR and the Dewis architecture had to be amended to accommodate this. We wanted to avoid the potentially de-motivating effect of students receiving low scores. Clicking on the 'Now Get Targeted Support' takes students to a Summary page, which contains three choices, as shown in the top right of Fig. 4. Again, students can click on the blue question mark icons for further information about each choice. In Fig. 5 we show an example of the e-assessment feedback, but for brevity only the Solution for each question is presented. Normally the question(s) that the student received, together with the report detailing how they did on each question is also included.

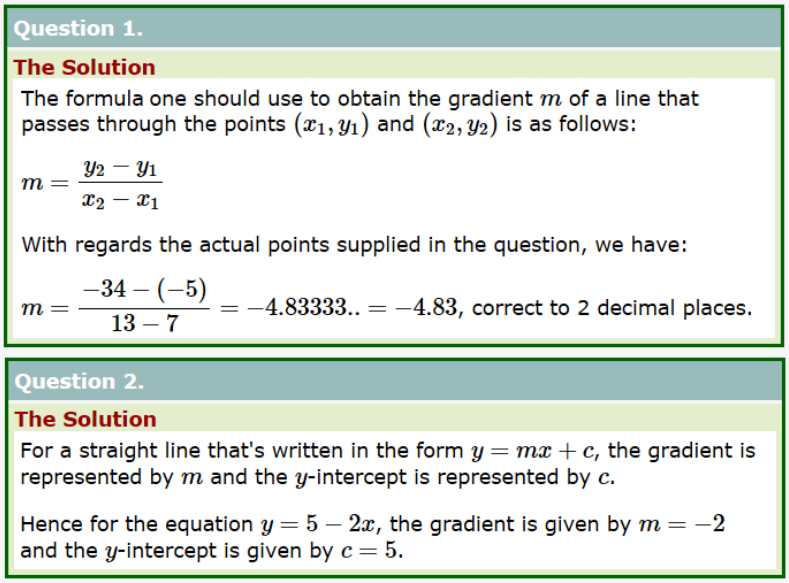

Figure 5: Sample Dewis e-assessment feedback (solution only is displayed).

Upon clicking on the 'What you did well' tab, students are presented with a dropdown box similar to that displayed in Fig. 6. Note that for this particular sub-topic, namely 'Plotting and Interpreting Straight Line Graphs' we have identified two key skills within the sub-topic. These skills are:

1. To be able to obtain the gradient and y-intercept from the equation of a straight line;
2. To be able to obtain the gradient of a line passing through two points.

The Dewis e-Assessment presented to the student, as displayed in Fig. 4 happens to be partitioned such that each question assesses just one of these skills. However it is possible to have more than one question testing the same skill and for one question to assess more than one skill. Because we answered Question 2 of the Dewis e-assessment correctly we have been deemed to be competent with obtaining the gradient and y-intercept from the equation of a straight line. As a result we have been given a green tick icon for this skill. Although it has not been deemed necessary for the student to do any additional work on this skill, they may still choose to access the additional learning material by clicking on the blue information icon. Doing this will take the student to the XLR created for that particular skill. This comprises a standardised form in Xerte as described in Section 2.3.

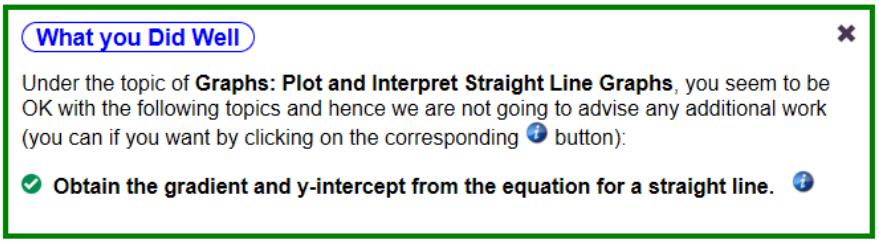

Figure 6: Sample of what appears when clicking on the 'What you did Well' tab from the Summary page.

Upon clicking on the 'What you Need Help On' tab as shown in Fig. 4, students are presented with a dropdown box similar to that displayed in Fig. 7. Here, students are advised as to the skills they need extra help on. They have the option of clicking on the Additional Help tab in order to access the XLR associated with that particular skill. This takes the standardised form in Xerte as described in Section 2.3. Once students have accessed the material in this XLR the Additional Help button turns green and students are recommended to have another assessment attempt. Alternatively students are able to have another attempt at the Dewis e-assessment, prior to accessing the additional help. For both additional assessment attempt routes, students will be given new versions of the questions shown in Fig. 4. However, because this particular Dewis test assesses two skills, and the student has been deemed to be competent in the first skill, they will be given the option of choosing to have the input boxes to the Dewis question(s) associated with skill 1 to be automatically populated with the correct answers. The rationale for this approach is that students can thus concentrate on the mathematical

skills that they need the most support on. Once a student has successfully answered all the questions in the Dewis test correctly they are deemed to have successfully completed a sub-topic. The text for that sub-topic turns green (as in Fig. 3) and students may move onto a new area as they wish.

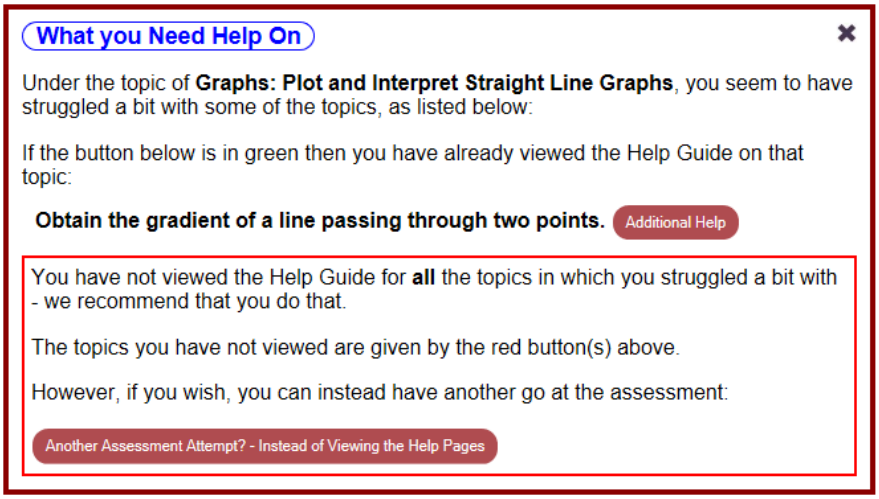

Figure 7: Sample of what appears when clicking on the 'What you Need Help On' tab from the Summary page.

Once students have successfully completed all the topics they have the option of printing out a completion certificate, which can be forwarded to their tutor for confirmation.

4 IMPLEMENTATION AND EVALUATION

The resource will be trialled on the Foundation Year students of BSc Architecture in the first semester of 2019/20 and the January 2020 intake of the Health Science Apprenticeships. The evaluation process will involve three approaches. All users of the pilot of this resource will be asked to evaluate the resource. This will take the form of a short questionnaire accessed at the end of each topic as well as sending out an e-survey. At the end of this evaluation process we will interview the programme leaders that have engaged with the project, in order to gauge the impact it has had on their students as well as to gather suggestions for future developments. We will also investigate the Dewis e-assessment data – this data will be partitioned into programme-based cohorts to determine student usage and their competencies. A long-term analysis of student performances can be employed by studying 'common student errors' [26,27] and feeding these results back into the feedback/signposting mechanism.

5 DISCUSSION AND FUTURE WORK

The output of the project is an on-line resource/diagnostic tool to provide mathematics support to students where mathematics is not a course requirement. Currently it has been developed for two courses run at UWE and will be trialled in the 2019/20 academic year to existing students. Following the evaluation of the resource as detailed in Section 4, we plan to improve the resource and make it available to applicants to those courses. The expectation is that applicants, having access to this resource, will be confident about having applied to UWE, feel more supported in their transition to University and start at UWE with a stronger mathematical base. Student engagement in academic study has been identified as a key contributor to student success [4]. As a result, we anticipate that the project will have a positive impact on retention as well as on recruitment and continuation rates. There has been considerable interest in developing the resource for other courses at UWE and a future direction is to consider the best ways of presenting appropriate, and in-context, material to different student cohorts.

ACKNOWLEDGEMENTS

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