

USING E-ASSESSMENT TO IMPROVE NUMERACY IN PRE-REGISTRATION NURSES AND MIDWIVES

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Abstract

Numeracy is a core requirement for all pre-registration nursing programmes studying in the U.K. At present each nursing discipline at the University of the West of England, Bristol provides their students with a numeracy booklet which they are expected to work through in their own time. This booklet is intended to prepare them for the compulsory numeracy tests which all students must pass in their first and final years in order to progress with their degree. Students have access to some additional resources, however many students are still very anxious and lack confidence in numeracy.

In order to provide additional support we created a suite of numeracy questions using the university's DEWIS e-Assessment system. The numeracy resource created contains questions covering general numeracy, calculations relating specifically to Child Nursing and typical numeracy in nursing calculations (e.g. drug calculations, drop rates etc.) This was initially trialled on a particular cohort of nurses in April-May 2012. The algorithmic nature of DEWIS allows for question generation, at each assessment attempt, to be performed dynamically as opposed to selecting a question for instance from a question bank. In such a process, the question parameters (keywords and numerical values) are generated randomly within certain constraints. Another key difference is that, on submitting their answers, students see a fully worked solution to each question. This feedback enables students to gain confidence and refine their techniques. Following positive feedback the numeracy resource was rolled out to a greater number of nursing awards for the following academic year.

Students were invited to leave feedback on the DEWIS numeracy resource after each attempt. This feedback has been overwhelmingly positive and has enabled us to improve the resource, for example enabling access from mobile devices and clearer instructions on whether a calculator may be used on certain questions. Analysing student performances on their official numeracy tests has enabled us to measure the impact that the DEWIS numeracy resource has had on students' numeracy.

Keywords: e-Assessment, numeracy, nursing.

1 INTRODUCTION

Nursing is currently facing significant change and modernisation. Since 2013, in the U.K., it has been a requirement that all new nurses are educated to degree level [1], [2] and this was achieved at the University of the West of England, Bristol (UWE) in 2011. In addition, the changing policy context demands a highly skilled work force that is able to manage increasing complexity within health and social care settings. Numeracy is a core requirement for all pre-registration nursing programmes and has professional regulations that demand a first and final year successful assessment [3], [4].

Numeracy is an essential skill that directly impacts on patient safety. Increasing technologies, medicines and treatments in nursing require high levels of numeracy and it is suggested by stakeholders that these skills are often under developed for some nursing staff. Nursing draws upon a number of different art and science theories associated with caring and compassion and continues to develop numeracy skills related to nursing practice.

All nursing students at UWE are required to pass a numeracy test in their first and third years. In addition, some nursing awards have compulsory numeracy testing in the second year as well. Numeracy isn't a formally taught; each nursing discipline at UWE (e.g. adult nursing, mental health nursing) provides their students with a numeracy booklet. Students are encouraged to independently work through these numeracy booklets, use the numeracy Skills webpage [5] and visit espressoMaths, the University's drop-by Mathematics support service [6] in order to prepare for the compulsory tests. Despite this, many students are still very anxious about and lack confidence in numeracy.

In order to provide additional support to students we developed an on line numeracy resource. This allows students to self-assess their mathematical skills and the value of using this approach is that it

enables the student to self-evaluate their knowledge using mathematics as the foundation for applied clinical practice.

2 BACKGROUND

2.1 Numeracy testing at UWE

The compulsory numeracy tests used at UWE were created over ten years ago and consist of a bank of 500 static multiple choice questions, covering 20 topics. The test, as presented to the student, contains 25 questions, where each question is selected randomly from the bank of questions for each topic. The multiple choice questions always contain exactly four choices and each question is equally weighted. It is accessed through the Blackboard Virtual Learning Environment (VLE). On completion, there is an indication of which questions were answered correctly/incorrectly. The correct answer is displayed but no feedback, for example in the form of model solutions, is provided. Students in their first year must score at least 75% and students in their third year must score at least 84%. Up until a year ago, students were able to have a maximum of six attempts at the test per year and could access the tests in their own time. The policy changed for 2014/15, in that students were given as many attempts as they wanted at the numeracy tests for formative purposes but had to sit the official test under controlled conditions and pass to progress with their studies.

2.2 The DEWIS e-Assessment system

2.2.1 Overview

The DEWIS e-assessment system was created by a team of developers at UWE and supports an algorithmic approach to question generation, marking and feedback, all within a server based system [7], [8]. It is a completely stand-alone web based system used for both summative and formative assessments. It was primarily designed for numerate e-Assessments and is currently used in the fields of Business, Computer Science, Nursing, Engineering and Mathematics. This algorithmic approach enables the separate solution, marking and feedback algorithms to respond dynamically to a student's input and as such can perform intelligent marking [9], [10]. As such, the system enables an individualised approach whereby, through extensive, specific feedback the student can self-evaluate, identify and rectify their knowledge level.

Feedback from students at UWE using DEWIS has been extremely positive. For example, students in the first year of their Mathematics degree praised the tests that they were receiving stating that receiving instant detailed feedback early on in the course was invaluable. They expressed the wish that more modules adopt the system. On a second year Engineering module at UWE students were asked to compare their experience of DEWIS tests with tests using a different system (QuestionMark Perception), which they experienced in their first year. Universally they said that the new style of tests were superior. In a recent module evaluation of the e-assessments on the first year Engineering module at UWE, 70% found the tests "very useful" and 13% found them "quite useful". We have also found that DEWIS has had a positive impact on students' engagement, marks and progression in Engineering Mathematics [11].

2.2.2 Questions

The DEWIS system supports a number of different question types. These include numerical input (integer and floating-point), multiple choice, dropdown selection, multiple response, text input, algebraic input and matrix input. A given question can contain a mixture of such types. In this paper we shall show questions involving the first three input types listed above; a selection of all these different question types is available at the DEWIS web-site [7]. In an e-Assessment, the input by the student can be checked by the system for validity prior to submission of the answers. Hence, for example, the input of text where a numerical input is expected can be flagged to the student prior to submission.

An example of a basic numeracy question in DEWIS is shown in Fig. 1 which requires one numeric entry. Using the algorithmic approach, the question as presented in Fig. 1 is generated by a single question-style, as opposed to being selected from a static bank of questions. In each realisation of the question the following parameters are randomly generated:

- Type of milk: (whole, semi-skimmed, skimmed, flavoured)

- Quantity asked for: (calories, grams of fat, grams of protein, grams of carbohydrates, milligrams of Calcium, percentage of the RDA of Calcium)
- Quantity of milk supplied: (110,120,...,250)ml

The nutrition information is pre-determined by the randomly selected type of milk, in this case semi-skimmed milk. The precision, to which the question should be answered to, is predetermined by the quantity asked for. Note that DEWIS performs pre-submission checks; in this case an answer of 23.65 has been entered. The student is warned that this answer is not to the required precision by this input box turning red and the following message: "Your entered answer has 2 decimal places but we requested an answer to 1 decimal place." This is an example of a student-friendly feature that has been added due to feedback from students using the system.

Question

The table below shows the calorie and nutrition values (per 100ml) for semi-skimmed milk.

Nutrition information	
Typical values	Per 100ml
Calories	47 kcal
Protein	3.6 g
Carbohydrates	4.8 g
Fat	1.8 g
Calcium	124 mg

Note that 100ml of semi-skimmed milk provides roughly 15% of the recommended daily allowance (RDA) of calcium for a healthy adult.

How many grams of fat are contained in a 240 ml glass of semi-skimmed milk? Enter this number in the box below, giving your answer correct to the nearest tenth of a gram.

23.65 g

Figure 1: An example of a numeric entry question in DEWIS. Note that the answer of 23.65 has been entered for illustration purposes.

Some of the key advantages of this algorithmic approach over the static bank of questions method are:

- For each question-style only one question file is required. Provided the programming is correct, there is a guarantee that the calculated solutions are correct;
- Alterations to the question-style require only one piece of question code to be edited (as opposed to alterations to multiple questions in a question bank). Minor alterations to questions are often required as part of the continued question-improvement process. For example, improvements to feedback may be made following reflection on the efficacy of a given assessment.
- The marking and feedback algorithms are computer programs that treat the student's input as a variable within the programming environment. As such the system provides a mechanism to generate feedback specific to the student's input;
- The number of potential questions generated per question-style is typically large – limited only by the range of the question parameters;
- Questions can be reverse engineered to enforce, for example, integer solutions if required.

When the student submits their answers, the marking is executed immediately on the server, and the student sees the results of the marking together with a link to the feedback. This feedback is specific to the questions the student was supplied with and the answers the student gave. An example of such feedback for the question shown in Fig. 1 is given in Fig. 2 in response to the student's answer of 23.65. Normally, the feedback includes a copy of the original question but this has been omitted here to save space. Having access to full, bespoke feedback is an important feature of an e-Assessment system since it has been found that students learn from e-Assessment feedback, using it to perfect

their technical knowledge [12]. There is also evidence that students find the availability of practice tests to be one of the most useful study resources which supports their learning [13]. An additional feature of DEWIS is that students may access the feedback pages for all of their previous attempts at any subsequent time. Such a feature is possible since data for all assessment attempts is saved on the DEWIS server so that the full reporting of any assessment attempt is reproducible.

The Solution

From the nutrition information table, we see that there is 1.8 g of fat per 100ml of semi-skimmed milk.

So in a 240 ml glass there will be

$$\frac{1.8}{100} \times 240 = 4.32 \text{ g}$$

which rounded to the nearest tenth of a gram means that there is 4.3 g of fat in 240 ml .

Therefore, the answer is 4.3.

The Report

Your answer (23.65) for the question is incorrect.

You scored 0 marks for this question.

Figure 2: Feedback, as shown to the student, for the question displayed in Fig. 1.

2.2.3 Reporting

The DEWIS system has an extensive reporting mechanism for academics to track the progress of an assessment. Included in the Reporter is information about every assessment attempt, containing the question parameters and corresponding solutions, the answers submitted and the result of the marking process. Fig. 3 illustrates how academics may easily view how a cohort is doing on an assessment, in this case viewing the mark awarded for each individual question in the test. Each mark is a web link, which contains the realisation of the particular question delivered to that student, their submitted answers and the resulting feedback given to them. This integrated reporting facility may be used to monitor student engagement [11] and inform our understanding of students' issues with particular questions. Through the reporting facility, we can analyse responses to each question asked and spot common errors (mal-rules) made by the cohort [10]. This enables us to systematically improve the question database and is an ongoing project. For example in the question presented in Fig. 3 the question asks the student to convert 50 milligrams to micrograms. An incorrect response would be for the student to enter 0.05 instead of 50000. For this particular question, this common student error of dividing by 1000 instead of multiplying by 1000 has been coded into the question. On triggering this error, the bespoke feedback, as shown in Fig.3 is displayed. This highlights to the student exactly what they did wrong and how to correct it in the future.

The DEWIS reporter may also be used to show all marks awarded to a particular student or cohort and also highlights the maximum mark for each student over multiple attempts. All log-ins to the system are recorded, including the client machine's IP address.

2.2.4 Additional features

We have already mentioned a number of features of the DEWIS system that are aimed at improving the students' experience of e-Assessment. These include pre-submission checks of the integrity of the student's solution and access to feedback on all previous assessments. In response to students and academic requests other recent features include:

- the ability for a student to continue an assessment even after they have closed down their browser/computer;
- warning messages against students wanting to browse away from the assessment window;
- network-down recovery systems to allow students to submit answers even if their computer's network has been disabled;

- re-marking facility so that, for example, if an improvement is made to the feedback/markings algorithms, these algorithms can be applied retrospectively to previous assessment attempts;
- ability to view marks reporting for a sub-set of students within a specific cohort, for example a tutorial group or a list of 'at-risk' students.

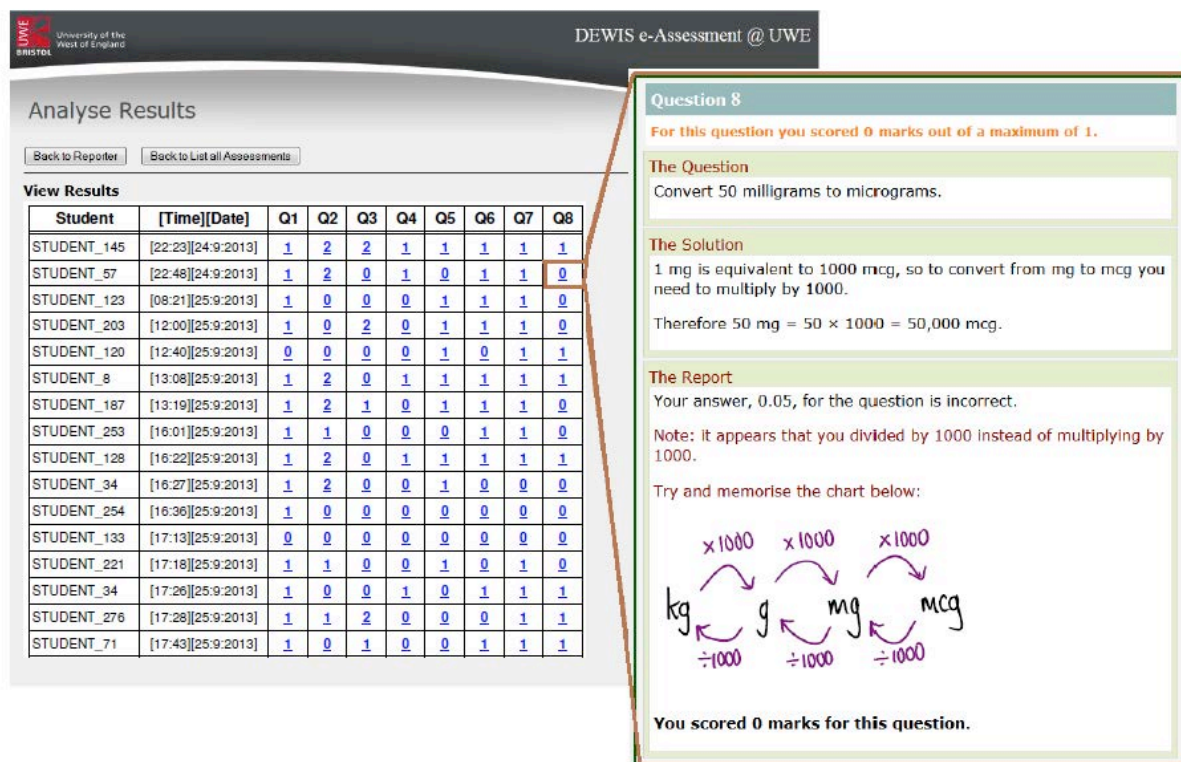


Figure 3: *Left:* An example of the Reporting feature of DEWIS. Note that only a selection of results is displayed here and student details have been anonymised. *Right:* An illustration of the full and bespoke feedback that students receive on each question.

3 METHODOLOGY

In order to provide additional numeracy support for pre-registration nurses and mid-wives at UWE we created a suite of numeracy questions using the DEWIS e-Assessment system. The numeracy resource created contains questions covering general numeracy, calculations relating specifically to Child Nursing and typical numeracy in nursing calculations (e.g. drug calculations, drop rates etc.) This cross-faculty project was initially funded through the HE STEM grant 'An interactive, online numeracy resource for pre-registration student nurses and midwives' in 2011 and then through a UWE Teaching & Learning grant in 2012. Because of the algorithmic nature of DEWIS, each time the student attempts these practice questions they see a different set of questions. Another key difference is that, on submitting their answers, students see a fully worked solution to each question. This bespoke feedback enables students to gain confidence and refine their techniques.

The numeracy resource had been trialled on a small group of students from April-May 2012 and although limited, the feedback was overwhelmingly positive. That gave us the impetus to roll the resource out to a larger group of nursing students. In particular we wanted to gain further student feedback on the numeracy resource which would in turn enable us to improve the resource accordingly. In order to achieve this aim, nursing discipline programme managers were approached in April 2013 and the numeracy resource was made accessible on seven VLE modules from the summer of 2013. An illustration as to how the students access the DEWIS practice numeracy test is shown in Fig. 4.

Although different access methods are available, such as to use bespoke DEWIS passwords, grant anonymous access, we decided to set up a SCORM package so that students would be automatically granted access to the test through the VLE. The advantage of this approach is that students do not

need to enter their username/password to access the test; this is automatically passed to DEWIS from the VLE. Additionally we have a record of how each student performs, which would not be possible using anonymous access. This is necessary in order to measure the impact that DEWIS has on their official numeracy test scores.

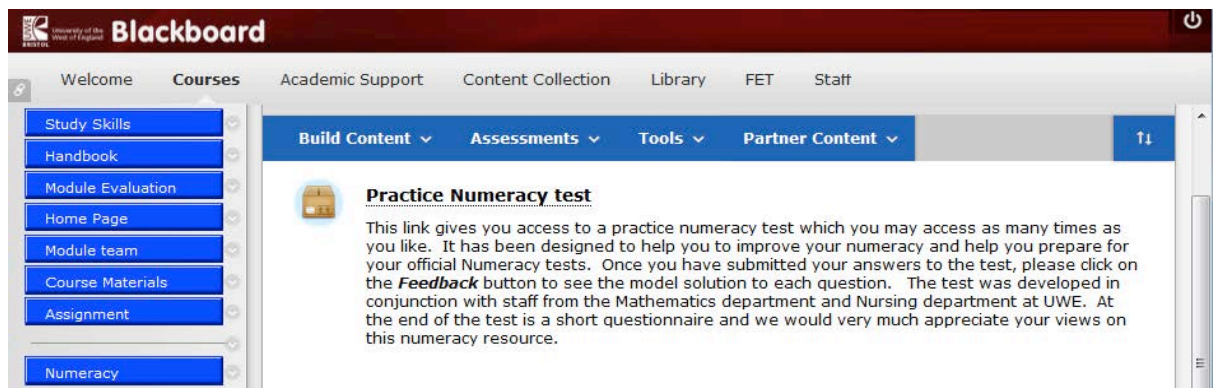


Figure 4: An example of how the front page of the practice numeracy test appears to students in the VLE, when they click on the Numeracy tab from Blackboard.

For Child Nursing students, the test contains 15 questions covering general numeracy and calculations relating specifically to Child Nursing. For all other disciplines, the test contains 13 questions covering typical numeracy in nursing calculations (e.g. drug calculations, drop rates etc.) Realisations of two questions used in the DEWIS numeracy tests are shown in Fig. 5. The first question is an example of a multiple choice question which involves a drug calculation for drugs in liquid form. The second question is an example of a dropdown selection question, involving a drug calculation for drugs in tablet form. Again both of these questions uses random variables, in that the drug name, dosage and stock strength are randomly created each time the question is asked. It was felt that it was important to use real drug names and the correct stock strength of such drugs together with feasible doses: We are grateful to several prescribing pharmacists at UWE for help with supplying us with realistic drug information data. Question 2 is an example of a question which is reverse-engineered, in that the answer (half, one, one a half, two, three, four) tablets has been randomly chosen first and using this the dosage thereby calculated (in this case 20mg) to be displayed in the question.

Question 1.

A prescription chart requires that you give 175 mg of Ibuprofen liquid. The stock bottle strength is 100 mg in 1 ml. Calculate how many ml you need to give, correct to 2 decimal places.

☐ 4.73 ml
☐ 9.45 ml
☐ 6.09 ml
☐ 1.75 ml
☒ not answered

Question 2.

The prescription chart states you need to give 20 mg of Prednisolone. The stock bottle contains 5 mg tablets. How many tablets would you administer?

Select the number of tablets: Select

Select
 Half a tablet
 One tablet
 One and a half tablets
 Two tablets
 Three tablets
 Four tablets

Figure 5: A realisation of two of the DEWIS numeracy questions used by the nurses at UWE.

In order to encourage students to trial the resource we offered ten £10 Amazon vouchers to students who attempted it by 31st October 2013. By offering this incentive we were able to collect some early results. Typically, nursing students find numeracy off-putting/challenging and since they did not have to pass the official numeracy test until the end of the academic year, many students delay working towards it. Over the initial assessment period of four months, a total of 283 students had trialled the resource and the ten winners were selected from these students.

4 RESULTS

4.1 Overview

We report on results collected for those students who took just the general test (i.e. not the Child one) over the period 19/09/2013 to 18/09/2014. There is not a common academic year shared by all nursing students at UWE, so a period of a calendar year seemed to be the most suitable to consider. Over this period, there were 2,631 attempts at the practice test by 559 students. That is, just over half of students who had access to the numeracy test made use of it in this period. In Fig. 6 we show the number of attempts at the DEWIS practice test by students. We can see that just over a quarter of the students attempted the test once; however the majority of students attempted the test at least three times. The average mark of all the attempts was 73% and the average of the highest mark achieved by each student was 85%.

Considering only submissions in which that particular question was answered, we found that, the average score achieved by students on Questions 1 and 2 displayed in Fig. 5 was 97% and 92% respectively. These two questions were the ones that students scored best on. Interestingly, when Qn 1 of Fig. 5 was asked as a numeric entry style question, the average score scored on it decreased to 79%. This supports the anecdotal evidence that multiple choice questions are easier. A possible improvement of future multiple choice questions would be to add a fifth choice of “None of the above”, making sure that this is the correct response in some of the realisations of the question and/or to penalise for incorrect answers. For example, in multiple choice questions, negative marks could be awarded for an incorrect choice and zero marks if the question is not answered. This marking scheme has been adopted in a statistics DEWIS assessment, in which some of the questions involved Yes/No selections, in order to discourage guessing [14].

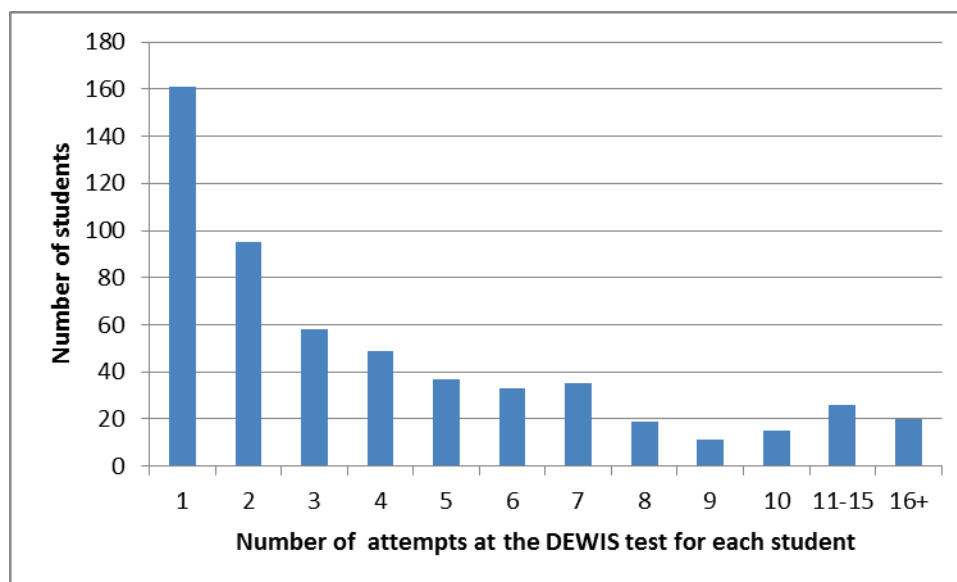


Figure 6: Number of students using DEWIS against the total number of attempts at the DEWIS practice test by each student.

The two questions which students scored worse on (66% and 68%) were both numeric entry, multi-part questions: The first part of each involved drug calculations in liquid form and the second followed on from this. The single input question which student scored worst on (69%) was the question displayed in Fig. 1.

4.2 Questionnaire

All students taking the test were invited to leave feedback on the online numeracy resource, through an online questionnaire which was available at the end of each test attempt. The questions asked and the responses received are shown in Table 1. This data is compiled from the 289 completed feedback questionnaires which were submitted between 19/09/2013 and 18/09/2014.

Table 1: The questions asked in the questionnaire, together with the responses received.

Question	Yes (%)	No (%)	N/A(%)
<i>Do you feel confident about your numeracy skills?</i>	49.5	48.4	2.1
<i>Did you complete all the questions in the time allowed?</i>	94.1	3.1	2.8
<i>Did you need to use any support materials (e.g. books, calculators or web-based material) to complete the questions?</i>	78.2	18.7	3.1
<i>When answering questions incorrectly were you able to determine where you made mistakes?</i>	88.6	7.6	3.8
<i>Did this test help you understand numeracy processes?</i>	92.4	5.2	2.4
<i>Was the test easy to access?</i>	87.5	9.7	2.8
<i>Was the test easy to use?</i>	95.5	2.1	2.4

The final question asked: "Have you any suggestions as to how this e-assessment could be improved?" There were 64 responses, 23 of which were very positive. For example:

- "This is a really fantastic idea, it has helped explain exactly where the mistakes are that I have made."
- "Hooray – It's taken me 4 attempts to score 100% from an initial score of 54% so this method of Numeracy assessment has really improved my numeracy skills in a relatively short time. Fabulous resource. More of these please! Thank you"

Other suggestions for improvements, made by more than one student, are categorised as follows:

- Request for more questions/greater coverage of the real numeracy test [17 students]
- More clarity on the number of decimal places to enter answers to and/or whether a calculator is allowed. [8 students]
- Would prefer to be able to access from Ipad/mobile devices [8 students]
- Misunderstanding of some of the features of DEWIS. [5 students]

The feedback has been overwhelmingly positive. When looking at the responses in Tab. 1, the first thing to notice is that approximately half the student responses had confidence in their numeracy skills. Nearly all the students reported that they were able to complete the questions in the time available (2 hours). Note that, for the official numeracy tests, the students must complete 25 multiple-choice questions in 2 hours. The majority of students made use of supporting material when accessing the test. In the old compulsory testing regime at UWE, students took the compulsory test in their own time, so would be able to access materials while doing it, however this is no longer allowed since they must now take the compulsory test under controlled conditions. Only 7.6% found that they were not able to determine where they made mistakes. We would hope that this number could be reduced further by adding bespoke feedback for common student errors [10]. However a high proportion of students found that the DEWIS test helped them with their numeracy processes. Nearly all respondents found the system easy to use. A few students did not find the test easy to access (9.7%) which may have been due to that particular release not being accessible on all internet browsers. The questionnaire responses have enabled us to improve the resource, more clarity is now given on whether a calculator may be used on certain questions and the test is now accessible from mobile devices.

4.3 Impact of DEWIS

In this section, we analyse student performances on their official numeracy tests in order to allow us to measure the impact that the DEWIS numeracy resource has had on student's numeracy. The first point to note was that of the 551 students who took the DEWIS practice numeracy test only 183 of these students have registered an official numeracy score since 18/9/2013. This is due, in part, to the different award structure in the Nursing degrees at UWE, whereby all students do not experience the same academic year. We calculated the highest mark achieved in the official numeracy tests for those students who made use of the DEWIS numeracy resource compared to the highest mark achieved by the cohort, on a year by year basis and our results are presented in Table 2.

Table 2: The average value of the highest official score achieved by students on their official numeracy test for each year of study if they accessed the DEWIS numeracy resource compared to the whole cohort of students.

	Year 1	Year 2	Year 3
Accessed DEWIS	85.5%	85.7%	88.9%
Whole cohort	83.7%	85.9%	86.8%

We can see that for students in years 1 and 3 who accessed DEWIS, there has been a positive impact in their highest official score, when compared to those achieved by the whole cohort. However, we find that there is very little difference for students in Year 2. Aggregating the data over all the years, we find that the average of the highest scores of the whole cohort is 86.2% and this increases to 86.4% for the students who accessed DEWIS.

Table 3: The average value of the highest official score achieved by students on their official numeracy test compared to the number of times they accessed the DEWIS numeracy resource.

Number of attempts at the DEWIS resource	1	2	3	4-5	6-9	≥ 10
Average highest official numeracy test score	86%	91%	89%	83%	82%	78%

In Table 3 we can see that students who accessed DEWIS the most times (10 or more) had the lowest highest test score average at 78%. One explanation is that this group contained a significant proportion of students who are aware that their numeracy is weak and are making use of available resources in order to practice at it. In fact we find that the group of students who did best were those that accessed DEWIS exactly twice. Students accessing DEWIS between one and three times recorded a higher official score than those who did not access DEWIS and those that accessed DEWIS four times or more.

This analysis seems to indicate that the practice numeracy resource has had a positive impact on students' official numeracy scores, however it is difficult to draw conclusive statements given the small numbers involved and the absence of an unbiased control group to test against.

5 CONCLUSIONS AND FUTURE PLANS

The DEWIS numeracy resource has been well-received by students, as evidenced through questionnaire responses and the number of students using it more than once. The resource was trialled by approximately one tenth of all the students studying nursing at UWE. Preliminary results indicate that using DEWIS has a positive impact on students' official numeracy results.

One of our future aims is to improve the resource, primarily by increasing the number of questions in each test, to better reflect the range of topics covered in their official numeracy test. Once this has been achieved we plan to make the numeracy resource available to more nursing students at UWE.

This will initially impact on the pre-registration nursing programmes, (adult, child, mental health and learning disabilities). However, with students developing and using these enhanced numeracy skills in

practice, other nursing groups will be influenced by this initiative. The demand for competent numeracy skills is not solely for pre-registration students, it is required across the healthcare professions. Consequently, although this work was directed mainly at nursing students, there is future potential for use in health care organisations and in nursing continuing professional development (CPD) programmes. It should also be noted that UWE has a large partnership base with a diverse range of further education organisations and health care providers while, and is currently the South West centre for all learning disabilities education. Thus the development and promotion of this work may have a far reaching impact across the South West locality.

REFERENCES

- [1] Department of Health (2008) A high quality workforce. NHS next stage review.
- [2] Nursing and Midwifery Council (2008) Developing new standards for nursing education in the UK.
- [3] Nursing and Midwifery Council (2006) Standards of proficiency for nurse and midwife prescribers.
- [4] Nursing and Midwifery Council (2010) Standards of Pre-registration nursing education.
- [5] Numeracy Skills: <http://learntech.uwe.ac.uk/numeracy/> (accessed 19/05/2015)
- [6] Henderson, K. and Swift, T. (2011) espressoMaths: A drop-by station. MSOR Connections, 11(2), pp. 10-13.
- [7] DEWIS welcome page: <http://www.cems.uwe.ac.uk/dewis> (accessed 19/05/2015)
- [8] Gwynllyw, Rh. and Henderson, K. (2009). DEWIS: a computer aided assessment system for mathematics and statistics. CETL-MSOR 2008 Conference Proceedings, pp. 38-44.
- [9] Gwynllyw, Rh. and Henderson, K. (2012). Intelligent marking in summative e-assessments. Proceedings of the HEA STEM Learning and Teaching Conference.
- [10] Walker, P., Gwynllyw, Rh. and Henderson, K. (2015). Diagnosing student errors in e-assessment questions. Accepted for publication in Teaching Mathematics and its Applications.
- [11] Henderson, K., Gwynllyw, Rh., Hooper, A. and Palipana, A. (2015). Using e-Assessment to Promote Engagement in Engineering Mathematics. Proceedings of the IMA International Conference on Barriers and Enablers to Learning Maths.
- [12] Greenhow, M. and Gill, M. (2008). How effective is feedback in computer-aided assessments? Learning, Media and Technology 33(3), pp. 207-220.
- [13] McCabe, M. (2009). The exponential growth of mathematics and technology at the University of Portsmouth. Teaching Mathematics and its Applications 28(4), pp. 222-227.
- [14] Gwynllyw, Rh., Weir, I. and Henderson, K. (2015). Using DEWIS and R for multi-staged statistics e-Assessments. Submitted to Teaching Mathematics and its Applications.