The purpose of this mini-project was to investigate the wider use of DyscalculiUM, which is a first-line screening tool for dyscalculia in HE and to further develop and evaluate this electronic tool. Principally, the current project allowed further testing of the tool to be carried out in several FE and HE institutions (HEIs).

The aims of the project were:

- To improve the screening of students who have dyscalculia and not dyslexia.
- To improve support for students who have dyscalculia.
- To bring into wider use DyscalculiUM – a web-based tool for learning support tutors to screen students for dyscalculia.
- To evaluate the effectiveness of DyscalculiUM within other HEIs’ screening procedures.
- To disseminate findings to HEIs and FE colleges.
- To raise awareness of dyscalculia and the need for tools to screen for dyscalculia in HEIs and FE colleges.

Background to the Current Project

In 2003 it became apparent that there was an urgent need for a suitable screening test for dyscalculia in HE. Students who were possibly dyscalculic, were frequently being referred for screening and no such screening tool exists.

In the previous two phases of the project, DyscalculiUM: a first-line screener for dyscalculia in HE was developed and piloted in both electronic and paper formats. These initial trials, conducted at Loughborough University, showed little difference between the two versions. Furthermore these trials yielded very promising results in the use of the test as an effective screening tool for dyscalculia. The development and early trials in phases one and two of the project are reported by Beacham, N. and Trott, C. (2005) [1].

Following this some modifications were made to the test and the current project has allowed the team to continue this development through two further phases, namely, phases three and four.

A detailed project map outlining all phases of the project is shown in Fig 1.

Phase Three

Phase three was the first phase of the current project and involved 30 participants. The participants were organised into three groups by means of their Educational Psychologist’s report: The first group had the primary specific learning difficulty of dyscalculia, the second group had the primary specific learning difficulty of dyslexia and the final group had no specific learning difficulty and so acted as a control group. In each group there were 10 students. The participants were from a wide range of academic areas including business, social sciences and human sciences. Each participant undertook the electronic form of the screening test on an individual basis and the screening was preceded by an interview in which they were asked about their mathematical background and experiences. The participants were observed throughout the process. Four Higher Education Institutions took part in the trials: Bournemouth University, Harper Adams University College, Leicester University and Loughborough University. The screening test was not
timed but participants were encouraged to move through the test and not dwell on any item for too long. The removal of the timing factor meant that the participants were not placed under pressure of time. This was felt to be important to reduce high anxiety levels that exist among many dyscalculic and dyslexic students.

**Results from Phase Three**

The results sought to compare the dyscalculic group against the dyslexic and control groups in terms of sensitivity and specificity. Sensitivity is the probability that a dyscalculic student performed below the acceptable threshold, that is, how good is the screener at correctly including individuals who are dyscalculic. Specificity is the probability that a non-dyscalculic student performed above the acceptable threshold, that is, how good is the screener at correctly excluding individuals who are non-dyscalculic. A threshold of 89% was used in the trials. On comparing the dyscalculic group with the control group, it was found that, with this threshold, scores for both sensitivity and specificity of 100% were achieved. In earlier trials sensitivity and specificity measures were 83.3% and 92.3% respectively, since when the test had undergone some modifications. The results for the dyscalculic and control groups show that the control group all performed above the threshold score, while each of the dyscalculic group performed below this threshold.

Next, the dyscalculic group was compared with the dyslexic group. The sensitivity was 100% and the specificity was 70%. It is of prime importance that the screener is discriminatory with regard to dyslexia and dyscalculia, while still recognising that both specific learning difficulties sometimes occur in conjunction. Subsequent modifications to the screener have increased the specificity to 90% with one participant remaining on the borderline. These modifications and the specificity of the dyslexic group will be discussed later in this report.

Finally, the dyslexic group was compared with the control group. The specificity was 100% since none of
the participants were dyscalculic. However, the sensitivity was 30\% and was again determined by the three dyslexics who scored below the threshold. However, the results improved upon the earlier trial in phase two that gave the sensitivity and specificity as 50\% and 87.5\% respectively. Using the threshold of 89\%, it was found that three of the dyslexic group fell below this threshold and appear to be in the dyscalculic range. Their scores are 75.8\%, 82.5\% and 85.8\%.

A Kruskal-Wallis test was performed on the scores of the 3 groups giving a significant difference between groups ($\chi^2 = 18.522$, df=2, $p < 0.0005$). Further Mann-Whitney tests showed significant differences between the dyscalculic and dyslexic groups and between the dyscalculic and control groups, but not between the dyslexic and control groups.

The screening test must necessarily discriminate between dyscalculics and dyslexics and a few items in the test did not do so. In fact, in some cases these items particularly impeded the dyslexic participants. Consideration will now be given to some exemplary items from the screener, together with their results. These examples will illustrate some of the problems encountered as well as highlighting some of the successful material.

In the first example, taken from the section on comparing decimals (see Fig 2 and 3 which show the percentage of each group who gave the correct response), two of the questions showed different results. Item (a) shows good discrimination between the dyscalculic group and the other two groups. In order to answer this item correctly, the participant must understand the concept of decimal place value. Item (b) does not show the required discrimination and a correct response can be obtained without an understanding of decimal place value. The reversal in the digits has resulted in discrimination against the dyslexic participant. This item will therefore be removed from the screener.

Rourke (1989) [6] found a high correlation between dyscalculia and non-verbal learning disability (NLD). Subjects with NLD often have good language and verbal reasoning skills, but poor visual-spatial orientation e.g. reading maps, graphs and charts. Visual-spatial orientation is an important part of the current screening test. Items focus on direction, graphs and charts. The following examples show a marked difference in two items on direction. In the first (Fig 4a and 4b which show the percentage of each group who gave the correct response), participants have to follow a set of directions involving left and right. The results for this item show a good discrimination between the dyscalculic group and the other two groups. The second direction item (Fig 5a and 5b which show the percentage of each group who gave the correct response) involves clockwise and anticlockwise. This item appears to discriminate more against the dyslexic group. It appears that the dyslexic group were able to follow the directions for the map relatively easily by adopting coping strategies. It was observed that this group used the mouse as an aid to help them keep track of where they were on the map. This enabled them to focus on the reading and processing of each instruction in turn and thereby limiting the amount of cognitive effort placed on their working memory.

For the item requiring clockwise/anticlockwise directions, coping strategies, based on available aids such as the mouse, were less effective (see Fig 5a and 5b). Accounts were given by participants describing how they visualised the direction that the screwdriver
needed to be turned, and then superimposed this direction on to the face of an analogue clock. They could then relate this direction to turning in a clockwise or anticlockwise direction, and decide which of the two words described this rotation. This seemed to place a greater cognitive load on the working memory and as a consequence appears to have made the task more difficult for the dyslexic group.

One of the questions in the DyscalculiUM screener relates to a bar graph. This question is in two parts and it is interesting to compare these parts. In the first part participants are asked to read off a value for the height of a particular bar and in the second part, they are asked to compare the increase in the heights of the bars and identify between which two bars the “smallest increase” occurred. The results for both parts of this question are shown in Fig 6a and 6b, which show the percentage of each group who gave the correct response. Somewhat surprisingly, all participants found the first part of this question difficult. However, good discrimination is still apparent here. The reading on the vertical scale was more difficult for the dyscalculic group. In order to give a correct response to the second part of the question, participants need to consider the relative step sizes for the heights of the bars, but do not need to put a numerical value on these steps. This allows the dyscalculic to respond without having to compare numerical quantities. Some of the dyslexic group appear to have had difficulty with the wording, in particular, “smallest increase”. The words in this phrase are almost opposite in meaning. This part of the question will need to be reworded or deleted from the screener.

The screener also employs some items that focus on abstract symbolism. This section of material also relates to NLD, but also has relevance to the understanding of mathematical symbolism and the
development of algebraic thinking. The dyscalculic group generally found these items more difficult than did the other two groups and so provided a good discrimination.

Research by Dehaene and Cohen (1997) [3] has shown that poor visual-spatial skills result in difficulties with number bisection tasks. The number bisection tasks that are included in the DyscalculiUM screener support this. Significant differences were shown to exist between the dyscalculic group and the other two groups in the trials.

**Between the Phases**

From the results of the trials in phase three of the project some items in the proposed screening test were amended or deleted, in particular, those items that appeared to impede dyslexics. A subtest was created which consisted of 61 items that show good discrimination between dyscalculics and both dyslexic and control group users. It is anticipated that the shorter subtest can more easily be accommodated within existing screening procedures and used alongside other tools.

Scores from all the participants in the trials of phase three of the project were adjusted in accordance with the newly created subtest. The threshold was then adjusted to 81%. However, good sensitivity and specificity have been preserved and slightly improved. The removal of those items that discriminated against the dyslexic group meant that two of the three students, who previously scored below the threshold, now moved above the threshold, while the third student achieved a borderline score.

Technical changes were also necessary. Changes were made to the page layout of some of the questions to ensure they could be viewed on a screen, that is set to a 1024 x 768 resolution, without the need for scrolling. This included adjusting the size of images so that they required less space, reformatting text to ensure that it occupied fewer lines and placing one question item per screen.

The background was changed from white to yellow to reduce the amount of glare experienced by dyslexic students. The background of the question items was also changed accordingly to yellow to ensure that it coincided. The background of some of the images on the navigation frame was changed from yellow to blue to retain the distinction between the test’s navigation controls and the question items. A number of columns in an item with a bus timetable were removed to simplify the information and also to reduce the likelihood of participants experiencing pattern glare.

A number of unnecessary controls and buttons, such as a question list and Help button, were removed to make the screen less cluttered and the test easier to use. The question list was removed to prevent participants selecting questions in a random order and to ensure participants visited each question in sequence before submitting their answers.

The sixty-minute timeout feature was removed to allow participants to attempt each question at their own pace. It was felt desirable to remove the pressure and anxiety caused by having a timer count down in the corner of the screen.

The functionality of the Submit button was changed so that it remained hidden until participants reached the final question. This reduced the likelihood of a participant pressing the Submit button by mistake.

**Graphs**

Reading off the vertical axis on a bar chart.

**Graphs**

Between which years the “smallest increase” occurred.

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**Fig 6a** Results from bar graph (i): Showing the percentage of each group who gave the correct response

**Fig 6b** Results from bar graph (ii): Showing the percentage of each group who gave the correct response
Small changes were made to the marking scheme so that each individual item was allocated one mark for a correct answer. This allowed a clearer picture to emerge for the discrimination of each item and will simplify the profiling process in the future.

Consideration was given to removing the Previous button. This would prevent participants from revisiting any of the previous questions. However, the decision was made to retain this functionality so that the electronic and paper versions coincide. It was felt that by allowing participants to review previous items, they were being given the best chance of reaching their full potential.

**Phase Four**

Phase four, the second phase of the current project, has involved trials of the subtest that was created as a result of the phase three trials and the technical alterations discussed above. Four Institutions of Higher Education and three Further Education Colleges were involved in the trials. Each of these centres operated under differing conditions; some were able to screen large groups of students, while others worked with individuals or small groups. However, in every case, trials involved the use of both the new shorter screening test and the ‘Mathematics Competency Test’ created by Vernon, Miller & Izard, (1995) and published by Hodder and Stoughton [9]. The purpose of this was to allow for the possibility of using this test as a validation tool, since it is a published test with standardized norms and readily available validation statistics. It also appears on the DIIS approved list of tests (2005) [5].

At Loughborough University, the screening test was trialed with the recent intake of new students taking the Science and Engineering Foundation Studies course. The trial involved 109 students completing DyscalculiUM and the Mathematics Competency Test.

Robert Gordon University planned to use the screener with a small group of new first year nursing students, in order to help identify those students who had mathematical difficulties and so may be at risk.

At Harper Adams University College, students are normally tested at the beginning of their first academic year using a short Mathematics test produced by the university. This allows the identification of mathematically weaker students. For the purpose of the trials, it was planned to give this group of students DyscalculiUM and the Mathematics Competency Test. It was hoped that the results would inform the need for referral and the type of support necessary.

Leicester University used the tests on an individual basis, alongside other screening tools for dyslexia, such as the Dyslexia Adult Screening Test (DAST), to also help inform the learning support tutors with regard to referral and advise on subsequent support. The students had been referred to The AccessAbility Centre for screening.

Three Colleges of Further Education were also involved in trials in phase four of the project. The Additional Support Team at Wyggeston & Queen Elizabeth 1 College, Leicester, trialed both DyscalculiUM and the Mathematics Competency Test with four small groups of students. The first group comprised students who had specific learning difficulties including dyslexia or both dyslexia and dyscalculia. This group receives regular support. The second group had Asperger’s Syndrome and received support, the third group comprised students whose first language is Portuguese and not English and the final group was composed of students from outside the Special Needs Unit and this group acted as a control group. The Student Support Unit at City of Stoke-on-Trent Sixth Form College and the Learning Support Centre at Franklin College, Grimsby, trialed the two tests with a small group of students with specific learning difficulties.

**Results from Phase Four**

The results from this phase were viewed from several perspectives. Firstly, comparisons were drawn between DyscalculiUM and the Mathematics Competency Test in terms of both correlation and screening for students at risk. Secondly, the data from students at the screening stage will allow DyscalculiUM to be further evaluated as an effective screening tool for dyscalculia. Sections of the data can also inform on other issues: use with students for whom English is not the first language and students whose primary learning difficulty is not dyscalculia or dyslexia. Furthermore, the trials of the screener in seven different institutions with differing screening procedures allows an evaluation of the ease of use of the screener and its ability to be accommodated alongside existing arrangements.

All the results from DyscalculiUM and the Mathematics Competency Test were used to obtain a correlation between the two tests. The data from DyscalculiUM is, as expected, skewed. The purpose of the screening test is to highlight those students who have severe difficulties with the understanding of mathematics; the majority of students who do not fall into this category were able to achieve high marks in the screener, thereby making the data appear skewed. The correlation was therefore run...
using Spearman’s Rho for ranked data. This gave a value of 0.623 (p < 0.005). One of the difficulties has been the use of a competency test to correlate with a screener. There is a clear distinction between a test that focuses on performance, competency or mastery and a screening test for a specific learning difficulty. The former “do not provide any basis for understanding the underlying cause of the observed phenomena” Gregoire et al (2003) [7], they are not founded on a cognitive model and cannot identify a specific learning difficulty.

The manual for the Mathematics Competency Test states: “from the stage of secondary education mathematical competency stems more from mathematics teaching and experience of mathematics problem-solving”. Thus, the correlation between the two tests should be viewed with some caution.

From a total of 137 students, the DyscalculiUM screening test identified 16 students who fell below the adjusted threshold, and were therefore considered to be at risk. Of these 16 students, 13 were also in the lowest 20% for the Mathematics Competency Test, further supporting the suggestion that they are at risk of dyscalculia. They included two students for whom English was not their first language and their results are discussed in more detail below. Of the remaining 3 students, one has ADHD and this is also discussed further on in this report. Another student only completed 80% of DyscalculiUM, which clearly adversely affected the score and the third student scored the exact threshold score in DyscalculiUM and just outside the bottom 20% in the Mathematics Competency Test. Based on this sample, the overall figures suggest an 8% prevalence of dyscalculia. This is in line with, although at the upper end, of estimates by Geary (2004) [6] of between 5% and 8% and by the Belgian study of Desoete and colleagues (Desoete, Roeyers & de Clercq, 2004) [4] who estimate between 3% and 8%, but slightly in excess of those of Butterworth (1999) [2] who estimated 4% to 6%. However, all these estimates are based on school-age children and there are no current estimates for post-16 students.

Three students, each from a different institution, were in the process of being screened for a specific learning difficulty. DyscalculiUM was used to inform this screening process. In the case of the first student, the score on DyscalculiUM fell within the “at risk” band, although slightly above the threshold. The student also scored in the bottom 7% of students in the Mathematics Competency Test. This suggests that this student should therefore be referred to an Educational Psychologist for assessment. The second student also scored within the “at risk” band on DyscalculiUM, although, again, slightly above the threshold. This student, however, achieved a better score in the Mathematics Competency Test, placing them above the bottom 25% of students. This suggests that this student should also be referred to an Educational Psychologist for assessment, although the situation may prove to be a borderline scenario. The third student achieved average scores on both tests and is therefore considered not to be at risk.

The DyscalculiUM screener must discriminate purely on the basis of mathematical understanding and not be dependent on language levels and ability. It is therefore important to consider the data for students for whom English is not the first language, two Chinese students took the screening test in phase three of the project and both achieved scores above the “at risk” banding. In phase four, three Portuguese students sat the trial; of these, two students scored below the threshold in DyscalculiUM and also scored in the lowest 10 students in the Mathematics Competency Test. It is not clear if, for these two students, their difficulties are mathematical, language based or a combination of both. Further investigation of this issue will need to be undertaken.

It is interesting to note that two students with Asperger’s Syndrome took part in the trials. Both students scored in the normal range for both tests. Another student with ADHD participated in the trials. He scored well below the threshold in DyscalculiUM, but the score in the Mathematics Competency Test placed this student just in the normal range. This discrepancy may be due to a lack of concentration, since both tests were undertaken in the same session. Concentration is a key factor in ADHD. Again, further investigation is needed.

The ability of the DyscalculiUM screener to discriminate between dyscalculia and dyslexia has already been extensively investigated in phase three of the current project. In phase four, 23 students were registered as dyslexic, and one other student was uncertain about the result of their assessment. Of these 24 students, ten scored below the threshold in DyscalculiUM, but the score in the Mathematics Competency Test placed this student just in the normal range. Of these 24 students, ten scored below the threshold in DyscalculiUM, including the student who was doubtful about their assessment. All of them achieved low scores in both DyscalculiUM and the Mathematics Competency Test, suggesting dyscalculia, although this was not highlighted in their assessments. However, these students have already been identified as having additional needs and the majority were in receipt of support.
Evaluation

Phase three of the project demonstrated that the screener:

- Provides an effective screening tool for dyscalculia in HE
- Can effectively discriminate dyscalculia from dyslexia
- Is easily manageable

Phase four of the project demonstrated that the screener:

- Can effectively discriminate dyscalculia from other SpLDs such as Asperger’s Syndrome and ADHD
- Is easily manageable
- Is effective in both HE and FE
- Can be accommodated easily into various screening processes
- Has a good correlation with other published data, although realising that this data is competency based and not for screening purposes
- Can be used to screen large groups of students as well as used on an individual basis

During both of the two phases of this project several HE and FE institutions were actively involved in trials. Thus, in the course of the current project, the team was able to evaluate the screener as an integral part of various screening procedures and develop a framework for the implementation of the screening tool within other HE and FE institutions. The screener has been shown as an effective tool that can be successfully embedded into a variety of screening procedures at FE and HE and used to successfully highlight students at risk of dyscalculia. It can further discriminate dyscalculia from other SPLDs, such as dyslexia or Asperger’s Syndrome. However, an issue of students for whom English is not their first language has still to be resolved.

The original aims of the project have not only been met, but also extended so that further valuable information has been collected and a greater evaluation of the screener has been possible.

Additionally, the profile of dyscalculia as a learning disability has been raised and there is a growing awareness of its prevalence and identification in the wider community. To this end, the team has disseminated the findings of phase three of the current project at two national conferences:


Secondly, The National Association of Disability Officers (NADO) conference “Beyond Compliance” (July 2005).

The screener was well received by delegates who attended the conference presentations and by all those involved at the trial stages, including many learning support tutors and assessors who will form the target user group for the screener and whose endorsement is essential.

References


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