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What Can Analytics Contribute to Accessibility in e-Learning Systems and to Disabled Students' Learning?

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What Can Analytics Contribute to Accessibility in e-Learning Systems and to Disabled Students' Learning?

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ABSTRACT

This paper explores the potential of analytics for improving accessibility of e-learning and supporting disabled learners in their studies. A comparative analysis of completion rates of disabled and non-disabled students in a large five-year dataset is presented and a wide variation in comparative retention rates is characterized. Learning analytics enable us to identify and understand such discrepancies and, in future, could be used to focus interventions to improve retention of disabled students. An agenda for onward research, focused on Critical Learning Paths, is outlined. This paper is intended to stimulate a wider interest in the potential benefits of learning analytics for institutions as they try to assure the accessibility of their e-learning and provision of support for disabled students.

Categories and Subject Descriptors

K.3.1 [**Computers and Education**]: Computer Uses in Education – *collaborative learning, distance learning.*

K.4.2 [**Computers and Society**]: Social Issues – *assistive technologies for persons with disabilities, handicapped persons / special needs.*

General Terms

Design; Human Factors; Measurement

Keywords

Learning Analytics; Metrics; Accessibility; HCI; Technology Enhanced Learning; Higher Education

1. INTRODUCTION

More and more universities are now rolling out learning analytics across the institution. To date, there has been little attention paid to the benefits that learning analytics may bring to disabled students, to those who support them in their learning, and to those responsible for ensuring that courses are accessible.

This paper reports research at The Open University (OU) that explores the utility and validity of using learning analytics to identify accessibility deficits in courses and course components and to target support for disabled students.

2. ACCESSIBILITY AND ANALYTICS

A review of the key points of reference for learning analytics [4] shows that, when identifying technical and research challenges, disability and accessibility have not been subjects of particular interest to researchers [4, 12]. Where these subjects have been addressed is within the academic analytics literature in the context of retention and success rates, [10]. Academic analytics marry 'large data sets with statistical techniques and predictive modeling to improve decision making' [3]. Retention and success rates are areas of particular concern, and work on these topics draws on large-scale studies that often predate modern analytics approaches; for example, Tinto's studies of factors affecting student persistence [13]. Such studies typically segment students using categories including gender, ethnicity and class. Disability is one variable amongst many [13].

3. DISABILITY AND ACCESSIBILITY

Disabilities have traditionally been described with reference to the medical conditions from which they were seen to arise. This 'medical model of disability' is encapsulated in the international classification of impairments, disabilities and handicaps produced by the World Health Organisation (WHO) [16].

The main alternative to the medical model of disability is the social model [14], which considers that disability is caused by the ways in which society is organised and responds to people. It is not an inevitable consequence of impairment but the product of physical, organisational and attitudinal barriers. This view has been highly influential in shaping policy, practice and attitudes.

In 2001, the WHO revised its definitions, in part as a response to the social model, and in part because the medical model was of limited use in defining effective responses to the needs of disabled people. It described disability as 'the outcome or result of a complex relationship between an individual's health condition and personal factors, and of the external factors that represent the circumstances in which the individual lives' [17].

The IMS Global Learning Consortium offered more education-specific definitions when introducing its work on the development of technical standards for accessibility in e-learning. It defined disability as 'a mismatch between the needs of the learner and the education offered'. Accessibility is 'the ability of the learning environment to adjust to the needs of all learners' and is

determined by 'the flexibility of the education environment (with respect to presentation, control methods, access modality, and learner supports) and the availability of adequate alternative-but-equivalent content and activities' [7].

The term 'accessibility' is often used in the context of web design, and the W3C web standards body states, 'Web accessibility means that people with disabilities can perceive, understand, navigate, and interact with the Web, and that they can contribute to the Web' [18]. A design can be said to be accessible if it facilitates full interaction by all users, irrespective of the assistive technologies or access approaches that may be adopted by some.

3.1 Disability flags and access profiles
Key to the development of learning analytics for accessibility is knowledge of which students have declared a disability. This <disability flag> carries no additional information. However, data that many universities are required to collect and report enables the use of a richer data element, <disability type>.

'Disability type' is medical-model based. The UK's Higher Education Statistics Agency defines disability in relation to 12 broad categories, including sight impairment, hearing impairment and dyslexia. These categories do not map meaningfully to disabled people's functional requirements for interacting with web resources but may still be useful in terms of analytics.

An alternative is the Access for All 3.0 Personal Needs and Preferences (PNP) specification developed within the IMS Global Learning Consortium, which went to public draft in September 2012 [7]. This provides a candidate approach that could enable comprehensive profiles of individuals' access approaches and assistive technologies to be stored within a user database. Disabled students could generate their own functional profiles, possibly with the help of disability advisors, by inputting their access approaches and requirements. These profiles would help in identifying accessibility problems and where and how they arise.

3.2 The law and external standards
Most developed countries now have legislation which impacts on the access of disabled people to education. These laws vary in nature from country to country. The UK, for example, has 'anti-discrimination legislation' rather than 'accessibility legislation'. This is the case in most developed countries, although the US has some accessibility legislation that is linked to public procurement.

In the UK, the key current legislation is the Equality Act (2010) [5], which builds on other legislation, including the Disability Discrimination Act (2005). In essence, these require educational institutions not to discriminate against disabled students on the basis of their disabilities; to make 'reasonable adjustments' in order to meet disabled students' needs in all aspects of their education, and to anticipate the needs of disabled students.

The law is understandably not specific about what the phrase 'reasonable adjustments' means in terms of accessibility of online offerings. However, it is widely accepted that the Web Content Accessibility Guidelines (WCAG) 2.0 recommended by the W3C are the baseline if a case is taken to court [19]. These guidelines are targeted at web developers and cover technical accessibility. In addition, accessibility in e-learning should include accessibility of learning design and the pedagogically appropriate use of alternative formats, which may employ diverse media.

Accessibility should be built into everyday practices throughout the product lifecycle from conception and specification, through development, to delivery and maintenance. Recognising this, the British Standards Institute developed BS 8878: 2010 Web Accessibility Code of Practice [2]. This facilitates a pragmatic application of WCAG 2.0 within a process-based approach.

4. ANALYTICS FOR ACCESSIBILITY
Researchers investigating drop-out rates of campus-based students have drawn on institutional records and survey data when developing models of persistence and attrition [1, 13]. Similar approaches have been used to predict drop-out rates on online courses [8, 15]. Student attributes, skills and contexts have been used to develop predictive models [12]. Researchers can now make use of online interaction data in order to identify links between participation in various activities, rates of participation at various stages of the course, and drop-out rates [9].

Little of this work has taken disability into account, although age, gender, ethnicity, family background and study habits have all been considered [1, 13]. This is a significant omission, because prominent theoretical models of academic attrition imply that disability could be a significant variable if it results in students feeling they do not fit in, or that their studies are putting too much pressure on their resources and well-being [1, 13].

Retention issues are key institutional drivers for the adoption of learning analytics. If disabled students encounter critical elements or required modes of study that are not accessible to them, then this will impact negatively on their chances of passing a course and may lead to them dropping out before the final assessment.

5. DESCRIPTION OF DATASET
In order to explore whether learning analytics can be used to identify modules with such accessibility deficits, a large dataset was compiled and analysed, in a project focused on the retention of STEM (science, maths, engineering and technology) students.

This dataset contained data from OU modules (units requiring 300 or 600 study hours). It included five years of data (2009-2013) from two OU faculties, Maths Computing & Technology (MCT) and Science, covering all module presentations for which complete data were available (N=1,338). For each module presentation, numbers of students declaring a disability ('disabled students') or not ('non-disabled students') were recorded, as were percentages of both groups completing and passing. Students were considered to have completed a module if they submitted the final summative assessment. Pass and completion rates of disabled and non-disabled students could then be compared.

Overall, analysis of the dataset indicated that the OU had improved the accessibility of its modules over time. Only three modules in the dataset that were presented after 2012 showed the completion rate of disabled students to be markedly poorer than that of non-disabled students (indicated by an odds ratio of >2.95).

6. RESULTS
6.1 Results of quantitative analysis
The average completion rate for non-disabled students in the dataset was 75.3% and for disabled students it was 69.5%. However, many factors other than disability impact on completion rates. The objective of our analytics approach was to identify modules in which accessibility was a dominant factor in determining the completion rates of disabled students and then to focus remedial efforts on those modules. Table 1 shows that in 68% of module presentations a greater proportion of non-disabled students completed the module than disabled students. However, it might be expected that non-disabled students would do better than disabled students, so it is perhaps more significant to note that in 30.6% of cases the converse was true. The range of

differences in completion rate (non-disabled students minus disabled students) was from -49.5 percentage points to 96.0 percentage points.

Table 1. Rates at which disabled and non-disabled students complete modules

	No. module presentations	% of module presentations
Higher % of non-disabled students complete	923	68.0%
Higher % of disabled students complete	415	30.6%
Equal % students complete	19	1.4%

The more extreme results were mainly found in module presentations with a low population of disabled students. This effect of population size can be illustrated with an example. If a module has only two disabled students and one drops out then the completion rate is 50%. If the same module has many non-disabled students, their completion rate will be very close to the mean of the course, say 70%. This results in a difference of 20 percentage points. However, this difference would be due to one student dropping out, not necessarily because of accessibility.

To avoid this distortion, in subsequent analysis modules with fewer than 25 disabled students were not considered, reducing the number of module presentations in the dataset to 668.

Table 2. Rates at which disabled and non-disabled students complete modules (modules > 25 disabled students)

	No. module presentations	% of module presentations
Higher % of non-disabled students complete	537	80.4%
Higher % of disabled students complete	129	19.3%
Equal % students complete	2	0.3%

In this modified dataset, differences in completion rate on a module (non-disabled students minus disabled students) ranged from -22.1% points to 35.0 percentage points.

Initial analysis considered differences between the percentage completion of these groups for each module presentation. This approach was refined by the use of odds ratios, a standard statistical approach that enables comparisons to be made across different modules when the underlying phenomenon varies.

When using odds ratios, if the probability of the members of Group 1 achieving an outcome is p, with 0 indicating it will never happen and 1 indicating it is certain to happen, then the odds of this are $p/(1 - p)$. If the probability of the members of Group 2 exhibiting that outcome is q, then the odds of this are $q/(1 - q)$. The odds ratio is the ratio between these odds $[p/(1 - p)]/[q/(1 - q)]$, which equals $[p(1 - q)]/[q(1 - p)]$. Odds ratios vary from 0 (when $p = 0$ or $q = 1$) to infinity (when $p = 1$ or $q = 0$). An odds ratio of 1 means there is no difference in the odds of the two groups' members achieving the outcome (when $p = q$). An odds ratio less than 1 means the members of Group 1 are less likely to achieve the outcome than the members of Group 2; while an odds ratio greater than 1 means the members of Group 1 are more likely to exhibit the outcome than are the members of Group 2

Odds ratios are often used to generalise from a sample population. Here, though, we calculated and compared the odds ratio for all

students on each module presentation, classifying non-disabled students as Group 1 and disabled students as Group 2. The odds ratio is therefore >1 when non-disabled students perform better than disabled students on a module. The larger the odds ratio is, the greater the disparity between the two groups.

We suggest that when the odds ratios are above a certain threshold they indicate a module is presenting accessibility issues that are significantly impacting on the performance of disabled students. The plot in Figure 1 was used to set a threshold of 3.0. Although the plot is difficult to interpret at this scale, the main thing to note is that most data points lie between 1.0 and 3.0. Working with an odds ratio of 3.0 was therefore considered likely to filter out cases where factors other than disability would have the most significant effects on student performance.

This approach points to cases where significant accessibility issues may exist; it says nothing about what those accessibility barriers might be. It can therefore be used to decide where accessibility reviews should be carried out. This has the advantage of focusing the limited accessibility expertise available across a university on the modules where it is likely to have most impact.
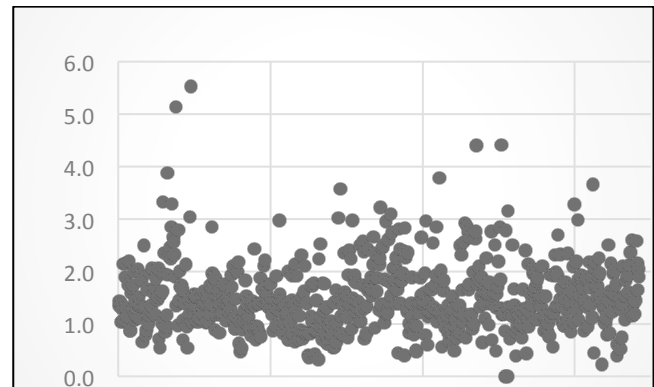

Figure 1. Distribution plot of odds ratios of completion rates; each dot represents a module presentation (distributed along the *x* axis in no particular order); *y* axis is the odds ratio

6.2 Comparison with qualitative data

In order to contextualise this quantitative approach to identifying possible accessibility deficits, qualitative data were also analysed in a small-scale investigation.

At the end of each module presentation, OU students are asked to complete a survey that explores their study experience. This survey includes three opportunities to provide free-text comments. Since 2012, the survey includes a question about the experience of disabled students, so this section of our research focused on module presentations that had used this form of the survey.

Free-text survey responses from six module presentations were analysed qualitatively, with the focus on responses from students who had declared a disability. For three of the sample modules quantitative analysis had indicated accessibility challenges; for three modules no problems had been identified.

6.3 Results of qualitative analysis

Table 4 summarises the qualitative analysis of survey responses (the coder had not seen results of the quantitative analysis). Ranking of the selected modules for accessibility on the basis of free-text survey responses by disabled students was markedly different to the ranking by odds ratio of completion rates comparing disabled and non-disabled students. Reasons for this difference, and its implications, are discussed in the next section.

Table 3. Modules selected for qualitative analysis ranked in descending order of odds ratio.
M represents a mathematics module and S a science module

| Module Code | Total | Disabled | | | | Odds Ratios |
| | | No | | Yes | | |
		No.	% complete	No.	% complete	
M1	247	221	67.0	26	26.9	5.517
S2	145	118	71.2	27	44.4	3.096
S1	230	199	70.9	31	45.2	2.954
S3	291	229	64.2	62	53.2	1.578
M2	320	282	70.2	38	63.2	1.372
S4	148	117	76.1	31	71.0	1.301

The selection criteria used to obtain this sample (Table 3) were:

- Modules were at Level 3, comparable to modules taken by students in the final year of undergraduate study
- Presentation had at least 25 disabled students registered
- Field trips and summer schools (face-to-face lab work) were excluded
- Modules thought to include significant accessibility barriers had a completion rate odds ratio of >2.95
- Three modules, selected from many, thought to be non-problematic from an accessibility perspective had a completion rate odds ratio of < 1.6.

Unfortunately, for three of the selected modules the data were incomplete because an unrelated data-cleansing process had caused the over-writing of some responses.

Table 4. Relative ranking of modules by access issues reported in survey responses (with summary of reasons for the ranking) compared with ranking by odds ratio

Module Code	Summary of Reason for Ranking from Survey Analysis	Survey analysis ranking (worst = 1)	Ranking by odds ratio completion (worst = 1)
M2	Two-thirds of students with declared disabilities had complaints that could relate to their disabilities.	1	5
S1	Difficult for dyslexics to follow, videos lacking subtitles, no alternative to using website.	2	3
S4	*Incomplete data*. Lack of printed material was a problem for some	3	6
S3	*Incomplete data*. One had problems with online copy. However, three noted other options were available.	4	4
M1	Data incomplete. No problems identified.	5	1
S2	No problems AND students were very positive.	6	2

7. DISCUSSION

Comparative analysis of completion rates between disabled and non-disabled students, over a large set of module presentations, confirmed that disabled students are less likely to complete a module than non-disabled students. However, it revealed wide variation between modules. Identifying modules with the greatest disparity between performance of disabled and non-disabled students indicates where significant accessibility challenges lie.

This approach was not valid when the numbers of disabled students on a module was low. We suggested that a minimum of 25 disabled students on a module was appropriate. This figure halved the number of modules analysed in this study and limits the contexts in which the approach would be applicable. In the context of a large university like the OU, this approach would identify the accessibility deficits that impact on a significant majority of disabled students. At many universities, far fewer courses would have sufficient disabled student numbers to make the approach valid. However, one context in which we suggest that it would have particular utility and validity is that of massive open online courses (MOOCs).

Disabled students do raise issues relating to module accessibility when surveyed. These include difficulty with reading material on screen, and lack of subtitles on videos from external providers. However, we run into a number of problems if we rely on end-of-module surveys to reveal where accessibility problems may be significantly impacting on disabled students' learning:

(1) Those who are most profoundly affected by accessibility deficits and decide to withdraw are unlikely to complete an end-of-module survey.
(2) Student responses do not align with drop out rates (Table 4).
(3) Problems reported by disabled students are not necessarily the main problems.
(4) On modules with a high drop out rate, disabled students may report no problems.
(5) 'Declared disability' is a very broad classification. A problem that is insurmountable for blind students may have no effect on others who are hard-of-hearing or dyslexic.

Analytics provide another way of approaching the problem of identifying where major accessibility deficits lie. First, we identify quantitatively the modules with disproportionately high drop out rates of disabled students. Having done that, we can (in future) carry out critical learning path analysis of those modules, and compare the critical learning paths of disabled students and non-disabled students. This potentially enables us to pinpoint where the accessibility problems lie that are really impacting on learning.

8. ONGOING AND FUTURE WORK
8.1 Analytics to support disabled students

A major theme in learning analytics has been to facilitate the offering of targeted support to the students most in need of it. Declared disability could have significant utility in this process. If tutor dashboards, when highlighting those at risk, also identified which students had declared a disability, this could prompt an enquiry as to whether this disability, or accessibility issues with the course, were having a significant impact on performance. A tutor could then support the student to make use of appropriate access approaches. This could trigger a negotiation about reasonable adjustments or prompt the student to obtain support from specialist disabled student support services.

This could be done at different levels, depending on the use of such dashboards and the levels of information collected and made

available to the learning analytics system. If the learning analytics system just uses the <disability flag> then only a basic prompt that this student has declared a disability is possible. However, if the system models disabled students' needs and preferences for access approaches then it is possible to point both tutor and student to more specifically appropriate guidance.

8.2 Analytics to reveal critical learning paths

Students working on an online system can typically choose how and when they access the learning materials provided. Some learning activities are inevitably more critical for success than others. Machine learning methods can be applied to historical module data in order to discover which types of activity are important for a particular module at a particular time. For example, being inactive in a forum in the first week of a module presentation can be implicated in lower performance in module A, yet have no impact in module B. Through mapping the activity space of a module and identifying the pathways of successful and unsuccessful students through the activities, it is possible to identify critical activities along the pathway to success and, conversely, to identify strategies that are not successful.

Current work at the OU (building on [15]) represents multiple student paths through a module as a probabilistic Markov chain of independent transitions between one activity on the virtual learning environment (VLE) and another. A graphical representation of the Markov chain for a given module can highlight how many students made a transition between certain activities and how this impacted on their final outcome. This shows the critical pathways to success.

Currently, this work is being investigated at the level of VLE 'activity type'. If any critical activities pose accessibility problems, then this could limit progress for some disabled students. Comparing pathways of successful and unsuccessful disabled students with the pathways of others could highlight problems with a module's activities. In addition, the accessibility of activities that fall on the pathways of successful students will have more impact on the success of disabled students than activities that appear to have little impact on student success. Thus this approach could be used to prioritise remedial accessibility work on a module.

9. CONCLUSIONS

Disabled students experience a wide range of challenges in their study. Educational institutions need to extend accessibility of their courses to reduce those challenges. This paper has shown that an analytics approach based on comparative analysis of completion rates between disabled and non-disabled students could identify where accessibility deficits are having real impact on learning and thus focus remedial attention. Based on ongoing work on critical learning path analysis, the paper has outlined how analytics could be used to identify module components that are presenting accessibility challenges. Where learning analytics dashboards are being used to support students directly and enable their tutors to support them, these approaches could be extended to target effective support for disabled students. It is hoped that this paper will stimulate others involved in the research, development and roll-out of learning analytics to work towards realising their potential to meet the needs of disabled students.

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