CASE STUDY

Project-based learning integrated with e-Assessment

Ben Derrick, Mathematics and Statistics Research Group, University of the West of England, Bristol, UK. Ben.Derrick@uwe.ac.uk
Iain Weir, Department of Computer Science and Creative Technologies, University of the West of England, Bristol, UK. Iain.Weir@uwe.ac.uk

Abstract

This paper explores a recent move towards project-based learning for a first-year undergraduate statistics module at the University of the West of England, Bristol. The course is aimed at students specialising in Mathematics and Statistics. A classroom-based end of module project week was developed with the focus on project-based learning, supported by Dewis-R data generation and e-Assessments. Simulation of a practice-based environment with a dedicated working area and daily deadlines is incorporated to enhance the activity. Students are faced with a highly relevant statistical analysis task, that is large and has not had the prior data screening or cleansing that they may be accustomed to in basic didactic teaching. Indications are that the project-based learning approach, assessed during a project week with supplementary e-Assessments and a final report, is well received and leads to improved student outcomes.

Keywords: project-based learning, e-Assessment, statistics.

1. Introduction

This case study focuses on an end of module week-long assessment activity on an introductory statistics module. Students are tasked with identifying and implementing appropriate statistical analyses, that allow the delivery of a report that satisfy research questions supplied by a client. This is an example of project-based learning, which involves the use of real-world problems with authentic complexity beyond that taught in basic textbooks (Solomon, 2003). This approach is gaining in popularity in higher education with widely accepted potential for strong student outcomes (Guo et al., 2020), and many studies have demonstrated empirical evidence in favour of it (Kokotsaki et.al., 2016).

Project-based learning shall be referred to as PBL throughout this paper, and not to be confused with either problem-based learning or practice-based learning. In problem-based learning students discover concepts and principles through a real-world problem, whereas in our case these concepts have been previously taught. Practice-based learning arises from problems within a genuine working environment, whereas we are working in a simulated setting.

Without due care and attention to data checking and preparation, analyses may be flawed and worthless. For example, a fundamental step often overlooked in statistics textbooks and courses is the work required to get data into a format suitable for analyses. A move towards PBL can be of great benefit towards learning statistics, changing the student perspective from simply performing a statistical test as directed, to thinking about the entire analytical process. PBL can provide effective active learning of introductory statistics to non-specialists (Marshall, 2019; Karpiak, 2011; Tarmizi and Bayat, 2010).

Real-world statistical analyses cover all the essentials of PBL identified by Larmer and Mergendoller (2010). Among these essentials, statistical consultancy offers meaningful and compelling work, with different choices to explore and a final product to present to a client. Statisticians also require strong 21st century skills such as communication and collaboration. Of note is the need for PBL to enhance feedback and revision, we will demonstrate how this can come via classroom interaction and supplemented by e-Assessments.

A limitation of automated e-Assessments is that they install an algorithmic view of statistics which may be perceived to conflict with PBL (Pearce and Derrick, 2019). However, a well-formed automated e-Assessment can not only provide summative assessment, but also give students immediate assurance of correct approaches or feedforward based on any common mistakes that are made (Sikurajapathi et al., 2020).

This paper provides a case study showing how e-Assessments can be used within a PBL and assessment approach for students specialising in Mathematics and Statistics, followed by discussion of the effectiveness of the methodology. The e-Assessment system used is Dewis-R, developed at the University of the West of England, Bristol (UWE). This is a subsidiary to the Dewis system used at the same institution but allowing for R code to be used in the programming environment. Dewis-R is a fully algorithmic web-based e-Assessment system (Gwynllyw et al., 2020). The Dewis-R system is already used to assess non-specialists in statistics (Weir et al., 2017). In the academic year 2022-2023, over 2,000 UWE students were using Dewis-R e-Assessments across three faculties plus federation colleges.

2. Implementation

The focus of this paper is on an end of module PBL week designed as the final assessment of a core first-year mathematics undergraduate module called ‘Statistical Investigations’. Historically the final assessment was a traditional written exam involving SPSS output supplied to the student, and manual calculations. Now the students are examined throughout the academic year by a series of computer-based in-class e-Assessments that deliver data to be analysed in SPSS, with a concluding week to replicate real world application of the taught materials together with some new skills. All programme resources and contact time are diverted to the module for the week, students have no scheduled teaching on other modules. There are contact hours every day, and the project is designed to be completed as part of a standard 35 hour working week. The module is completed a few weeks before the end of term allowing students more time to focus on other modules with traditional end of year exams.

The PBL activity that is inspired by a real statistical consultancy project conducted by one of the authors. The lecturers on the course play the role of management for a consultancy business, scheduling the contact time as meetings designed to progress towards project completion. Students are given the opportunity to work in a designated community space from 9am to 5pm, in a manner that simulates an office-based environment. A key feature of the week is promoting best practice within industry, this includes information prior to the start of the week of the standards required by management to ensure that students are active members of the team (e.g. attendance or apologies for absence).

There are 12 hours of formal contact time split across five days, scheduled at the start of every morning and afternoon. Each session starts with up to 1.5 hours of instructor led discussion and small group activities. Following this, the students are free to build upon developments from the session either independently or in groups.

The project design is such that most of the techniques taught during the academic year are needed and students will need to identify and perform appropriate parametric tests or their non-parametric equivalents. Real world challenges and best practice are introduced to the students during the week.

Each day has one or two summative deliverables with a deadline of 8pm that day. To give instant feedback on progress, this includes four small e-Assessments available from 5pm. Students are permitted one submission attempt for each daily engagement activity and must take personal responsibility to submit these before the deadline. The highest weighted task is a final report of no longer than eight pages due after the completion of the week.

The report is due one to three weeks after the completion of project week, depending on the timing of the Easter Holidays. A daily breakdown of activities within project week is given below.

2.1 Monday

The consultancy scenario is introduced that concerns an employer wanting to know the reasons behind a high employee churn rate. Students are briefed to design and author an appropriate questionnaire that considers potential analyses to address the clients' needs and comprises:

- A question asking about the employee's intention to leave;
- Two questions for each of three latent variables regarding aspects of employee's attitudes;
- Two questions regarding the employee's work status;
- Two questions regarding the employee's demographic makeup.

In line with good practice procedures, students are presented with an activity log template to maintain records of key activities during the week.

The daily engagement assessment is an individually authored Qualtrics questionnaire with supporting synopsis.

2.2 Tuesday

Students are provided with a bespoke data set that is larger than they have experienced before, containing over 100 respondents to the final questionnaire determined by the academic. The data is supplied in a .csv format of messy data by design, typical of how data is received in practice. This means that students need a preliminary effort to format data so that it can be analysed by SPSS. Student focus is on data set creation, and univariate exploratory data analyses. As part of best practice procedures, one of the requirements is that syntax is required for these tasks.

The same 22 variables are given to each student, but with a different number of responses and different signals within the data. The datasets are generated using Dewis-R. As part of the generation of multiple bespoke datasets for the cohort, the following are included by design for each student:

- A unique set of data values;
- Some missing values (missing completely at random);
- Varying combinations of 'significant' and 'not significant' variables;
- Varying distributions of variables in terms of skewness and kurtosis (normal and non-normal);
- Either equal variances or non-equal variances, for relevant bivariate comparisons;
- A variable with observations outside an appropriate range;
- Variables supplied in string format that need to be converted to numerical;
- Likert style responses that form part of a summed Likert scale, where some are reverse coded;
- Variables that have categorical responses with low frequency counts.

Students obtain their bespoke dataset via the Dewis-R interface (figure 1).

Figure 1. Dewis-R interface for student collection of bespoke dataset.

Set-up as a formative e-Assessment, students are instructed to open the dataset and report the number of respondents and number of variables. This confirms that each student is working on their own unique dataset. Submission acts as receipt that students have collected the data, those that have not submitted can be contacted by the module team. The student username and unique dataset number is included to allow academics to access the dataset and solutions for each student if necessary. The dataset number remains constant throughout all e-Assessments for that user.

There are two summative daily engagement checkpoints: SPSS syntax to create and clean the dataset; an e-Assessment relating to univariate analyses. An example of a summative e-Assessment is given in Section 2.3.

2.3 Wednesday

Bivariate analyses of the dependent variables are required. Student focus is on identifying the correct tests to perform and the interpretation of the results.

An example summative e-Assessment is given in figure 2.

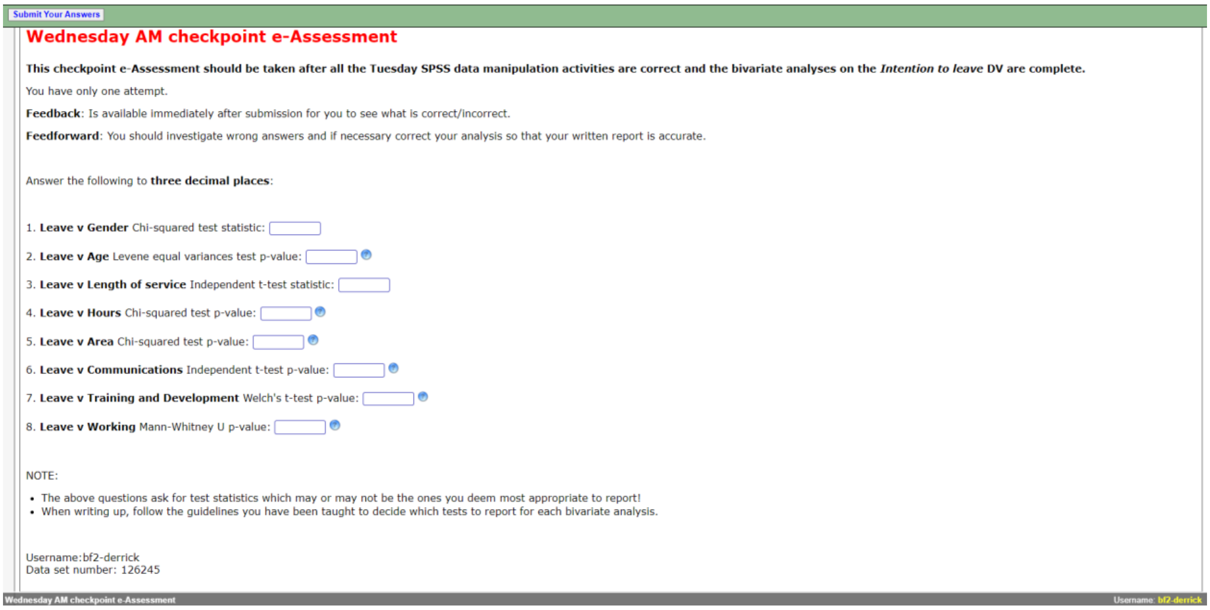


Figure 2. Example of Dewis-R checkpoint e-Assessment.

Upon submission, students are greeted with options to view their feedback (figure 3) and feedforward (figure 4). Students can view their feedback and feedforward at any time after the deadline, even if the deadline was missed.

The Report

Wednesday AM checkpoint e-Assessment

This checkpoint e-Assessment should be taken after all the Tuesday SPSS data manipulation activities are correct and the bivariate analyses on the *Intention to leave* DV are complete.

You have only one attempt.

Feedback: Is available immediately after submission for you to see what is correct/incorrect.

Feedforward: You should investigate wrong answers and if necessary correct your analysis so that your written report is accurate.

Answer the following to three decimal places:

1. Leave v Gender Chi-squared test statistic: 0.213
2. Leave v Age Levene equal variances test p-value: = 0.007
3. Leave v Length of service Independent t-test statistic: -1.618
4. Leave v Hours Chi-squared test p-value: <0.001
5. Leave v Area Chi-squared test p-value: = 0.841
6. Leave v Communications Independent t-test p-value: = 0.062
7. Leave v Training and Development Welch's t-test p-value: = 0.115
8. Leave v Working Mann-Whitney U p-value: <0.001

NOTE:

- The above questions ask for test statistics which may or may not be the ones you deem most appropriate to report!
- When writing up, follow the guidelines you have been taught to decide which tests to report for each bivariate analysis.

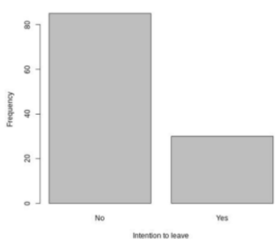
Wednesday AM checkpoint e-Assessment — Username: bf2-derrick

Figure 3. Example feedback given to student upon completion of e-Assessment.

The feedback in figure 3 details the numerically correct answers for different statistical tests. Students are also given a report which details which question/s they answered incorrectly. Students can then look at any feedforward supplied for the questions. The feedforward in figure 4 gives an indication to how the answer to the first question may be arrived at, which may be useful for diagnosing mistakes and subsequent adaption for part of their final report.

WEDNESDAY AM: BIVARIATE ANALYSIS ON INTENTION TO LEAVE DEPENDENT VARIABLE

Intention to leave



Intention to leave v Gender

		No	Yes
Female	Count Expected Row % Std. Res	38 38.3 73.1% 0.0	14 13.7 26.9% 0.1
Male	Count Expected Row % Std. Res	46 45.7 74.2% 0.0	16 16.3 25.8% -0.1

Wednesday AM checkpoint e-Assessment — Username: bf2-derrick

Figure 4. Example feedforward given to student upon completion of e-Assessment.

In this example you can see the correct Chi-squared value (figure 3) and the supporting additional information shows a table of counts (figure 4) which should trigger understanding of how the answer was derived and prompt the student to correct any data errors. Many parametric and non-parametric statistical tests are covered in the e-Assessment, and students are directed to look at the module materials including e-Assessments completed during the year for guidance to which statistical test may be appropriate for their report, based on their unique dataset.

A small but previously unseen urgent client request surfaces towards the end of the afternoon, to further mimic industry working conditions and test student resilience.

There are two daily summative engagement checkpoints: an e-Assessment based on analyses of the categorical dependent variable; an e-Assessment based on analyses of the scale dependent variable, including the additional client request.

2.4 Thursday

Multiple regression analysis of the continuous dependent variable is developed, with discussion of model assumptions. Some new challenges are included for linear regression analyses with categorical explanatory variables of more than two levels.

All the statistical analyses are completed by the close of business on Thursday, and thus the remaining focus is purely on the report write up.

The daily summative engagement checkpoint is an e-Assessment relating to regression analyses.

2.5 Friday

Student focus is on succinct report writing for the target audience, considering formal statistical reporting, appropriate style and content. The delivery includes group discussions with comparison between group ideas on the content to include in a client-orientated report, and quizzes that ascertain and challenge misconceptions about how the report should be written, e.g. at the outset many students believe that mathematical theory of their applied techniques should be included.

The daily summative engagement checkpoint is the activity log detailing daily activities.

To simulate workplace colleague dynamics, we state that from close of business on the final day tutors are away on holiday and/or busy working on other projects, fully entrusting the student to submit the report for the client when it is due.

3. Discussion

Having adopted this PBL approach, academics on the programme have found that the cohort progress from the first year with far greater key transferable and technical skills than students on the equivalent module prior to the move to PBL. There is a distinct observable improvement in students’ confidence and readiness to tackle statistical analyses of large, messy, and missing data.

Students are encouraged to work in groups on common analytical ideas, while being assessed separately. This collaboration is made possible because the unique datasets ensure that the most appropriate choice of statistical tests differ among students, and the subsequent interpretation of results require each student to have a bespoke response.

While the structure of the week facilitates peer collaboration, the use of Dewis-R to generate unique datasets means that students cannot rely on peer collusion to ascertain and report on statistical output.

This leads to some interesting reports to mark, thanks to different conclusions which are often obtained via unique and sometimes innovative student approaches.

The project is devised in such a way that all students receive similar challenges, but differences within the datasets encourage students to find their own solutions and express their individuality. For example, one challenge implemented is that some students may have ages recorded as below 16, whereas other students may have ages recorded as greater than 80; another example is that some students, by design, need to report the independent samples t-test, whereas other students need to report the Mann-Whitney test. In addition, a student will have significant results to report relating to a subset of the variables within their dataset, whereas other students will have different subsets of variables leading to significant results. The bespoke offering to each student arises from a combination of many of the separate challenges that have been programmed, but the similarities in what may be considered reasonable student approaches to each challenge ensures that every bespoke assessment is congruent to each-other and the learning outcomes; there has been no perception of unfairness reported by students.

The five principles for the future of assessments (Jisc, 2020) are core to the adopted assessment strategy:

1. **Authentic.** Students are active learners, with interactions and technology that they will experience in their careers, including general communication skills, computing skills, and specialised statistical software.
2. **Accessible.** The e-Assessments have the benefit of a familiar format, allowing students to report results in a standardised manner. Students have a high degree of familiarity with Dewis-R e-Assessments because they are used both formatively and summative throughout the module, based on Weir et al. (2021). Students can practice these questions an unlimited number of times and revisit them as necessary during project week.
3. **Appropriately automated.** In addition to the Dewis-R e-Assessments, appropriate analyses are generated by the system for the academic to cross-check against their final report.
4. **Continuous.** The Dewis-R system records all student interactions and results throughout the week, assisting with both short-term student monitoring and long-term identification of threshold concepts.
5. **Secure.** The student footprint reveals exact timings of entering and completion of assessment. This is not an assignment that could be readily completed by artificial intelligence, which is becoming a concern about some assessments.

The presence of e-Assessments with automated feedback allowed academics to promptly intervene for any students that were struggling, this intervention is facilitated by the daily timetabled contact with students and local working environment throughout project week.

There are challenges timetabling a large group of students in their own space for the whole week, but we deem it necessary to have this community working environment to emulate practice-based learning. There were some information technology issues experienced mid-week by some of the students, reflecting challenges that can be faced when working authentically. It was great to see students overcome challenges as part of a community of workers, building their overall resilience.

Students were given plenty of forewarning of an intense week replicating a 9am to 5pm office style working environment. Some students had to juggle childcare and other commitments and took individual responsibility for this. Those that needed to miss meetings forwarded appropriate apologies, this is an example of how the simulation of a professional environment embedded a professional response from the students.

Engagement was high throughout the week, with attendance far greater than experienced for a typical hour of formal contact time during the academic year. Many students also remained working on campus outside of timetabled contact hours in the area reserved for them. Students recognised the need to be working full time to reach the targets of the next sessions and/or daily assessments.

Students performed very well in the project week daily activities, as these were designed to retain engagement rather than be onerous tasks. The final report represented a bigger challenge for the students, given that this is their first attempt to write a formal statistical written report. Nevertheless, with the high work ethic initiated during the week and the dedicated report writing session, the students were able to produce good reports.

Student feedback shows a consistent theme of this project week being a "*good*" and "*challenging*" experience, with key comments referring to the week being "*demanding*" but "*enjoyable*" and "*rewarding*".

4. Conclusion

This paper details a project-based learning approach, integrated with summative e-Assessment, for the teaching of Statistics.

Dewis-R is used to generate bespoke datasets. This provides each student with individual problems, that are solved through collaborative active learning. Using the e-Assessments, students can introspectively examine their methodology and correct it where appropriate.

Project week fosters a community of learners met by enthusiasm from students and lecturers alike. The partial e-Assessment approach reduces the marking burden during the week and assists in monitoring student engagement which can lead to timely academic intervention if required. However, challenges for teaching in this manner on this basis include the high volume of preparation involved, the intensity of the week, and scheduling constraints.

This end of module project week has improved student cognitive outcomes and behavioural outcomes. Since the move to PBL, we have for the first time recruited several completing first year students to provide paid consultancy work on behalf of the university. We have found that this novel form of assessment is very well received by students with positive feedback.

The concept of using Dewis-R to provide each student unique PBL based challenges has subsequently inspired other well-received assessments within the university, including formative assessment in the second year of the same degree programme, and summative assessment on a postgraduate data science programme. This includes additional data challenges such as other forms of messy data, and extensions to other types of analyses. We strongly believe that this PBL approach is superior to historical traditional methods. Further embedding and extensions of the PBL principles demonstrated in this paper is recommended for these modules and beyond.

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