CASE STUDY

Towards practical learning using air quality monitors

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Abstract

In this study, we explore the use of a low-cost air quality monitor as an experiment within a first year undergraduate statistics setting. The aim is to enhance student engagement and to provide a basis for both individual and group assessments. A pilot, during the summer months of June-September 2023, involved 52 volunteer students who collected indoor and outdoor air quality data. The students shared their data and analytical insights. "*Fun/enjoyment*" was frequently mentioned in student feedback, suggesting this practical approach may improve student engagement.

Keywords: active learning, statistics, engagement, air quality monitors, volunteers.

1. Introduction and Background

This case study focuses on the potential of using an improved activity in a first-year statistics course offered at a UK-based distance learning university. Several qualification pathways including economics, data science and mathematics/statistics require students to take the course and a wide range of other students taken it as an option. The course currently combines the use of printed materials with online tutorials, asynchronous forums and individual feedback on assignments from tutors. Tutorials are intended to be interactive and make substantial use of polling to engage students. For several years a home experiment, where a student measures the lengths of the roots of seedlings they have grown, has formed a part of one of the four assignments on the course.

The original learning objective for the experiment was to "*appreciate the requirements in setting up, maintaining and completing a small scientific experiment*". Participation in the experiment has shown a decline over the past few years, with current engagement at approximately 30% of active students. Students consistently express dissatisfaction with the experiment, based largely on lack of relevance and a perceived trivial nature.

A replacement activity was sought that had greater relevance, was capable of supporting both individual and group work assessment, that contributed to personal and university commitments to health and ecological issues and could run as a theme throughout the course. In the 1990's, when graphical scientific calculators were relatively expensive, the university supplied all students on an introductory mathematics module with a T1-83 graphical calculator. With this as precedence, it was hoped to issue students a monitor to use and re-use that would provide a stronger scientific element to the experiment.

The American Statistical Associations' Guidelines for Assessment and Instruction in Statistics Education (GAISE) College report (Aliaga et al, 2012) contained several key recommendations which included using projects, group problem solving and discussion activities to encourage more active learning in Statistics. Empirical evidence supports the benefits of active learning in terms of a possible 6% improvement in exam scores. Lugosi & Uribe (2022), Freeman et al. (2014), Theobald et al. (2020), Nguyen et al. (2021) all support the benefits of active learning in terms of around an 6% uplift as well as potential improvements in student engagement and enjoyment. Similar problem solving and team-

based learning are seen as excellent approaches for statistics education in higher education in the UK (Jones & Palmer, 2021).

Statistics group work, on the level 1 statistics course, could contribute to several of the university's employability framework elements. The employability framework is summarised in figure 1 and the intention is that all students have the opportunity to develop employability skills. The Royal Statistical Society and The Institute of Mathematics and its Applications, both accrediting bodies for qualifications in which this statistics course is compulsory, require students to have the opportunity to develop problem solving, communication and collaboration skills.

A final major consideration, concerning an alternative experiment, is the potential to contribute elements to other applied statistics courses, courses in other areas of the university and outside the university. An experiment that generated real, relevant data to students could contribute to analysis on second year undergraduate statistics courses such as time series and multiple regression. Furthermore, the choice of a topic which has value in environmental courses, and which has a citizen science appeal to a broader range of students, would perhaps increase the 'value' of the data.

Fine particles in the atmosphere can affect the health of individuals and of our environment (Engel-Cox et al, 2013) and there is a growing contribution of 'citizen science' projects in the field of pollutants and climate change (CERC, 2021; EEA, 2019). Therefore, a practical replacement home experiment that collected atmospheric data might be viewed as relevant to students and foster an interest beyond the boundaries of their academic work.

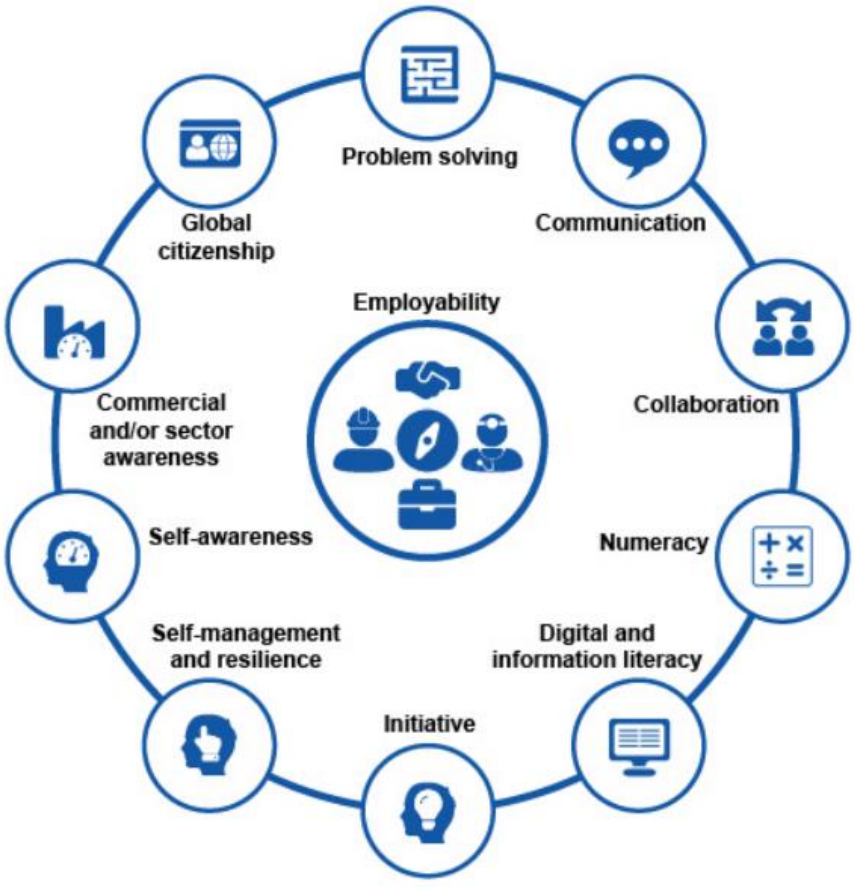

Figure 1. Employment Framework repository (source: The Open University, 2020-2023).

2. The pilot methodology

Mathematics and Statistics undergraduate students were recruited as volunteers during the summer of 2023 to collect and analyse data on atmospheric particulate matter. The aim was to evaluate the potential of this experiment as a possible replacement for the existing seedling experiment, A closed forum, accessible only to those taking part in the pilot, was the platform for sharing analyses and views on the new experiment. The forum also helped areas of joint interest emerge and hence potential group work topics.

A two-page information document was issued to any students expressing interest in the pilot. The document covered items such as safety when taking readings; the evolving nature of the pilot; the level of commitment required over the summer; and using the database. Students would only be allowed to enrol as volunteers when they confirmed they had read this document.

Legal advice indicated that students would need the express permission of the property owner and others in the household to collect indoor data. It would be impossible for us to ascertain this had been obtained on a course with 1,800 students and hence it was decided the main experiment had to be to ask students to collect outdoor data. However, as an additional activity in the pilot, students were also invited to collect indoor data with the proviso that they obtained the property owner permission.

Air quality figures are based on an average of readings taken at least every minute to provide typical real-world conditions. For the pilot we needed to provide an outdoor, portable monitor able to store readings and download them to a university server and capable of providing readings every minute.

A bespoke database was developed, enabling secure data upload and download for students. The database was required to enable students to share their data, compare it to those of their peers and to test hypotheses that the student defined and wished to investigate.

3. Results

3.1 Volunteers

A single invitation to volunteer was placed on all the websites for the statistics and mathematics courses. This resulted in 52 mathematics and statistics undergraduate volunteers across the UK and abroad. There were no financial incentives, but volunteers were informed that they could retain the monitors, if they wished to keep taking readings beyond the formal period of the pilot. We had more volunteers than monitors and so the volunteers were asked to return the monitors when they had completed their data collection. At the end of the pilot, 10 of the students had opted to keep the monitors, 16 were returned and the whereabouts are unknown of the remaining 17 of the 43 issued for student use. Of the original 52 volunteers, nine never registered to use the database and an additional three registered but failed to upload any data; these 12 volunteers were considered as non-participants in the pilot.

3.2 Air quality monitors

The intention was to produce a monitor internally but this proved impossible in the time scale. Hence we used a commercial monitor that cost on average £100 and which recorded data each minute including: temperature, humidity and two different sized particulates (PM2.5 and PM10). The monitor was powered by a rechargeable, internal battery or via a cable to mains electricity.

Information was stored in the monitor and students transferred the stored files, along with date/time of readings via cable, to their own machines. Subsequently students then loaded the data, along with location information, to the database. Only one monitor was found to be faulty although the temperature readings were misleading if the monitor had been left in direct sun. Monitors were delivered to student home addresses by standard mail systems and were packaged in an envelope that also contained a pre-paid return envelope. None arrived damaged and none were lost in the post. The monitor is shown in figure 2 with a pen shown for scale.

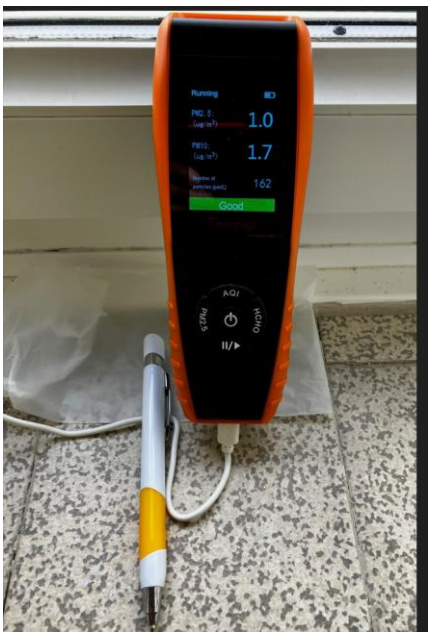

Figure 2. Commercial monitor

3.3 Taking readings, using the database and themes from forum posts

Posting on the forum was high, even though the pilot was taking place during the summer break, demonstrating students were clearly engaged and interested. Collection of indoor data only required the monitor to be plugged into a power supply, left for seven days and then the students had to upload seven files to the server. Outdoor data collection needed the student to power up the monitor each time and about 1-4 hours worth of readings were collected.

Thirty nine students posted on the forum; thirty six loaded 107 162 minute readings of outdoor data into the database and 33 loaded indoor data. Total data loaded was 571 845 minute readings.

Overall themes can be effectively split into 3 or 4 main categories. Volunteers expressed their positive feelings stating: enjoy/ment (14 mentions), fun (9), exciting (3), happy (14) in relation to taking part in the experiment. Indoor readings were affected by cook/ing (41) with the kitchen (18) and extractor (8) being noted along with fry/ing (12) and food (6) preparation in general. Database (47) and the processes of download/ing and uploading were also recurrent themes. Students also discussed pollution (16) and the effects of PM on health (5) noting the instances linked to traffic (5).

Many of these themes were interwoven in the forum threads and across time as students approached the experiments in their own time and dipped in and out of the measurements. Overall the tone of the forum was very positive, and volunteers suggested many possible ideas for comparative experiments or different ways to analyse and consider the data. These views are encapsulated in a sample of the quotes shown in section 3.4, below.

3.4 Student views

Some students expressed surprise at how much they were enjoying the pilot and several commented on the value of being able to see their own data and that of other students.

> *"Thanks for all this. I've been playing with the data in Minitab - really interesting. Can't believe that post-exam I'm this interested in using Minitab! For future M140 experiments I think there's definitely more interest for me in being able to see my data in comparison with others.*
> *"I felt M140 made efforts to use data that students could relate to, such as prices and wages. There are however limits to how current data can be and how much the data is appropriate to individual students."*
> Student 1

> *"The use of the air monitors meant that I was dealing with MY data, and it was current. It made me think much more about the circumstances of collecting data e.g. several people have commented about the impact of cooking on indoor data. It has encouraged me to experiment with different circumstances."*
> Student 2

> *"I found this experiment to be so much fun and much more interesting than the seedlings! The best part for me is the ability to collect so much data for myself, as well as access to tons of data from other students. The possibilities are endless and with such a large dataset I imagine it could be used in most units of M140."*
> Student 3

Students were specifically prompted for views on the suitability of the air quality activities as a replacement to the existing seedlings experiment.

> *"I have few comments about the statistics side of use for M140 as I am not a statistician and hate doing statistics. I loathed M140 and found it really boring, especially as it is compulsory module I would have not have chosen if I could have avoided it. I found the experiment to measure seedlings frustrating as the first lot didn't germinate and the second lot were fragile, bent and virtually impossible to measure. I just made the results up in the end.*
> *"I think from my point of view the air quality measuring would be a huge improvement, especially if it formed a recurring theme throughout the module. There would need to be lots of background information available so people could understand what the various measurements meant and the implications for human health, the environment etc. I have got really interested in the whole thing and am keeping the monitor for a bit to do some investigation of whether high particle counts in the countryside might be caused by pollen."*
> Student 4

> *"I have run another week indoors, and uploaded the data. I had the monitor in the same place as before but this time with a new cooker hood/extractor fan in the kitchen but also with a wood burning stove going in the evening in the living room where the monitor was for the last 3 days. Having had some spectacular PM readings frying bacon without a cooker hood in the first indoor week, the results this time round have persuaded my partner of the benefits of using the new cooker hood! I was surprised that the wood burning stove produced a lot less particles than the cooker hood-less bacon frying.*
> *"I shall be returning the monitor now. Have really enjoyed participating in this and as others have said I think it has great potential for M140 - though as a smallholder with a large veg plot I rather enjoyed growing mustard!"*
> Student 5

4. Discussion and conclusions

This pilot, undertaken at a distance learning institution, faced both unique challenges and advantages in terms of organisation and implementation. All communication had to happen asynchronously; we could not hold a physical meeting for the students to meet each other and to bounce ideas around with each other. But on the other hand, students were used to volunteering and comfortable with working in forums. It was relatively easy to recruit 52 volunteers, with no financial incentive, to think about statistics in their summer vacation.

In terms of scaling up to all students on the first-year statistics course, there are three broad areas to consider: the monitor, the database and the incorporation into teaching materials. A suitably priced monitor, whether built to an OU design or an existing commercial monitor, has still to be agreed, and it would be included in the current dispatch of course materials to students from our warehouse. Students would keep the monitors rather than return them for re-issue. Monitor costs are directly related to student numbers.

The database would require re homing on a different university server that was able to deal with a greater student loading. Little change would be needed to the current design of the database as it is already fully compliant with security and IT standards. The process of moving the database to a more permanent location is underway and will be relatively low cost although there will be ongoing maintenance costs which are largely independent of student numbers.

The biggest area, regardless of student volume, is that new assessment and teaching materials would have to be developed. These, and the existing student facing materials, would need to go through our formal learning development and accessibility, design and approval process. The intention was that the new experiment would be suitable for group work, and this is potentially more difficult to arrange at a distance learning institution than at other HE establishments. We will be separately trialling group work using the existing experiment and a parallel database, with volunteer students and tutors in March/April 2024.

A clear limitation of the piloting was that it was undertaken by volunteers in the summer recess. There is no way to ‘prove’ if participation would be greater than the current level of 30% of active students. However, the topic would seem to have wider appeal than the root lengths of seedlings grown in the light or the dark. Engagement was high, with 43 of the 52 volunteers registered to use the database and 39 successfully uploaded data. Ten students opted to keep the monitor to take further readings. The forum was very active and additionally some students directly emailed staff members.

The experiment actively engaged students in terms of generating their own hypotheses; communicating and collaborating with other students to investigate ideas; problem solving (especially in terms of the database); and working on the global issue of particulate levels. The data collected certainly involved data suitable for regression, time series and geographical analysis and the potential contribution to other environmental focussed courses is still being investigated.

The benefits to the students in terms of academic and professional development seemed considerable with many having concrete links to employability skills such as problem solving, critical thinking, and collaboration (see figure 1). Students seem to value the opportunity to take part in the investigation of a better experiment for future students and to explore their own questions about comparisons of their data to that of fellow students.

5. Ethics Statement

This study was considered a low-risk study and meets The Open University Human Research Ethics Committee (HREC) criteria for exemption from formal review (reference number: HREC/4775/Calvert: air quality monitoring), http://www.open.ac.uk/research/ethics/.

6. Acknowledgments

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