CASE STUDY

Whole Student Cohort Co-creation of Industry-Based Assessments in an Applied Mathematics Module to Promote Student Engagement Through Belonging

Thomas Hobson, School of Engineering and Physical Sciences, University of Lincoln, Lincoln, UK. Email: ThHobson@lincoln.ac.uk
Julia Cropper, School of Engineering and Physical Sciences, University of Lincoln, Lincoln, UK. Email: JCropper@lincoln.ac.uk
Fiona Bissett, Libraries and Learning Skills, University of Lincoln, Lincoln, UK. Email: FBissett@lincoln.ac.uk

Abstract

Student engagement has been shown to be impacted by a student's sense of belonging. As part of a wider initiative to enhance belonging amongst students on Mathematics, Physics and Engineering Foundation Year programmes, the Applied Mathematics team implemented a new assessment strategy using group-work and co-created industry contexts. The team co-created the industrial contexts with the whole student cohort, resulting in five industry themes. These themes were then used to develop five versions of a written test, with each version having questions contextualised to one of the five industry themes, and five versions of a group piece that each tackled a problem from one of these industries. Qualitative feedback from module evaluations suggested a positive impact on students. Additionally, the final exam, which was comparable with the previous year, saw an increase in attendance of 21% and increase in average attainment of 10%, suggesting a positive impact on student engagement within the module. However, this formed part of a wider initiative to promote student engagement through student belonging, and therefore these increases cannot be solely attributed to this assessment strategy.

Keywords: Student Engagement, Belonging, Co-creation, Employability, Group-Work, Assessment.

1. Introduction

Student belonging has been recognised as an integral part of the student experience, impacting student success, retention, and wellbeing (Thomas, 2016; Freeman et al., 2007, Skipper and Fay, 2023). Institutions have been encouraged to adopt strategies that foster a student's sense of belonging both outside and inside the classroom (UPP Foundation, 2021). This sense of belonging has been shown to correlate with student engagement (Webster, 2022; Gillen-O'Neel, 2021), with student engagement/dis-engagement being associated with attainment (Saqr et al.,2023).

Jackson, Capper and Blake (2022) argue that connection is fundamental to promoting this belonging; students who feel connected to their peers and their course are enabled to build support networks and develop confidence. Brown and Pawley (2024) find that students feel that community within a module or programme is the most important connection. One suggested mechanism to build connection is the use of groupwork and using employability themed groupwork has been shown to promote student engagement (Fairfax, 2022). Along with building connection, groupwork can build important skills for employability, even if students sometimes dislike this form of assessment (Francis, Allen and Thomas, 2022). A survey of employers by Quacquarelli Symonds (2022) found that the ability to work as a team was one of the top five most important skills employers are looking for in graduates.

Inclusion is key to developing a sense of belonging (Jackson, Capper and Blake, 2022), with students associating inclusive materials with a course's credibility and how well the course prepares them for the workplace. Co-creation has been shown to promote more inclusive practices (Mercer-Mapstone et al. 2017) with academics globally partnering with students to enhance the student experience (Reid et al., 2024). Bovill (2020) argues that whole class co-creation results in a more inclusive experience when compared with co-creation that only involves a smaller group of 'already-engaged' students. These engaged students often do not represent the breadth of experience and characteristics seen in the entire cohort. By using whole class co-creation, the views and opinions of a wider range of student backgrounds are taken into consideration. Blake, Capper and Jackson (2022) argue co-creation should become 'standard practice', with co-creation shown to be impactful in mathematics curricula (Morgiane and Brady – Van den Bos, 2024). This co-creation supports autonomy, another key factor in fostering a sense of belonging (Blake, Capper and Jackson, 2022).

In the 2023/24 academic year, staff teaching on Mathematics, Physics and Engineering integrated Foundation Year programmes at the University of Lincoln set out to enhance student engagement through initiatives to promote student belonging. The ~65 students enrolled on these programmes study a module entitled 'Applied Mathematics'. This module is designed to encourage students to use the learned mathematical content in context, preparing them for application throughout their programme. The students also study a second module in Mathematics, along with Physics or Chemistry and Study Skills. The Applied Mathematics team implemented a new assessment strategy to promote engagement through the use group work and embedded industrial contexts. The team used whole class co-creation to develop assessments that reflected the aspirations of the entire cohort. This approach aimed to promote inclusivity and student autonomy, which both foster a sense of belonging and thus enhance student engagement.

2. Student Co-creation Process

The students were introduced to the idea of a co-created assessment during one of the key lectures at the start of the year. The philosophy behind the co-created assessment was shared with them, with a particular reference to the desire to increase their sense of belonging and connection with the course. The students were surveyed to determine their career of interest, and these were collected into five different industries. Each student was issued with a post-it note on which they were invited to write down their first choice of career. The option to state 'unsure' was made available in order to avoid any pressure on those who were undecided. The students have several years of study ahead of them and this activity acts partially as a springboard to support them to begin to explore the careers that may be of interest to them.

The collected post-it notes were gathered into groups according to industry themes; these themes covered all the career paths that the students had stated. Since all the students were enrolled on Maths, Physics or Engineering programmes, the range of planned careers was limited, and this made it easier for the industry themes to be coordinated. These themes were:

- Aerospace Engineer.
- Astrophysics Lecturer.
- Biomedical Engineer.
- Mathematician.
- Renewable Energy Engineer.

In order to ensure that all students felt that they had been represented and to maintain the importance of inclusivity and belonging, the themes identified were shared with the students at the following lecture and they were invited to select which they felt best suited their career plan, again using post-it notes to gather responses. If a student felt that their preferred industry had not been included, then they had the opportunity to re-state their original choice.

If any students had not been happy with the options available then individual discussions would have been had with students to explain the options in more detail, and if necessary, provide additional test choice, however on this occasion the students were all happy with the options available and the industries listed above were used as a basis for the design of the assessments.

3. Assessment 1 – Industry based written test

The first assessment of the year, worth 30% of the module, included an online assessment followed immediately by a paper-based test, each equally weighted. The online section was as in previous years and assessed the underpinning mathematical skills through traditional questioning. The second part was written in five versions to incorporate each of the five co-created industries. Questions in this paper were contextualised and required more interpretation than the online section. Students were introduced to contextualised questions throughout the module in seminars, workshops and independent learning materials. The students were given the choice as to which one of the five papers they completed.

The five versions of the paper-based assessment included questions which related directly to the industry selected by the student. Each version contained questions with the same level of challenge and testing the same mathematical skills but with a context relevant to the industry of the title. By providing questions themed to the selected industry it was hoped that each student felt the content was relevant to their particular interest. The areas being assessed (probability, trigonometric functions and matrices) are all areas of mathematics that can easily be adapted to apply to a range of career paths and hence it was possible to find questions that were suitable for each of the options available to students. Three of the questions (out of six on each paper) were written to relate to the industry selected by the student. For example, the ‘Aerospace Engineer’ paper contained questions relating to detection of radar, orbit of a satellite (Figure 1) and drag forces acting on the wing of an aircraft, while the ‘Renewable Energy Engineer’ paper included questions that related to nuclear reactor accidents, wind turbines (Figure 2) and damage of electricity pylons.

Concerns about a potential lack of parity between the question papers were allayed by a thorough moderation process and analysis of the results of the papers after the students had completed the test. The analysis verified that the scores obtained by students were independent of their choice of paper.

In view of the length of time between the original invitation to select a career and the date of the assessment (the initial choices were presented at the beginning of the academic year in October, while the assessment did not take place until January) students were able to select an alternative assessment paper. This allowed for those who had altered their plans since the first choices were offered to update their selection.

The inclusion of the selected industries in the assessment was designed to reduce anxiety among students and to increase their sense of belonging. It was well received and appears to have succeeded in its goal. Students were advised in advance that they would be able to choose from one of five papers, and they appeared to enjoy making this selection on arrival; the reduction of the anxiety that they felt upon entering the room was visible. Feedback on the assessment was positive, with one student stating, *“I really enjoyed the industry-based exam … it was a really good way of experiencing what it would be like to problem solve in these industries”*.

5. A satellite's orbit traces an elliptical path around Earth.

The following pair of parametric equations model the path of the satellite:

$$x = \cos(t), \qquad y = \frac{9999}{10000}\sin(t)$$

where t is time after 12:00.

The coefficient of $\cos(t)$ is Earth's semi-major axis, the coefficient of $\sin(t)$ is Earth's semi minor axis.

Figure 1. Excerpt from the Aerospace Engineer question paper.

5. The blades of a wind turbine spin in a circular motion.

The following pair of parametric equations model the path made by the tip of one blade:

$$x = 52\cos(t), \qquad y = 52\sin(t)$$

where t is time after the blade starts spinning.

The coefficient of $\cos(t)$ and $\sin(t)$ is the length of the turbine blade.

Figure 2. Excerpt from the Renewable Energy Engineer question paper.

The workload in producing and moderating five different papers was significant for the three staff involved and should be a consideration for a team embarking on a similar project. Industries unfamiliar to the team required the most research to create authentic questions. The internal verification required in ensuring papers were of equal challenge was equivalent to the process that takes place to ensure assessments are of equal challenge between academic years. However, it was found that having established a process for producing these assessments the workload was reduced for the following year.

4. Assessment 2 – Desirable employer skills group work

The second assessment of the module, worth 10%, took place in April and was a live group work piece that assessed the students across the top five skills desired by employers, which were taken from the Quacquarelli Symonds 2022 report 'What do employer's want from today's graduates?' (2022, 9):

- Interpersonal Skills.
- Team Working.
- Problem Solving.
- Flexibility.
- Communication.

The students were asked to choose in advance one of the five available industry areas for this assessment, allowing them to select a different area from the previous assessment. They were then timetabled to the appropriate session. Sessions were deliberately timetabled in rooms that allowed the students to work in groups around a table, with space to move around and access to a whiteboard. In the lecture prior to the assessment students were provided with all the required information and most importantly advised that the assessment would begin at the moment they entered the assessment room; this was in order to model the environment experienced at an interview or meeting within an industrial context.

Upon arrival the students signed in and were allocated to a small group of four to six students. The students were purposely placed in groups with people outside of their friendship group and some time was allocated to networking which allowed the students to showcase their interpersonal skills. The students were observed during this time and were allocated a mark for interpersonal skills. Part of the aim of this was to encourage students to build connections with people on their course that they may not have interacted with previously. This provided an opportunity for students to make new connections and friends, which was particularly supportive for students who were still struggling to foster these relationships. Anecdotally, staff recognised students who had previously sat alone in lectures sitting with students from their problem-solving assessment group.

A short briefing outlined the session timetable and introduced the problem scenario. A different scenario was devised for each of the five industry areas which, briefly, were:

- Aerospace Engineer: You have been asked to design landing gear for a new aeroplane. This landing gear is under the wing and retractable. Mathematically model the movement of the landing gear.
- Astrophysics Lecturer: You need to run a session on the impact a passing meteorite would have on Earth's orbit. Calculate the distance between the Earth and the meteorite passing in a straight line.

- Renewable Energy Engineer: You are designing a robotic dog to replace humans to address maintenance situations in radioactive areas of a Nuclear Power Plant. Mathematically model the movement of the legs of the robotic dog.
- Biomedical Engineer: You have been asked to design a prosthetic arm. Mathematically model the position of the wrist as the arm moves.
- Mathematician: A Euler Brick is a cuboid where the length, width and height are all integers, and all face diagonals are also integers. Explore the properties that a Euler Brick must have.

It was made clear to the students that they were not expected to completely solve the problem, but that they should investigate how they would begin to tackle the problem in their small groups using the mathematical skills that they had acquired during the year and their employability skills. A variety of props were made available for their use if they wished, including paper and pen, balls, string, tape, boxes, stationery, whiteboards etc. and some students chose to use their laptops/devices. The assessment was open book, and students were invited to access any resources that they thought would support them in completing the task.

The students were observed to assess how well they interacted and worked as part of a team. Part way through the problem-solving phase a 'telephone call' was received which added new information to the scenario. This changed some aspect of the problem and was used to assess how flexible the students were; could they adapt to the required change?

After the allotted problem-solving time, the groups were given a short time to prepare and informally present their findings to the wider group, ensuring that every member had the opportunity to speak. Their communication skills were evaluated at this point. Once all the groups had presented, some feedback on the problem was provided and there was a brief discussion around the different approaches taken. After the students had left the room, their problem-solving skills were analysed by looking at the pages of working and/or models that they had produced.

The marking rubric was deliberately designed to be simple to use. A marking grid for each student that included the five skill areas was completed during and immediately after the assessment. Each marking point could be awarded 0 – 'does not meet standard', 1 – 'sufficiently meets standard', 2 – 'exceeds standard'. This method was chosen as it reflects the shortlisting practice for hiring at our institution, again linking the assessment to industry. The simplicity of the marking rubric meant that the marks were finalised shortly after each of the sessions.

This assessment was enjoyable and was well-received by the students and staff involved. Whilst some students seemed a little nervous when they first entered the room, the students relaxed for the most part and were smiling and laughing during the assessment, particularly when the fake 'phone call' altering the scenario came through. The team were conscious of students with support plans however, no adjustments were required in this iteration owing to the inclusive nature of the assessment. In future iterations, if any support plans require adjustments to the assessment the team will respond to any support requirements accordingly.

Students commented on how much they had enjoyed the session, and that it had been the best assessment they had ever done. One example comment *"[the best thing about this module was] the student-led assessments at the end of the year, giving us a chance to work together on industry related problems"*.

5. Conclusion

The Applied Mathematics team set out to use co-creation and industrial contexts to design, develop and implement an assessment strategy that fostered a sense of belonging amongst students. This formed part of a wider strategy to develop belonging in students on Mathematics, Physics and Engineering Foundation Year programmes with the ultimate aim of improving student engagement. Student feedback for this module suggested the initiative had a positive impact on the student cohort, with practitioners observing benefits to student engagement with both the module content and with their peers. Attendance at the final exam (a comparable assessment to academic year 2022/23) increased from 77% to 98% suggesting an increase in student engagement. Additionally, average attainment increased by 10%, suggesting students also saw impact on their learning. It should again be noted that this assessment strategy formed part of a wider initiative, so these results cannot be solely attributed to this innovation. A formal study is being considered for a future iteration however, this paper outlines a case study of how initiatives implemented to aid student belonging can support students to engage and attain.

6. References

Blake, S., Capper, G., and Jackson, A., 2022. *Building Belonging in Higher Education: Recommendations for developing an integrated institutional approach*. London: Wonkhe Ltd and Pearson. Available at: https://wonkhe.com/wp-content/wonkhe-uploads/2022/10/Building-Belonging-October-2022.pdf [Accessed 10 January 2025]

Brown, C. and Pawley, S., 2024. How important is community to mathematics and statistics distance learners? *MSOR Connections,* 23(1), pp. 45-59.

Bovill, C., 2020. Co-creation in learning and teaching: the case for a whole-class approach in higher education. *Higher Education*, 79, pp.1023-1037.

Fairfax, S., 2022. Improving student engagement through employability themed group work. *MSOR Connections,* 21(1), pp. 23-28.

Francis, N., 2022. *'I love group work'… said no student ever!* York: Wonkhe Ltd. Available at: https://www.advance-he.ac.uk/news-and-views/i-love-group-worksaid-no-student-ever [Accessed 10 January 2025]

Freeman, T., Anderman, L. and Jensen, J., 2007. Sense of Belonging in College Freshmen at the Classroom and Campus Levels. *The Journal of Experimental Education*, 75(3) pp.203-220.

Gillen-O'Neel, 2021. Sense of Belonging and Student Engagement: a Daily Study of First- and Continuing- Generation College Students. *Research in Higher Education*, 62 pp.45-71.

Jackson, A., Capper, G. and Blake, S., 2022. *The four foundations of belonging at university.* London: Wonkhe Ltd. Available at: https://wonkhe.com/blogs/the-four-foundations-of-belonging-at-university/ [Accessed 1 November 2024].

Morgiane, R. and Brady–Van den Bos, M., 2024. Student Co-Creation of Resources in a Second Year Linear Algebra Course. *MSOR Connections,* 23(1), pp. 60-69.

Quacquarelli Symonds, 2022. *What do employers want from today's graduates, Insights from the 2022 Global Employer Survey*. Quacquarelli Symonds. Available at: https://www.qs.com/reports-whitepapers/what-do-employers-want-from-todays-graduates-2/ [Accessed 29 November 2024].

Reid, F., Hunt, J., Chow, M. H. M., Henry, T., Matthews, K., Douglas, T., Campbell, C., Rodgers, T., Faulkner, S., Dombi, E., Jones, L., McMichan, L., Melville, G., Pather, S., Estêvão, M. D., Terwilliger, B., Faulconer, E., Deters, R., Chamberlain, D., Millmore, A., Tang, A., Wong, G., Wang, M., Hamidi, S., Arm, K., Ladipo, K., Wilson-Scott, J., Pryor, M., Besson, M., Turi, S., Perkins, J., Skopelitis, A., Hicks, S., Aftab, Z., Bovill, C., Waddington, K., Smeltzer, S., Ansari, A. N., Iftikhar, F., Moulton, J., Ross, J., Matthews, A., Willmers, M., Davison, E., Hobson, T., Iannucci, C., Lomine, L., Hervey, T., Lewitzky, R., Majeed, A., Briggs, S., Pol, H., Sum, K., Johannes, C., Yeung, T., and Parkin, J., 2024. Voices from the field: How did you come to engage in students-as-partners work?. International *Journal for Students as Partners*, 8(2), pp.241–259. https://doi.org/10.15173/ijsap.v8i2.5872

Saqr, M., Sonsoles, L-P., Helske, S. and Hrastinski, S., 2023. The longitudinal association between engagement varies by time, students' profiles, and achievement state: A full program study. *Computers & Education*, 199 104787. https://doi.org/10.1016/j.compedu.2023.104787

Skipper, Y. and Fay, M., 2023. The relationship between the sense of belonging, mental wellbeing and stress in students of law and psychology in an English University. *European Journal of Legal Education*, 4(1), pp.5-26.

Thomas, L., 2016. Developing Inclusive Learning to Improve the Engagement, Belonging, Retention, and Success of Students from Diverse Groups. In: Shah, M., Bennett, A. and Southgate, E. (eds) *Widening Higher Education Participation: A Global Perspective*, Whitney: Chandos Publishing, pp. 135-159.

UPP Foundation a 2021. *Turbocharging the future – The interim report of the UPP Foundation Student Futures commission*. London. Available at: https://upp-foundation.org/wp-content/uploads/2021/10/Turbocharging-the-future-.pdf [Accessed 10 December 2023]

Webster, H., 2022. *Building Student 'Belonging'.* York: AdvanceHE. Available at: https://www.advance-he.ac.uk/news-and-views/building-student-belonging [Accessed 10 January 2025].