Implementation of Enquiry-Based Activity Modules for Authentic Learning in Engineering

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SUMMARY

Engineering education in the UK is evolving, moving away from traditional lecture-based teaching towards more engaging and practical methods. The purpose of this is to develop problem-solving and teamworking skills in a practical, authentic environment. Activity-based learning is gaining popularity as a way to better prepare students for real-world challenges. Northumbria University's Mechanical and Automotive Engineering programmes have embraced this approach by introducing dedicated activity-based learning modules in 2021. Activity-based learning emphasises practical skills, integrating labs and hands-on experiences. This bridges the gap between theory and practice, helping students apply their knowledge effectively. It fosters collaboration and teamwork, encouraging students to work together to solve problems and share ideas. The engineering programmes at Northumbria University include two 20-credit activity-based learning modules in foundation year and each of the first and second years of the main programmes. These modules become more complex and interdisciplinary as students' progress. Assessment methods include technical reports, presentations, posters, and practical demonstrations. Despite its advantages, activity-based learning presents challenges, primarily around resourcing of space, equipment and materials. To overcome this, student interns helped review and develop a student-led maker space, a central hub for practical activities. This approach ensures that activities are engaging, relevant, and academically rigorous while creating a collaborative and creative environment. In summary, activity-based learning is a promising approach to engineering education in the UK. By emphasising practical skills, teamwork, and diverse assessment techniques, it better equips students to address complex issues and drive innovation in the field. This shift in pedagogy prepares students more effectively for the demands of the modern workplace.

INTRODUCTION

In 2021, undergraduate programmes in Mechanical Engineering at Northumbria University were redeveloped to provide a more engaging and authentic student experience. This comprises the Engineering Foundation Year (L3), and BEng/MEng Mechanical Engineering and Automotive Engineering programmes (L4-7). The motivation for change was primarily poor NSS results, however graduate readiness data and outcomes were also factors. Activity-based learning was adopted to address these challenges. At its core, students work in small groups to solve a series of authentic engineering problems, drawing on their knowledge of subject areas to develop innovative solutions. The programmes include dedicated activity-based learning modules that supplement the more conventional subject-based modules. These new modules have the aim of providing students with a more well-rounded education that emphasises practical skills and real-world problem-solving. Activity-based learning (Hattie & Anderman, 2013) is an educational approach that focuses on active engagement and participation by students in the learning process. It centres on hands-on, practical activities and experiences rather than traditional lecture-style teaching. In activity-based learning, students are actively involved in various tasks that require them to apply their knowledge, problem-solve, and collaborate with peers.

LITERATURE REVIEW

The foundations of activity-based learning can be traced back to the Progressive Education Movement, which emerged in the late 19th century and advocated for a more student-centred approach to education (Montessori, 1912; Cremin, 1959). In the mid-20th century, Kolb (2014) introduced the concept of experiential learning where knowledge is continuously gained through experiences, reflection, and experimentation. The late 20th century saw the rise of constructivist theories of learning (Sjøberg, 2010). Here, learners construct their understanding through active engagement with authentic problems. Active learning methods, such as problem-based learning and collaborative group work, gained popularity during this period.

Activity-based learning modules at Northumbria are inspired by the work on problem-based learning implemented at The University of Manchester in the early 2000s (Crowther *et al.*, 2001; Lennox *et al.*, 2002) and take this further by focusing more on practical outcomes. This enables students to link theory with practice and gain a better appreciation of how engineers work in the real world.

CONTEXT: THE ENGINEERING EDUCATION PROBLEM AND INTERVENTION

From the beginning, a holistic view (Shapiro, 2003) of the student journey was constructed and the overall educational framework of the programmes was designed from the ground up. Existing issues were not insignificant. It was found that in addition to low NSS scores, students were not applying for industrial placements and did not feel ready to enter the workforce upon graduation. Based upon discussions with students and teachers, it was clear that there were overarching and deep-rooted issues. Overall, students were anxious about going on and applying for placements and about their next career progression point. Two distinct themes emerged as underlying causes:

First, students lacked confidence in their learning and skills and were unconvinced of their achievements throughout their programme of study. This led to a desire from students to be spoon fed exam questions and solutions, mirroring their experience in high school. As a result, colleagues had adopted teaching sessions focused more on transference of knowledge (lectures) and rote learning of theoretical concepts (seminars) with students lacking in practical and problem-solving skills. Passive sessions meant feedback was lacking, and students were unable to build their confidence. Consequently, attendance and engagement were low, fracturing the staff-student community.

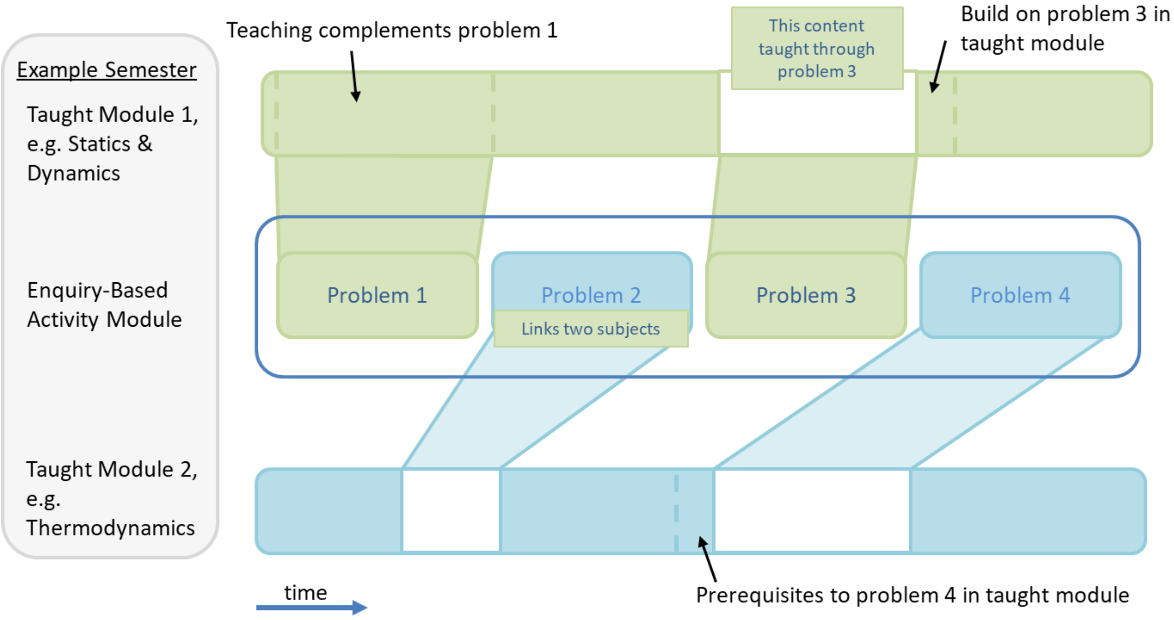
Secondly, expectations on students were unclear, leading to anxiety. Modules were not linked, and teams rarely interacted with one another leading to inconsistency in teaching and assessment. Students struggled to see how all the modules fit together to form a coherent subject.

A new programme framework was developed to address these issues. The aim of the new programmes is to produce confident, technical communicators by adopting an application focused curriculum where students take more responsibility for their learning. There is a greater emphasis on the learning community and higher value staff-student contact that is enabled through technology and innovative practice. The programmes encourage students to practice the Engineering Habits of Mind (Lucas & Hanson, 2016) through authentic activities and assessment, opportunities for creativity, adaptation, and improvement.

DESCRIPTION OF PRACTICE

Two types of modules are delivered on the programmes. The first is a more typical subject specific module delivered in lectorial sessions (Thalluri & Penman, 2018), a mix of lecture and seminar/tutorial, to encourage problem solving and critical thinking. Subject themes are interconnected by the second type: activity-based learning modules where students work together in small groups to apply knowledge and skills from a range of engineering subjects to produce practical solutions to authentic engineering problems. As well as developing teamworking and communication skills, this provides a clear link between different modules across the programme (figure 1). Practical solutions also give the students a sense of accomplishment that they can physically see and touch.

Figure 1. Example of a semester containing an activity-based learning module



At levels 3 & 4, students tackle short, well-defined activities (see figure 2 for examples) that introduce fundamental knowledge and skills. Each activity focuses on a single engineering subject, which when brought together introduce students to the breadth of engineering subjects. This is done to build student confidence in fundamental topics and themes. For example, in semester 1 students build a water-powered bottle rocket with the aim of launching an egg as high as possible without breaking it. At level 5, activities become more broadly defined and incorporate several subjects to produce more authentic outcomes (see figure 3 for examples). For example, in semester 1, students design, make and test a portable wind turbine for remote sensing applications. At this point, students have tackled a wide range of problems and have a good idea of their interests. At level 6, students undertake their individual Investigative Project that brings together knowledge and skills from across the programme in their chosen area of interest, and at level 7, students complete a group Interdisciplinary Project that involves a live project with industry stakeholders. Increasing complexity and authenticity of problems builds student confidence over time and gives reassurance that their programme is preparing them appropriately for a career once they graduate.

Figure 2. Example first-year activity outcomes

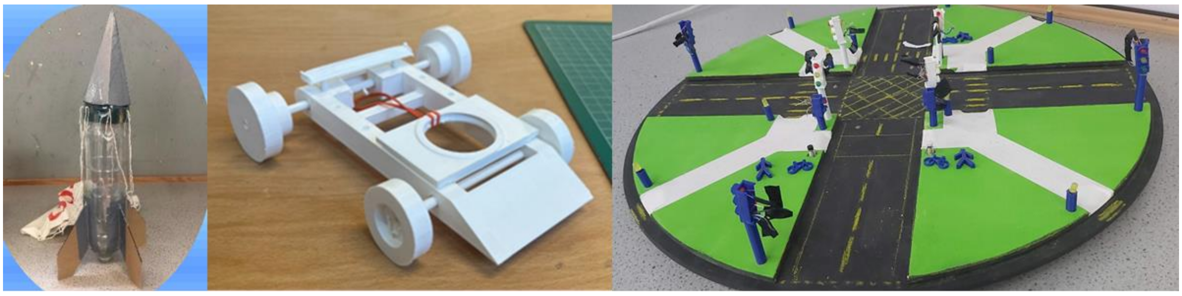


Figure 3. Example second-year activity outcomes

A significant barrier to implementing this new approach is the challenge of change. The programme documentation provides the framework, but it is also critical to provide essential resources, including both physical and staff support (Devecchi *et al.*, 2018). To facilitate the provision of the new programmes, great attention was placed on the learning environment. An appropriate learning environment should focus on "what the student does" not "what the teacher does" (Biggs, 1999). Considering this, all use of tiered lecture theatres was removed from the programmes with the goal being to move away from "sage on the stage" type delivery (King, 1993).

Figure 4. Activity-based learning and Maker Space

To facilitate activity-based learning, the primary goal was to provide a safe space for discovery where students are not afraid to fail. The space is a large area that promotes creativity and curiosity to explore solutions (figure 4). Hand tools are provided alongside equipment such as 3D printers, a laser cutter and soldering station. The space is located near a computer hub and laboratories for more specialist tasks. Two student interns were employed to help develop the space into an activity hub and student-led Maker Space where students can work on practical projects. Student reps manage the space and provide training to attendees to ensure safe working practices. It is envisaged the Maker Space will eventually act as a hub for the whole university and offer outreach activities to the wider community.

EVALUATION OF PRACTICE

The programmes have not yet completed a full student cycle, so NSS and graduate outcomes data is not available. Anecdotally, students are happy with their programmes and learning environment. Teaching staff have observed that students are more confident than previous cohorts and are willing to engage with practical work more readily. Internal module survey data supports this with activity modules scoring well.

In April 2023, the programmes received an accreditation visit from the IMechE aligned to AHEP4. The programmes were accredited with the following commendations:

The department is commended for its:

- bold, activity-led approach to teaching and learning.
- attempt to develop a better teaching and learning community.
- ongoing work with industry, especially the development of teaching and learning developed and delivered in partnership with industry.

DISCUSSION

Overall, the introduction of activity-based learning modules has been a success. Teachers and students have embraced the approach and the improvement in the practical skills and confidence of students is striking. Some academic staff were reticent about switching to a 'guide on the side' role and the uncertainty that brings, but through strategic allocation of module leads and peer mentoring, these worries were alleviated. A small number of students did report in an end-of-module survey that they wanted more lectures in activity modules. This is believed due to students being out of their comfort zone in the 'learn by doing' environment, therefore, students were given increased supervision to provide more focus and direction to groups without telling them explicitly how to solve an activity.

To determine the effectiveness of this approach in a more rigorous way, the next stage of work is to complete the action research cycle through focus groups with students to provide a qualitative understanding. NSS and graduate outcome data will provide a quantitative summary of progress.

CONCLUSIONS & RECOMMENDATIONS

The following recommendations to implement activity-based learning into an engineering curriculum are offered:

- Dedicated activity modules provide a focus for staff and students. These modules deliver a core learning stream that promotes engagement and inclusion.
- Facilities are essential. Students require access to a practical area where they can work largely unsupervised. Sessions should still be timetabled to promote regular attendance and reserve facilities.
- Staff training is key. Module leads must be well-organised and able to manage resources, facilities, and relationships with colleagues. Collaboration with technical staff is essential for smooth delivery.
- Enjoy it! Activity-based learning is rewarding for both students and teachers and provides a more collegiate and vibrant staff-student community.

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