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Using Systems Thinking To Design Education To Make A Difference – A Progress Report

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USING SYSTEMS THINKING TO DESIGN EDUCATION TO MAKE A DIFFERENCE – A PROGRESS REPORT (PRACTICE)

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ABSTRACT

The Birmingham Centre for Rail Research and Education (BCRRE) delivers research and education to benefit the international rail industry, including an MSc programme which is designed to equip students with the skills needed to lead multidisciplinary engineering projects. The authors are trying to apply some of the systems thinking taught in the programme to the programme itself. It is established practice to maintain learning outcomes for an educational programme and we do that, but we describe how we are trying to improve the information available to us about what the industry wants and the varying needs of our student population. Our information-gathering processes are not just passive feedback loops but are actively focussed on areas of interest. We are also using the V diagram (a systems engineering concept) as a framework for maintaining line of sight to the full set of

feedback information in order to assemble a richer picture to support more balanced decision-making. We describe how our approach is already producing richer input which we are using to improve our programme and why we are encouraged that our approach can make a positive difference to achieve a better educational experience in engineering disciplines.

1 INTRODUCTION

In this paper we describe our experience of applying some aspects of systems thinking to an MSc programme.

1.1 The Railway Systems Engineering and Integration MSc programme

The Birmingham Centre for Rail Research and Education (BCRRE) delivers education and carries out research that is intended to benefit the rail sector in the UK and worldwide. All three authors work at this institution where we are involved in the delivery of education as well as research into issues related to the delivery of education.

Railways are very interconnected systems. The trains, the track, the signalling, the stations, the timetable and many other things all work tightly together such that changing one part can very easily upset another. The different parts of the railway are looked after by different disciplines. As a consequence, in order to successfully deliver a project that will change the railway, it is necessary to manage the interfaces between the parts of the railway and co-ordinate the disciplines.

In other sectors, such as defence and aerospace, there has been, for more than half a century, a specialist discipline concerned with this management and co-ordination called ‘systems engineering’ (SE). As modern technology drives an increase in complexity and interconnectivity in railways, railways are increasingly coming to realise that they need to adopt the principles of SE in order to avoid expensive mistakes.

BCRRE’s educational offerings include an MSc programme in ‘Railway Systems Engineering and Integration’ (RSEI) on which students obtain a grounding in SE.

1.2 Systems engineering and systems thinking

SE involves obtaining a clear and accurate understanding of what is wanted from a system and then systematically focussing design, implementation and testing on delivering that.

The approach is often illustrated as a ‘V diagram’ and fig. 1 indicates how this might look for a project to replace some railway signalling. In the figure, time runs from left to right and the vertical dimension indicates ‘granularity’ with activities relating to the whole system at the top and activities related to parts of the system at the bottom.

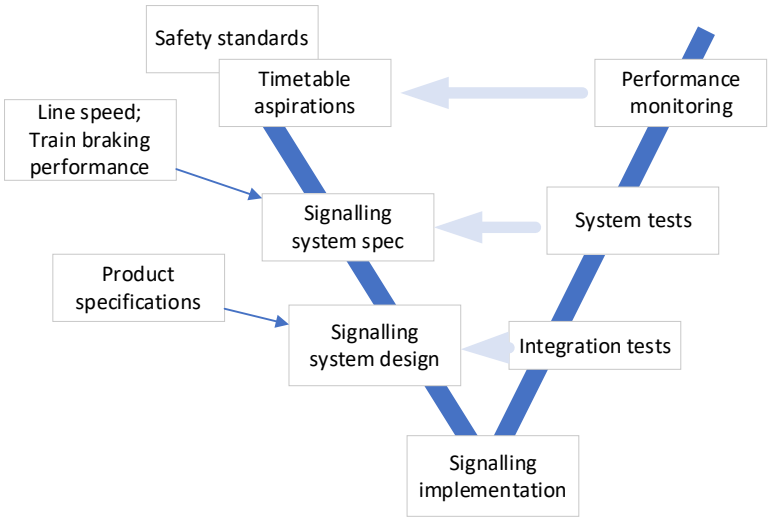

Fig. 1. A simplified V diagram for a signalling project

The activities on the left-hand side of the ‘V’ cover specification of the system and its components followed by design and implementation of the components. The activities on the right-hand side of the ‘V’ cover putting the components to work together and checking out the components and the system.

No system exists in a vacuum and the thin arrows coming in from the left indicate facts about the real world which need to be taken into account, if the system is to be successful.

If sufficient records are kept of the process, anyone designing or testing part of the system can establish how their work contributes to the overall objectives. One sometimes says that there is ‘line of sight’ to the objectives. Then, if the objectives or context, or our understanding of these things, should change, the V diagram provides a framework for efficiently and effectively changing the system in response.

In this paper the authors will explore how the V diagram and some of the ideas behind it might be used as a framework for efficiently and effectively changing the RSEI MSc programme rather than a technical railway system.

2 CURRENT PRACTICE

There has been a growing understanding of the importance of systems thinking as a requirement for successful engineers (McNaughton 2022) and the teaching of engineering has been moving away from reductionism and toward a more holistic perspective, with a need for engineers to have a broader knowledge of areas associated to their own and their interrelated systems. Thought has been given to teaching systems thinking both within engineering and other disciplines (Ravi et al. 2021) however the authors have found little consideration of how systems thinking could be used to improve teaching practice. If one accepts that systems thinking is an important skill for the engineer to develop, then thought also needs to be given to how a learning environment should be planned in order to facilitate its learning.

Of course, the principles underpinning the V diagram have already been partially adopted in further education. It is normal practice (Barkley and Major 2022) to define learning outcomes for an educational programme and then design the programme to meet these outcomes. Learning outcomes are based on what the learning institution and relevant advising bodies believe learners need to know. However, before embarking on or funding a period of education, students and their employers will normally have personal and business learning outcomes they hope to achieve. Successful programmes will be well aligned with these real needs.

In SE, one attempt to align industry needs with academic offerings has been ‘The Graduate Reference Curriculum for Systems Engineering’ (Pyster et al. 2012), a collaborative project designed to provide guidance on what providers of SE education should teach. It includes a V diagram with ‘Program Objectives’ at the top left. These adaptable objectives are focussed on student capability and employability. Similarly, Van Peppen and van der Ploeg (2000) established industry and learner objectives for a four-year master's programme in systems analysis, policy and analysis. In the UK, the Engineering Council publishes required learning outcomes for the Accreditation of Higher Education Programmes in engineering (Engineering Council 2020). These are frequently updated as the engineering industry undergoes change, such as changes in technologies. However, each of these documents, by necessity, serve multiple sectors with varying needs.

Some of our students take the MSc programme as part of the UK Rail and Rail Systems Principal Engineer degree apprenticeship. The standard for this apprenticeship (Institute for Apprenticeship and Technical Education 2018), which was written in consultation with the rail industry, specifies criteria for knowledge. skills and behaviours that an apprentice should have or exhibit upon successful completion of their apprenticeship. These criteria are about to undergo their first review, and with feedback from industry, it may be possible to identify the business benefits associated with meeting them.

However, although each of these sources provide elements for consideration, they sometimes contradict each other, and none provides a comprehensive and traceable set of business outcomes that are specific to our programme.

3 OUR APPROACH

As the authors have acknowledged, it is established practice to follow the constructive model, that is, to design educational material against defined learning outcomes and an understanding of what potential students want and then to assess whether these outcomes have been achieved. This could be represented as an application of the V diagram as illustrated in the boxes with a white background in fig. 2.

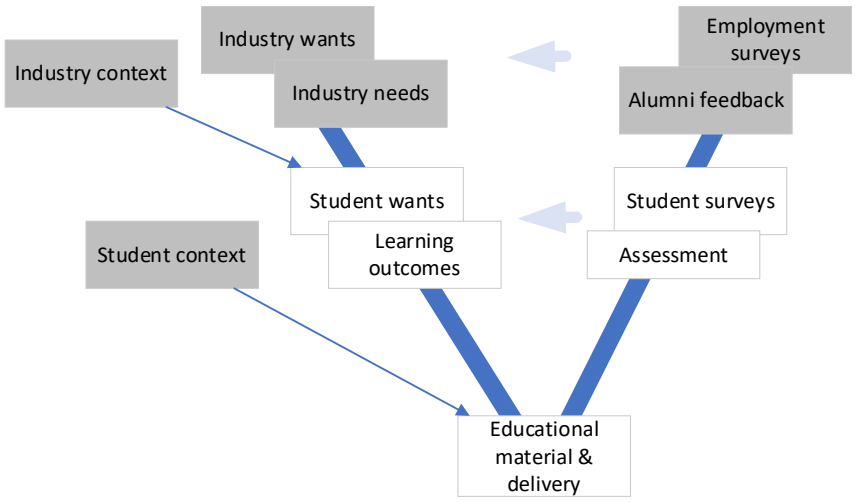

Fig.2. Current and extended practice in creating and improving an educational programme

We apply this process to the improvement of the RSEI programme, but our standard feedback arrangements provide us with feedback that is incomplete, potentially biased and occasionally conflicting. We are trying to improve the information available to us by extending it into the areas shown in grey. Our information gathering processes are not just passive feedback loops but are actively focussed on areas of interest. We are also using the V diagram as a framework for maintaining line of sight to the full set of feedback information in order to assemble a richer picture to support more balanced decision making.

4 KEEPING OUR UNDERSTANDING OF INDUSTRY WANTS AND NEEDS UP-TO-DATE

To contribute to industrial success, providers of relevant education need to help close ‘skill gaps’ - mismatches between the skills of available workers and the skills needs of employers (Department for Science 2021).

The RSEI MSc programme is designed to narrow the skills gap in the area of railway engineering. To understand this gap better the authors are carrying out research into the skill needs in this area in three different countries: the UK, the United Arab Emirates and Tanzania. To collect the skill expectations in these different cases, we are conducting online surveys and semi-structured interviews. We already convene a UK industry advisory board to collect industry feedback on the programme. We hope that these surveys and interviews will complement the industry advisory board by moving the discussion from the programme to the needs of industry and doing so for industry worldwide.

Only the literature review has been completed at the current stage. The literature review about the rail industry, its future, and railway education and training, shows that the skill expectations can mainly be classified in two categories: technical skills and soft skills. For the technical skills, the main gaps appear to be developing a holistic view of railway engineering and putting theoretical/technological knowledge into practice look like the main skill expectations from the industrial side. For the soft skills, the main gaps appear to be management and communication skills.

These findings are corroborated by other research into rail skills and skill expectations, most of which is of European origin. According to the European based research on skills education and training for the rail industry (European Union SKILLRAIL, SKILLFUL, and ASTONRAIL projects) (SKILLRAIL 2012), and UK Industrial Strategy – Rail Sector Skills Delivery Plan (GOV.UK 2018), there are also two main components of the skills gap in rail:

- Management and leadership skills.
- Being able to take account of new technologies and develop appropriate standards.

The RSEI MSc does cover management and leadership skills as well as innovation but, even though the findings of our ongoing research are very preliminary, the fact that these topics arise from multiple research activities is encouraging us to look again at them to see whether we should strengthen our teaching in these areas.

5 IMPROVING OUR UNDERSTANDING OF STUDENT CONTEXT AND WANTS

Students attending the RSEI MSc programme generally have rail industry experience. They will normally have specialised in one area of the rail industry and will be attending the programme to gain a wider knowledge of the industry as a whole. Around half of the cohort are students from the UK rail industry who by the end of the programme aim to have achieved promotion and/or engineering chartership. The rest of the cohort are international students, some of whom on completing the programme intend to return to home countries to further their careers, while others are looking for careers in the UK rail industry.

We also see students with a variety of educational backgrounds, including UK degrees, alternative qualifications such as a Higher National Diploma and overseas qualifications.

Therefore, we understand that our student cohort will have different wants, but also different needs in terms of support for them to achieve their learning goals. To be able to develop the programme and improve the support given, we need to have a better understanding of the students, and to obtain data on the optimum way to provide that support. It is worth considering that feedback obtained from students in a higher education setting can be prone to bias (Richardson 2005). This includes feedback collected from satisfaction surveys or other methods based on student opinion. Although, through surveys, anonymous data from large groups can be collected in a way that can be quantified, often this data lacks context which makes it difficult to interpret in terms of feedback for improvement (Desimone & Le Floch, 2004).

Other information such as the constant feedback loop between students and educators which comes from observing students' behaviour, questions, requests for help or even body language, can also be difficult to interpret. A few dominant students can give a skewed view and mean the view of the many is ignored, or data can be difficult to interpret in a non-biased way. Therefore, we need to look for

methods of data collection, both quantitative and qualitative which remove subjective bias, and we need to consider how to use a number of different data collection methods to support findings.

Examining attainment results achieved in assessments across the taught modules within the program, has allowed us to identify areas where there are differences between certain groups of students and where support may be needed. In the rail program one obvious difference in attainment was between home and international students, with the most recent results demonstrating home students achieving 8% higher on average across the modules. When looking at data across several years, this gap appears to be growing. Our previous assumption that work experience in rail would give students an advantage in the program, was not supported by the data. English as a first language also appeared to have little effect on results. The largest single indicator of low results appeared to be that previous academic study had been undertaken overseas.

To understand why this gap is occurring, a study was undertaken to look at assignments in one module containing 56 students, of which 29 were international and 27 home students. Although, there were certain errors that were common to all students, by examining the written assignments it was possible to identify areas where each group needed support. For international students support was needed with understanding how UK academic questions are phrased and how to start answering them. Describing evidence for arguments and demonstrating critical thinking skills were also areas which needed support. Comparison between home and international students in the examination demonstrated that international students tended to achieve a higher percentage of marks from mathematics questions than home students which again helps to target support.

More detailed data focused on programme improvements has been collected through interviews with students. Issues such as the need for assistance with vocabulary and the use of recorded teaching materials for support have already been acted on. However, perhaps more interesting was the way in which interview responses could disagree strongly with other findings. Some such as interviewees claims that they watch recordings of lectures are easy to check using our software analytics, while insistences that there is little difference between assessment undertaken in home countries and in the UK are not backed by the attainment evidence or that obtained by the detailed study of assignment responses.

Finally, feedback has been obtained through semi-structured observations of group interactions. Although a powerful tool, little research has involved classroom observation (Agostinelli, 2021) and there is little consensus on how observation should be carried out. In this case observations took place over a period of ten hours during a week of group tasks. The aim was to record interactions between students and to look for patterns in behaviour, such as which students were more likely to be taking leadership roles, who was dominating speaking and who did what. In general, observations appeared to support findings from other studies. International students were more likely not to attend the group sessions, were less likely to speak in the

group setting and appeared to complete a smaller percentage of the task, all issues which may lead to lower attainment in assignments at a later stage. Students were not directly questioned during the observation, however, several students wanted to talk about their experiences of group work which led to some interesting contrasts between what was observed and the perceptions of the students. For example, some home students were confident that they had tried to elicit discussion from international students, when observation suggested little contact. Also, a home student with industrial experience who had been observed to act as group leader and to organise other students, was convinced that they had undertaken no such role. One can observe what happens, but not what is in the mind of the student which demonstrates the need for multiple feedback loops.

This data that we have collected is already being used to inform changes in the coming year, with materials being developed for our Primer module to help students engage more effectively with assignments.

6 CONCLUSIONS

We have described how we are using the V diagram as a framework for improving the feedback available to us in order to inform improvements to the RSEI programme. We have sketched our research that we are carrying out into:

- what industry wants and needs from the type of education that we offer; and
- the variation in our student population and how we can take this into account to produce more consistent outcomes.

Our research is continuing but then so is the process of improving our MSc. We are committed to gradual but continuing improvement and, while we do not have definitive results yet, our interim findings are already providing us with richer input into the decisions that we are taking to improve our programme. Importantly, the results of our research are challenging some of our preconceptions which is an indication that our understanding is improved.

We are also using the V diagram as a framework for maintaining line of sight to the full set of feedback information in order to assemble a consolidated picture. Doing this brings into focus the conflicts between sources of feedback. Reconciling conflicting input is an unavoidable aspect of continual improvement. With richer input and the ‘line of sight’ afforded by the V diagram approach, we are confident that we can make better and more balanced decisions. Better and more balanced decisions should lead to a programme that is better aligned with the needs and wants of industry and students and the elimination of the effort required to undo undesirable changes.

We will complete our initial avenues of research, but we are already benefiting from the interim results and our research encourages that, if applied carefully, the ideas of SE can make a positive difference to achieve a better educational experience in engineering disciplines.

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