

## DECISIONS, JUDGEMENTS AND AGENCY: PREPARING ENGINEERING GRADUATES TO THINK THEIR OWN WAY THROUGH THE CLIMATE CRISIS

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**Abstract:** The careers of the next generations of graduates, across all disciplines but perhaps particularly so in engineering, will involve many difficult judgements and decisions related to mitigating the consequences of climate change. How graduates deal with *agency*—the capacity and responsibility to make one’s own decisions and cope with their consequences—will therefore be central to converting our society toward a sustainable state. We examine the responses and attitudes of current students enrolled on a typical chemical engineering BEng/MEng degree, to learning activities with differing degrees of agency. We consider students’ perception of agency in the current curriculum from a variety of perspectives and methods, ranging from whole-course perception, to experiences in a specific learning activity focussed on mitigation of climate change, designed particularly to engage students in developing and making their own decisions and judgements, ie to recognise and exercise their own agency in problem-solving. We study how student cohorts perceive their experiences through the lens of agency, and what coping strategies they develop. We draw some preliminary observations and conclusions about how prepared to cope with future high agency challenges students feel as we aim toward a degree experience that maximises engineering graduates’ readiness to combat the impact of climate change.

*Keywords; agency, graduate skills, chemical engineering, climate change, sustainability.*

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### 1. INTRODUCTION

#### *1.1 Agency, graduate skills and learning*

It is almost stating the obvious to remark that employers value graduates who can act with *agency*: who can make their own reasoned decisions, solve open-ended unfamiliar problems, show motivation, perseverance and resilience, work with others and flourish in unfamiliar contexts: in short, graduates who can *think their own way*. Numerous surveys demonstrate this unequivocally in the chemical engineering sector (WCEC 2004, Fletcher *et al* 2017). Moreover such qualities will be critical to the key challenge now facing us, *ie* mitigating the effects of climate change.

Agency can be defined broadly as ‘the power to create change’ (Goller and Paloneimi, 2017). The roots of individual agency reach deep into the psychological and social foundations of human existence (Kockelman, 2009; Emirbayer and Mische, 1998), igniting fierce discussion across disciplines from philosophy to neuroscience, in the public as well as academic sphere (Côté and Levine 2002, Burkeman 2021). Researchers have tended to associate agency with a wide set of concepts, from *intentionality* to *choice* to *self-efficacy*. When it comes to education, there are (at

least) two aspects to the issue: how education helps an individual develop their own capacity to cope with situations where they have agency, with resulting benefits in life and work; and to what degree learners have agency or influence over and during their actual educational experience. Taking the first aspect, clearly individuals must learn to act with increasing agency, progressing from infancy into adulthood via formal education (although exactly what role formal education plays in this development is not necessarily clear, *eg* Hunter, 2020). The second aspect, the issue of students having agency or control over their learning experience itself, has been much discussed in educational literature spanning at least a century from Dewey (1922), who posited agency as a counter to an education founded on behaviourism ('training' as it were), through to Bandura (2001), who emphasises the link between an individual's agency and their sense of self-efficacy.

Space precludes an extensive review of the literature on learning and agency. In engineering the work of Felder and colleagues (Felder and Brent, 2004; Felder, 2012) provides a useful starting point. Litzinger et al (2011) discuss the development of engineering 'expertise' while a wider literature explores how student agency relates generally to the development of 'learner identity' (Côté and Levine 2002; Holland and Lachicotte, 2001; Biesta *et al*, 2008; Sfard and Prusak, 2005), which further connects with policy, in the form of 'professional identity' and how this is determined by the currently dominant economic and employability drivers in HE (Wolf, 2002).

Here our aim is to use direct student perceptions to begin to explore which aspects of the learning experience may promote or inhibit the ability to act (and learn) with agency. We focus for concreteness on an example cohort of BEng/MEng Chemical Engineering students, though given the wide range of multidisciplinary activities undertaken and skills aimed for in Chemical Engineering, our observations should be of relevance across all engineering disciplines, and indeed beyond. Given the available space we report only on some key findings from a collection of studies, some of which are still ongoing, whose overarching aim is to help improve, based on clear observation of student experience, the extent to which such a degree education prepares graduates to act with agency in their careers (many of which go beyond 'core' chemical engineering). Indeed, the capacity to cope with and benefit from agency is clearly relevant to the whole of an individual's existence, a wider view captured in Biesta and Tedder's (2007) formulation of agency as 'the ability to exert control over and give direction to one's life.'

## 2. METHODS

### 2.1 Context and scope

The studies took place at the University of Strathclyde, Glasgow, between 2020 and 2022, involving various cohorts of full-time undergraduate (BEng Hons and MEng) students in the Department of Chemical and Process Engineering. In Scottish universities the BEng Hons degree is typically completed in 4 years, while MEng includes a final year 5. Each year involves a total of 120 credits of study. In years 1-4 at Strathclyde the curriculum for BEng Hons and MEng is identical. The degrees were most recently fully accredited in 2019/20 by the Institution of Chemical Engineers (IChemE 2020). Typical cohort sizes are 80-100 per year. Design and implementation of the research programme has involved MEng and MSc students as part of efforts to engage students themselves more deeply in improvements to teaching and learning.

Given space limitations, we must leave detailed analyses of the full datasets to future work (*eg* Pisani and Haw, 2022). Instead here we report brief highlights from two approaches—a 'whole

curriculum’ overview, and investigation of a specific activity linked to climate change mitigation—as a way of catalysing further study and debate around how to promote sustainability-related agency skills amongst graduates. Here we highlight some trends and differences, leaving deeper statistical analysis to be reported elsewhere. As often expressed, students ‘do not constitute an homogenous group, they inhabit enormously diverse histories and populations’ (Elliot 1997, p89): it is as much the range of different experiences and perceptions, as the statistical means and ‘average’ response, that gives us a meaningful and comprehensive picture of learning. Readers may decide whether this view is sufficiently (Elliot 1997) or far too (Cote and Levine 2002) post-modernist for their taste: the key point is that we are studying human beings, situated in a complex, ever-changing environment<sup>1</sup>, with at best imperfectly-defined measurement variables. So our key goal here is *insight*, as the seed of further understanding and improvement.

## 2.2 Agency across the curriculum

The ‘whole curriculum’ study explores students’ perceptions of the varying degree of agency afforded by different parts of the curriculum, for the most part using online questionnaire methods, a mixture of Likert-type questions (Likert, 1932) and free-text response. Data were collected from  $n=127$  respondents across a range of questionnaires aimed mostly at cohorts in years 3, 4 and 5. Anonymisation was used in all studies, and all were voluntary with no impact on student outcomes. All methods were approved by the Departmental Ethics Committee.

## 2.3 Agency in specific activities: decisions about climate change

Alongside the wide-angle lens view of agency across the curriculum, we have also studied some activities in closer detail. These include two core 60-credit project elements of the Chemical Engineering degree, the capstone group design project (occurring in year 4 at Strathclyde) and the final-year MEng individual project, results on which will be reported elsewhere. But here we focus on a smaller-scale activity, a decision-making/climate change-themed group coursework undertaken by year 3 BEng/MEng students as part of a 20-credit ‘Ethics, sustainability and economics’ class. As with the wider curriculum study we use questionnaire methods, mixing Likert-style and free text response. The task involves a decision-matrix approach (Cussler 2011) to researching and comparing potential mitigations of climate change, alongside an economic analysis of the chosen mitigation strategy, and reflection on the methodology and the role of groupwork within the task. It is designed to enable significant agency through minimum detailed definition of the focus (students can interpret ‘mitigation of climate change’ on any scale from global strategies to personal actions) and the requirement of the decision-matrix that students make their own comparative judgements, justifying them through their own research and reasoning.

# 3. RESULTS AND DISCUSSION

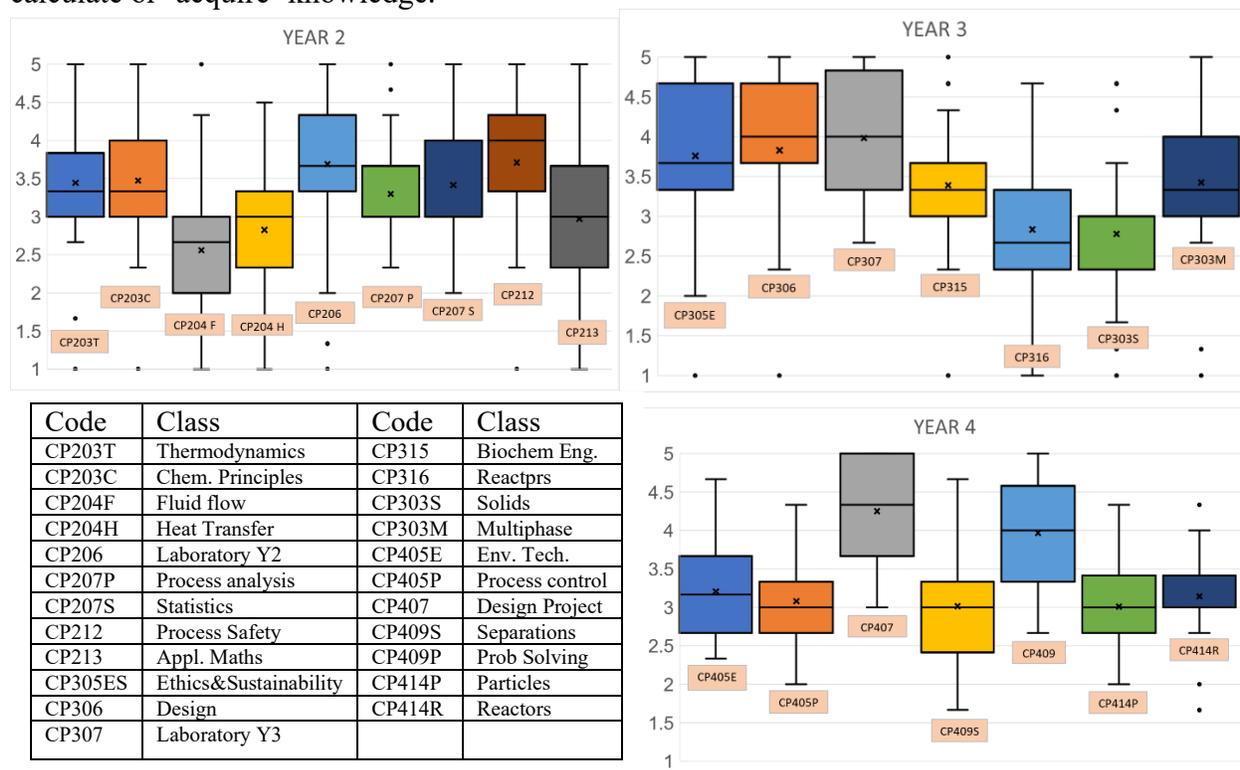
## 3.1 Whole-curriculum views

First we report an overall measure of students’ perception of the degree of agency afforded by a classes in years 2-4 of the curriculum, an average score derived from the Likert-scale questionnaires. We find (Figure 1) that while students perceive themselves to have higher agency in typically more ‘active’ classes (laboratories, project-based classes) compared to ‘standard’ lecture-dominated classes, the trend is not exclusive. In Year 3 for example, agency is rated highly in CP306 Chemical Engineering Design and CP307 Y3 Laboratory but also in CP305ES Ethics

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<sup>1</sup> As if University life was not dynamic and complex enough, the majority of these studies coincided with the COVID-19 pandemic, which saw most teaching and assessment at Strathclyde delivered through online platforms.

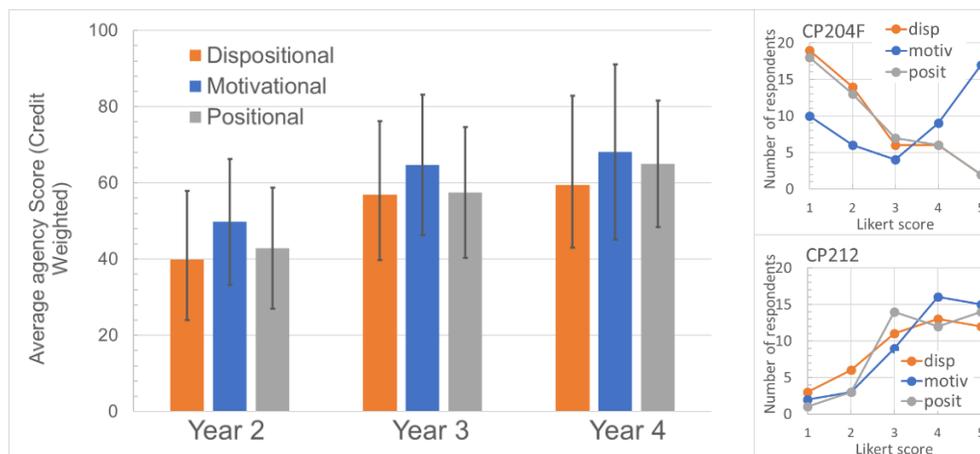
and Sustainability, a lecture-driven class. This is an indication that a close look at the *activities* (including assessed work) in a class may be important: CP305 includes various more free-form assessments such as presentations and blogs. Similarly, in year 2, CP212 Process Safety is rated joint highest: again a lecture-driven class, but one that includes substantial student reflection on safety incident case studies, requiring students to assemble and judge scenarios rather than simply calculate or ‘acquire’ knowledge.



**Figure 1. Agency in individual classes across Years 2, 3 and 4 (5= substantial agency, 1=none). Boxes show central 50% of responses, whisker bars show the data range excluding ‘outliers’ (shown as isolated points) which are classed as data points  $>(1.5 \times$  upper/lower quartile range) outside the central box. Table shows key to class codes.**

Measuring perceived agency through the course using averages across the class scores in Figure 1, but weighting each class by its number of credits, reveals an interesting trend (Figure 2): students perceive the agency afforded by the curriculum to steadily increase from year 2 to year 4. An increased degree of perceived agency is certainly consistent with the increasing degree of open-ended, deeper and more ‘whole system’ problem-based work which, at face-value, the curriculum is designed to deliver. Fig 2 also begins to break down the perception of agency to better explore in what ways students feel activities afford them agency. The study asked students to rate classes using Vaughn’s (2020) three dimensions of agency, viz. ‘dispositional’ (students feel control over the ways they learn), ‘motivational’ (students feel control over achieving their goals, eg overcoming specific barriers, attaining grades) and ‘positional’ (students feel agency within the wider context, such as how they relate to other students). Fig 2 shows that typically the ‘motivational’ dimension is rated highest in all years: goal attainment is the area where students feel greatest control over their experience. Interestingly, even in classes rated overall low agency such as CP204F, we observe that the motivational dimension is still rated highly by the majority

of students, similarly in fact to an overall high-agency class (CP212): the difference between low and high agency classes lies in the dispositional and positional dimensions. This is consistent with the (admittedly anecdotal) observation that the Strathclyde cohort tends to be highly driven to succeed, and the (less anecdotal) point that Strathclyde's Chemical Engineering entry tariff is one of the highest in the UK. Whether 'succeed' means 'gain important skills' or simply 'gain high marks'—just what these goals are that students feel agency over—is a question worth further exploration. This brief glimpse of data, alongside much more not presented here, broadly shows



**Figure 2. Left: Rating of agency across Years 2, 3 and 4, with individual classes' mean Likert score weighted by the number of credits each class represents in the curriculum. A separate measure is shown for each of the perceived dimensions of agency (see text). Right: individual histograms of scores for two example Year 2 classes.**

consistency with the perhaps unsurprising idea that agency is afforded by classes involving more complex demands such as practical work, open-ended design and 'reflective' activities requiring assimilation, comparison and judgement. But there is nuance that remains to be explored: for example, in some surveys laboratory work was rated by students as very *low* agency, participants commenting that experiments often followed quite rigid recipes.

### 3.2 A specific activity: Decision-making and climate change Year 3 Economics coursework

The first part of the questionnaire in this part of the research explored the general degree of agency perceived by students in the coursework task and their response. While total respondents was small for this preliminary study ( $n=11$ ) we can draw some initial pointers to guide further development and hint at interesting factors. 82% of respondents reported being 'challenged but managing' with the high agency aspects of the task, compared to 50% with the low agency aspects; while 40% 'coped easily' with the low agency elements compared to only 18% coping easily with the high agency elements. Interestingly only just over half (55%) agreed that 'The high agency or open-ended aspects of the task made it a better experience.' Looking to the future, 82% somewhat or strongly agreed 'I feel experience of high agency activities in my degree course will benefit me in my future career' and 73% 'feel more confident about high agency activities following the coursework task.' Linking then to mitigation of climate change, while 82% agreed 'Using my skills and knowledge to contribute to mitigating climate change is an important career goal for me', only 45% felt that, currently, they 'have skills that will help me contribute as a chemical engineer to

mitigating climate change.’ Consistent with this, 82% felt it ‘important to me that the rest of my course further helps me improve my knowledge and skills so I can better contribute to mitigating climate change.’

Space allows highlighting of just two observations breaking down the agency provided by specific elements of the coursework, explored through free text comments. Part of the task involves following a well-defined method for construction of a ‘decision matrix’ (Cussler, 2011). This element scored lowest in terms of fraction of students rating it as providing ‘a lot of agency’ (54%, compared to highest rating for ‘doing research on the topic’ scoring at 91%). A respondent commented: “The format of the matrix is set... [it] doesn't give much agency in how to decide on the best solution, [but] it does give structure to the task.” A key question is how best to balance elements of high agency with ‘structure-giving’ aspects. Sharif (2022) observed that in very open-ended tasks students actively searched for constraints, a ‘safety net’ of structure, sometimes to the extent of imagining ‘unwritten rules’ they felt they had to guess at in order to succeed.

Finally one comment illustrates the importance of support during the coursework task: “The regular feedback helped us understand what was expected ... However, this isn't available for some classes...I feel for high agency tasks, feedback has to be regular.” When students are making sequences of agentic decisions, methods of ‘checking back’ to provide confidence as they explore a complex problem become important. In this task two pre-submission feedback discussion sessions were devoted to the coursework. Ultimately of course, students will need to develop other methods of ‘sanity checking’ as they progress through complex projects: an interesting question then is how task design could build students’ ability to sanity-check their own decisions, beyond reliance on the lecturer. When graduates are leading on mitigation of climate change, it is unlikely there will be ‘authorities’ who can reassure them that they are on the right track.

#### 4. CONCLUSIONS

Our ultimate aim in the work on agency is directly linked to an urgent and pressing need: graduates who are ready to bring their own skills to the fore to help mitigate the impact of climate change. The most technically gifted engineer will be unable to do this if they cannot deal with the agency demanded by innovation, decision and judgment. Our results demonstrate some interesting aspects of how students perceive learning activities in a typical chemical engineering degree to deliver agentic experience. Early indications begin to link this to how prepared students feel to devote their careers to mitigating climate change. There is much more to explore in our data and much more to do to further understand students’ experiences and connect with graduate capabilities. Our studies so far do indicate however that it is possible to gain a student’s-eye view of development of agentic skills and, armed with this view, design further improvements to teaching and learning. Such improvements must take account not only of students’ concerns not to be ‘thrown in the deep end’ without support—while fulfilling and humanising, the sense of agency can also be daunting; but also of teachers’ resource and time limitations and the urgency of the climate change crisis. The coursework task briefly touched on here is an example of how existing activities can be ‘tweaked’ toward delivering greater agency without time- and resource-consuming wholesale changes of approach. Such wholesale educational ‘revolutions’ might in principle be desirable (Maxwell 2021, Orr 2004) but time to arrest irreversible climate damage is running out: rapid

improvement in agentic skills linked to mitigating climate change cannot wait for educational revolutions to run their course.

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